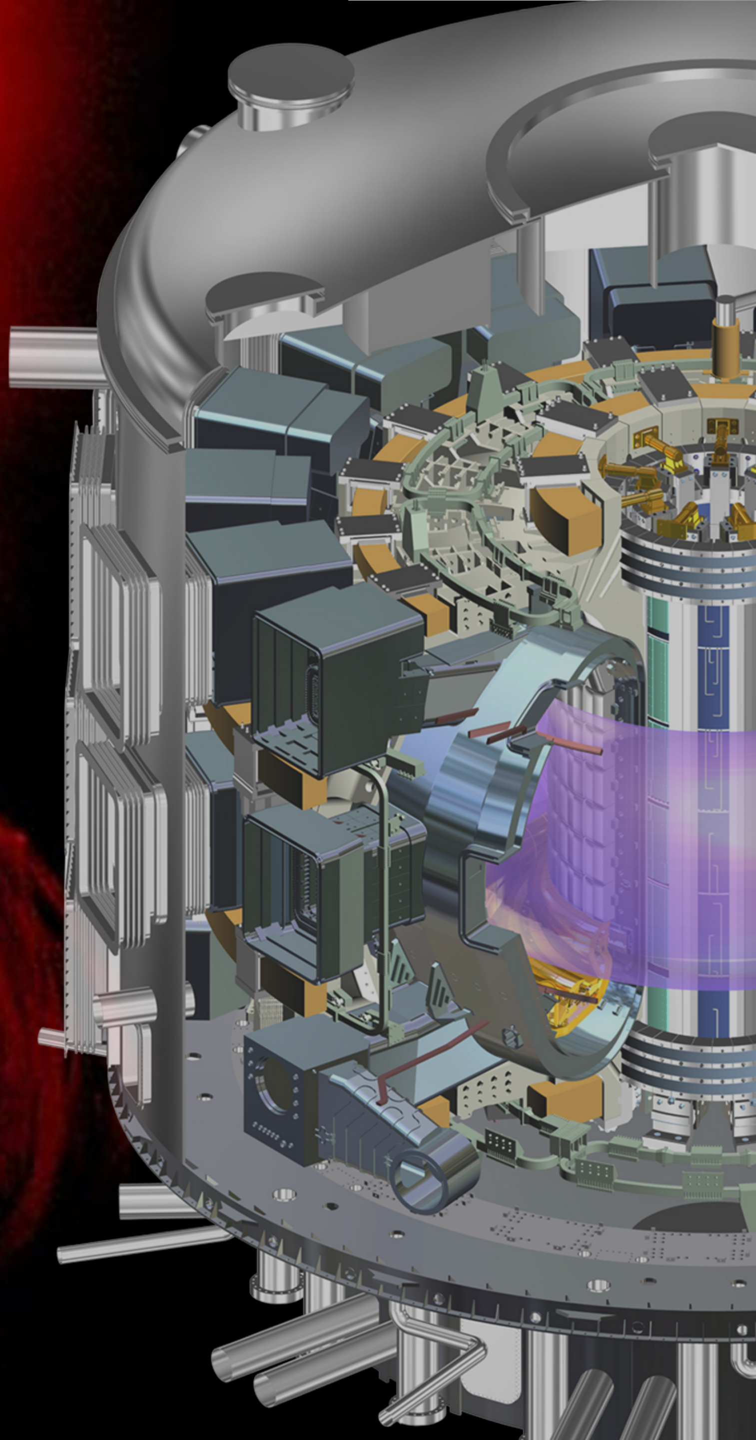
ITER Project Status

Fusion Energy Sciences
Advisory Committee Meeting

Ned Sauthoff
Director
US ITER Project Office

April 9, 2014



Major Progress: Construction Site

Photo: ITER Organization • September 2013

Major Progress:
ITER Headquarters Building

Progress: Tokamak Pit

Photo: ITER Organization • February 2014

Major Progress: Assembly Building

Photo: ITER Organization • June 2013

Major Progress:
