Status of US ITER Contributions

Ned R. Sauthoff
Director, US ITER Project Office

Fusion Power Associates
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US ITER Hardware Scope
Full Scope

- Central Solenoid
- ECH Transmission Lines
- ICH Transmission Lines
- 75% of Steady State Electrical Network
- 8% of Toroidal Field Coil Conductor
- Pellet Injection Disruption Mitigation
- Vacuum System & Roughing Pumps
- Tokamak Exhaust Processing System
- 14% Port Diagnostics

Key: Finished • Hardware in fabrication • Prototypes in fabrication • In design
ITER Project has Defined First-Plasma and Post-First-Plasma Hardware

<table>
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<th>R&amp;D and Design</th>
<th>Full Fabrication</th>
<th>Partial Fabrication</th>
<th>Completion of Fabrication</th>
<th>Full Fabrication</th>
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</table>
| Completion for All Hardware | • Central Solenoid (in fabrication)  
• Toroidal Field Conductor (completed in FY17)  
• Steady State Electrical Network (completed in FY17) | • Tokamak Cooling Water System (some delivered)  
• Roughing Pumps  
• Vacuum Auxiliary System (some delivered)  
• Pellet Injection  
• Ion Cyclotron Heating  
• Electron Cyclotron Heating  
• Diagnostics  
• Instrumentation & Controls | • Tokamak Exhaust Processing  
• Disruption Mitigation |
US Hardware
Toroidal Field Conductor Completed

Strand was produced by Luvata Waterbury, Inc. in Waterbury, CT (above) and Oxford Superconducting Technologies in Carteret, NJ.

Cabling of the strand was performed by New England Wire Technologies in Lisbon, NH.

The conductor was jacketed and integrated at High Performance Magnetics in Tallahassee, FL and Criotec in Chivasso, Italy (above).
US Hardware

Steady State Electrical Network Completed

The final shipments of power transformers were delivered in December 2016.

The final lots of reactive power compensators were shipped in September 2017.

HV transformers were delivered and installed on site in 2015.
Serial module fabrication is underway at General Atomics’ 64,000 ft² Magnet Technologies Center. The facility includes 10 work stations.
US Hardware
Central Solenoid Module Fabrication Progressing

1: Conductor receiving inspection
2: Winding (2)
3: Joints & Terminals Preparation
4: Stack and Join / Helium Penetrations
5: Reaction Heat Treatment
6: Turn Insulation
7: Ground Insulation
8: Vacuum Pressure Impregnation
9: Helium Piping & Measurement
10: Final Test at 50kA, full force

Module #1
Module #2
Module #3
Module #4
Module #5
Module #6
Mock-Up

November 2016
September 2017
Central Solenoid
Winding of Module 4 (of 7) is Underway

Winding table in action at General Atomics.
Photo: GA
Central Solenoid
Module 1 Completed Turn Insulation

Turn insulation station in action at General Atomics. Photo: GA
Central Solenoid Structures and Assembly Tooling in Fabrication

Lower key block fabrication at Petersen, Inc. in Ogden, UT continues.

Tie plate fabrication at Precision Custom Components in York, PA continues.

Assembly platform fabrication is complete and delivered.
Initial deliveries complete; piping fabrication underway

Final Design Review for First Plasma hardware was held in November 2017

Drain tanks fabricated in the US were the first nuclear-certified components delivered to the ITER site (September 2015).

Pipe fabrication is underway at the Schulz Xtruded Products facility in Robinsonville, MS.
Ion Cyclotron Heating First Plasma hardware FDR September 18-19, 2017

Prototypes in fabrication and testing; production unit fabrication started

• 20 megawatts total power transfer to the plasma
• Up to 6 megawatts per line

Water-cooled inner conductor prototype

Insulator flange with 3-spoke quartz pin supports
Prototypes in fabrication and testing; contracts for manufacturing processes awarded

- 20 megawatt total power transfer to the plasma
- 1.2 megawatts per line

A laser-based wave guide inspection system was developed

Waveguide switch prototype
US Hardware
Pellet Injection and Disruption Mitigation Systems

- Prototypes are in fabrication and testing; testing on current tokamaks continues
- Cryogenic pellet plasma fueling in development to perform at 300 m/s at 16 Hz

A shattered 7 mm neon pellet in DIII-D tokamak plasma

Shattered pellet injection components in a test stand at ORNL before installation on JET for further testing.
US Hardware
Vacuum Auxiliary and Roughing Pumps System

Deliveries continue; prototypes in testing

Vacuum Auxiliary System-01, FDR March 30, 2017
Roughing Pump System, CDR April 3-5, 2017
Vacuum Auxiliary System-03, CDR July 25-26, 2017

The full-sized cryoviscous compressor prototype was tested at ORNL’s Spallation Neutron Source Cryogenic Facility before shipment to ITER for further testing.
State of the art distributed plasma diagnostics have been in design, with prototypes in fabrication and testing.
Tokamak Exhaust Processing PDR May 16-17, 2017

- High-throughput (240 Pa*m^3/sec) tritium processing system is in design
- Palladium membrane separates hydrogen isotopes from methane-steam reforming reaction
US Industries, Universities and National Laboratories are Engaged

General Atomics, San Diego, CA
AREVA Federal Services, LLC, Charlotte, NC
Luvata Waterbury, Inc., Waterbury, CT
Precision Custom Components, York, PA
Oxford Superconducting Technology, Carteret, NJ
Transfair, Sea Tac, WA
High Performance Magnetics, Tallahassee, FL
Schneider Electric, Palatine, IL
Robatel Technologies, Roanoke, VA
Petersen, Inc., Ogden, UT
Superbolt, Carnegie, PA
Hyundai Corporation, Houston, TX
New England Wire Technologies, Lisbon, NH
Transproject, Houston, TX
Robatel Technologies LLC, Roanoke, VA
Hamill Manufacturing, Trafford, PA
Major Tool & Machine, Inc., Indianapolis, IN
Mega Industries, LLC, Gorham, ME
Dielectric Communications, Raymond, ME
Siemen's Industry, Inc., Wendall, NC
Eaton Corporation, Cleveland, OH
G&G Steel, Russellville, AL

Massachusetts Institute of Technology
University of Texas at Austin
University of Tennessee
Florida State University
University of Wisconsin at Madison
University of California Los Angeles
University of Michigan
University of California San Diego
Columbia University
Washington State University
Indiana University

Oak Ridge National Laboratory
Princeton Plasma Physics Laboratory
Sandia National Laboratory
Savannah River National Laboratory
Los Alamos National Laboratory
Lawrence Livermore National Laboratory
Idaho National Laboratory
Fermi National Laboratory
Argonne National Laboratory
Lawrence Berkeley National Laboratory
Over 80% of Awards and Obligations Remain in the US

600+ contracts awarded to US industry and universities, and obligated to DOE national laboratories in 44 states

500+ direct jobs and 1100+ indirect jobs created or maintained per year.

Total: ~$957M Since 2007

Data as of September 30, 2017
DOE Deputy Secretary Approved First-Plasma Performance Baseline and Total Project Range on January 13, 2017

DOE-approved Package (Jan 2017)

First Plasma Project Baseline (CD-2/3):
- Total project cost (TPC): $2.5B
- CD-4: December 2027

Total US ITER Project Range (CD-1R):
- Cost range: $4.7B−$6.5B
- CD-4: 2034–2038

Driven by budgetary constraints—not technical

September 2034 – March 2038
US ITER has demonstrated consistent strong performance when resources are available.

Partnership in ITER enables US participation in the study of burning plasmas . . .