Poloidal Field Coil Winding Facility

Photo: ITER Organization • June 2013

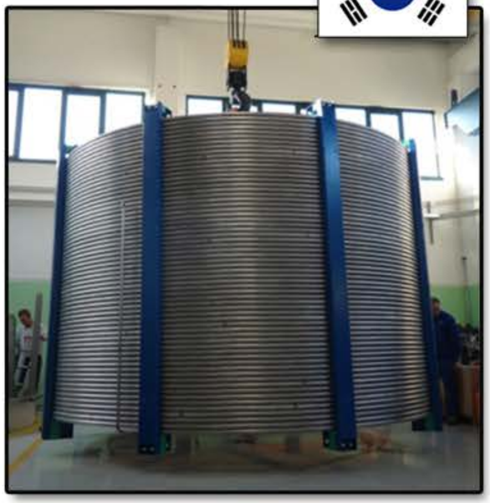
Major Progress: ITER Cryostat Building

Photo: ITER Organization • January 2014

Fabrication of ITER Components by Global Partners is Underway

Toroidal Field (TF) Conductor Fabrication by 6 Domestic Agency Contributors

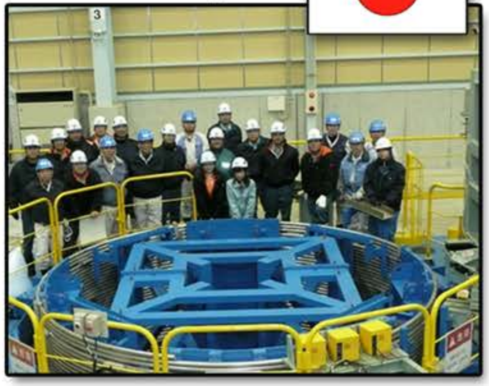
Korea



Russia

China

Japan

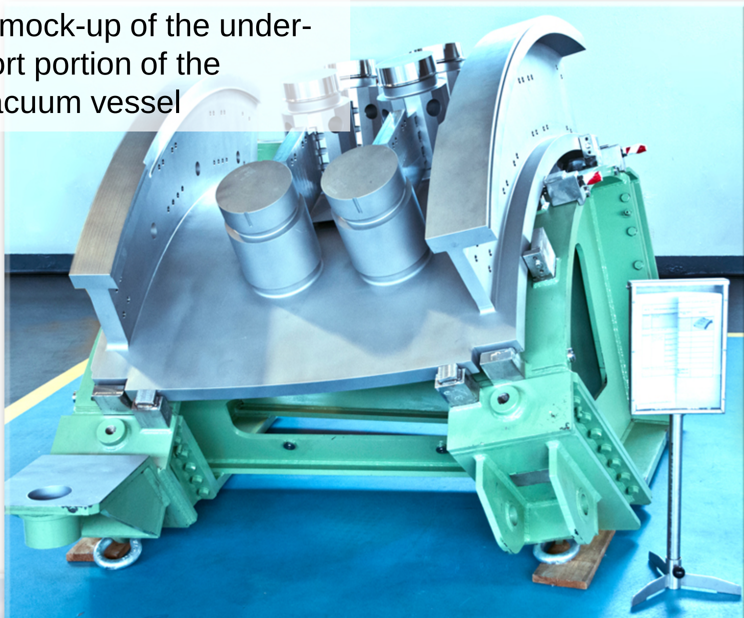


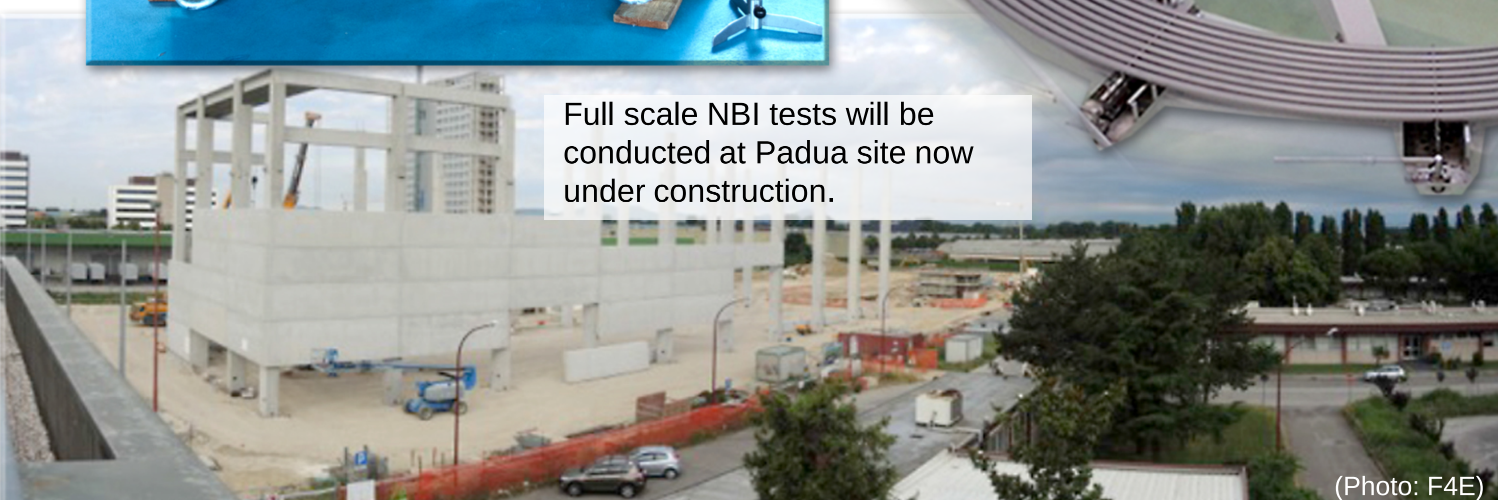
EU

United States

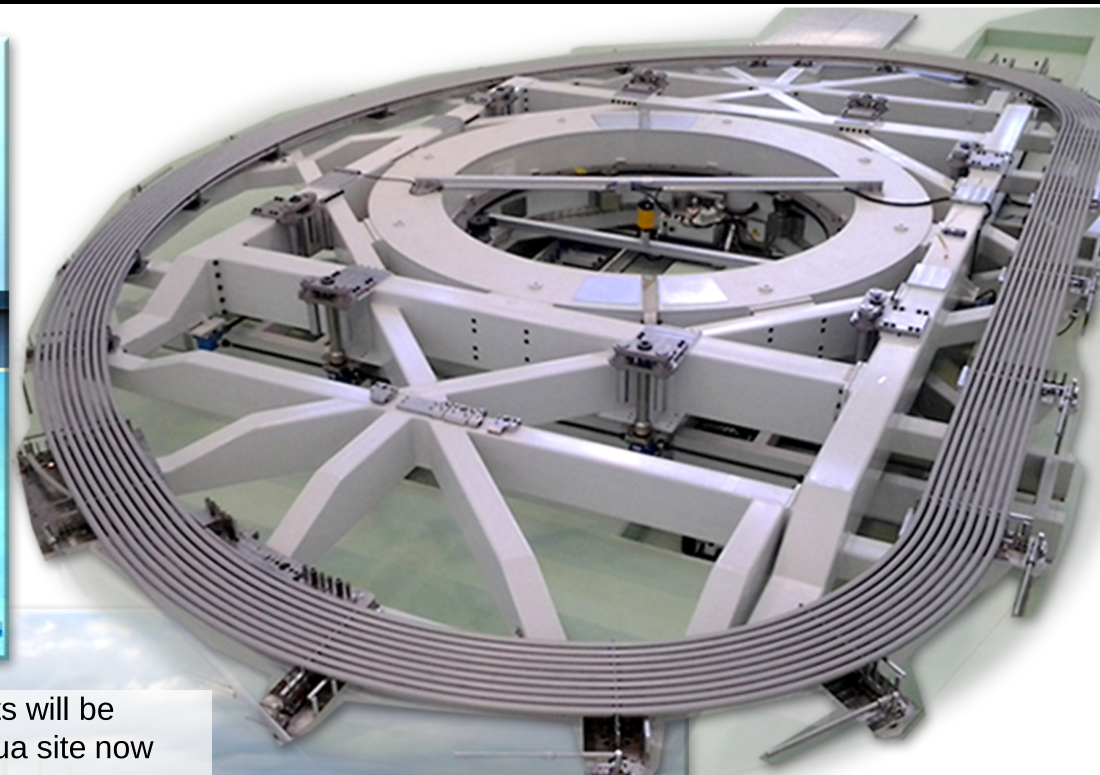
Sample toroidal field conductor has been produced by the six responsible Domestic Agencies.

EU – Buildings, TF Coils, Vacuum Vessel, and Neutral Beam Injection


A mock-up of the under-port portion of the vacuum vessel

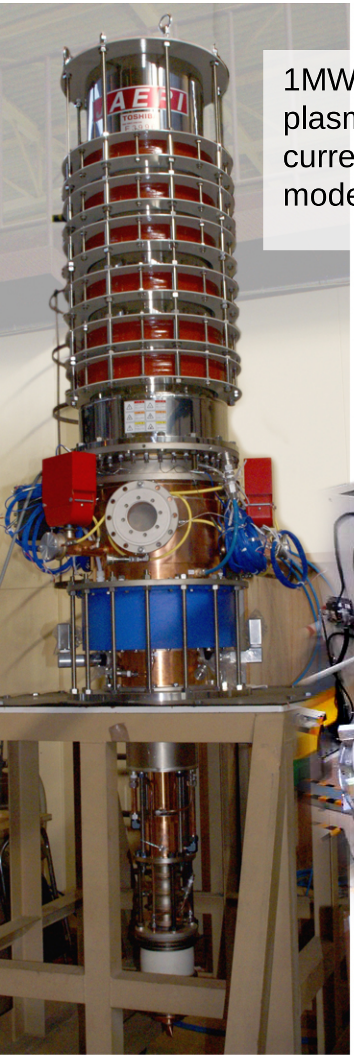

Full scale NBI tests will be conducted at Padua site now under construction.

(Photo: F4E)

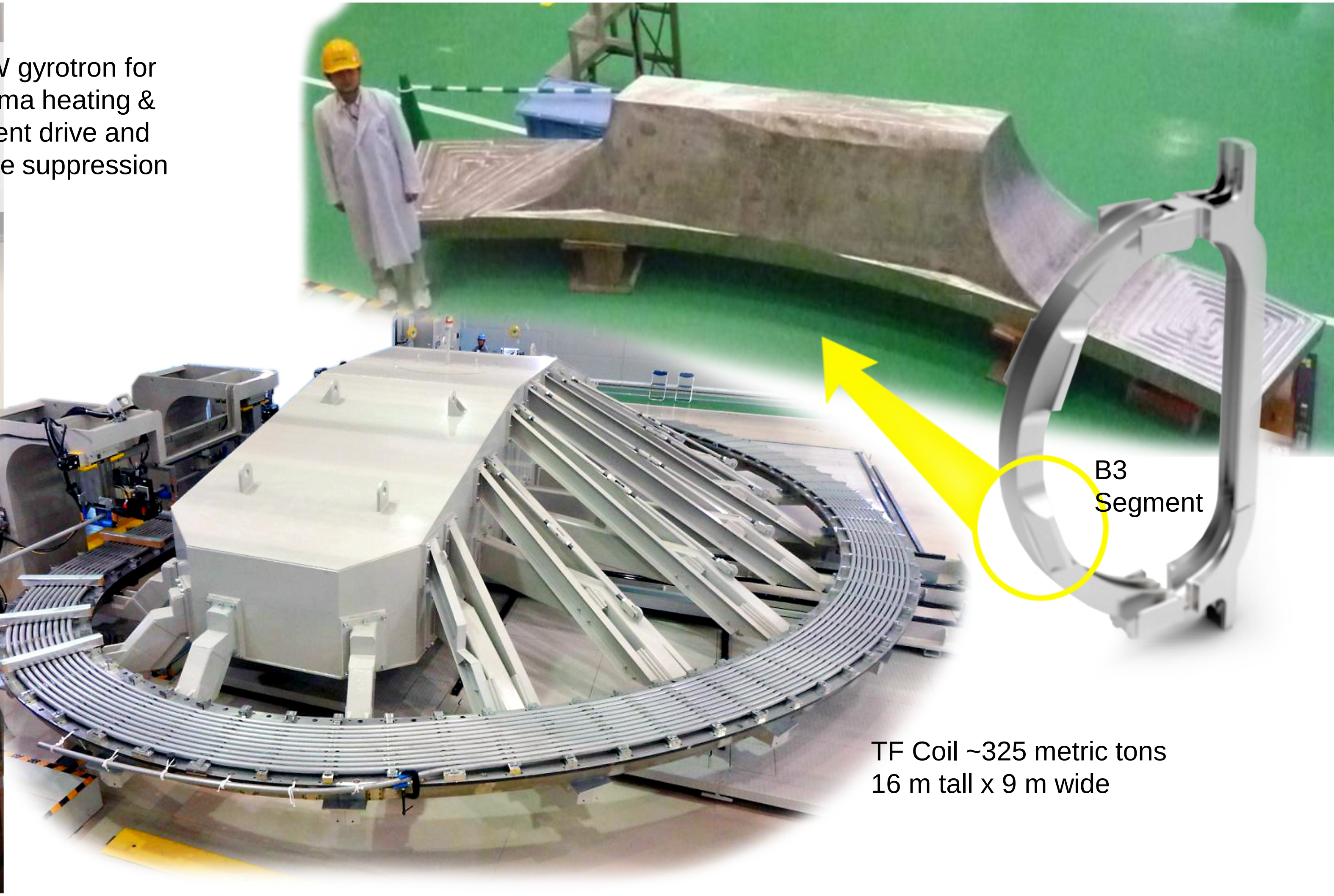

First double pancake prototype being wound for toroidal field conductor

(Photos: F4E)

Japan – TF Coils and 170 GHz Gyrotron



1MW gyrotron for plasma heating & current drive and mode suppression



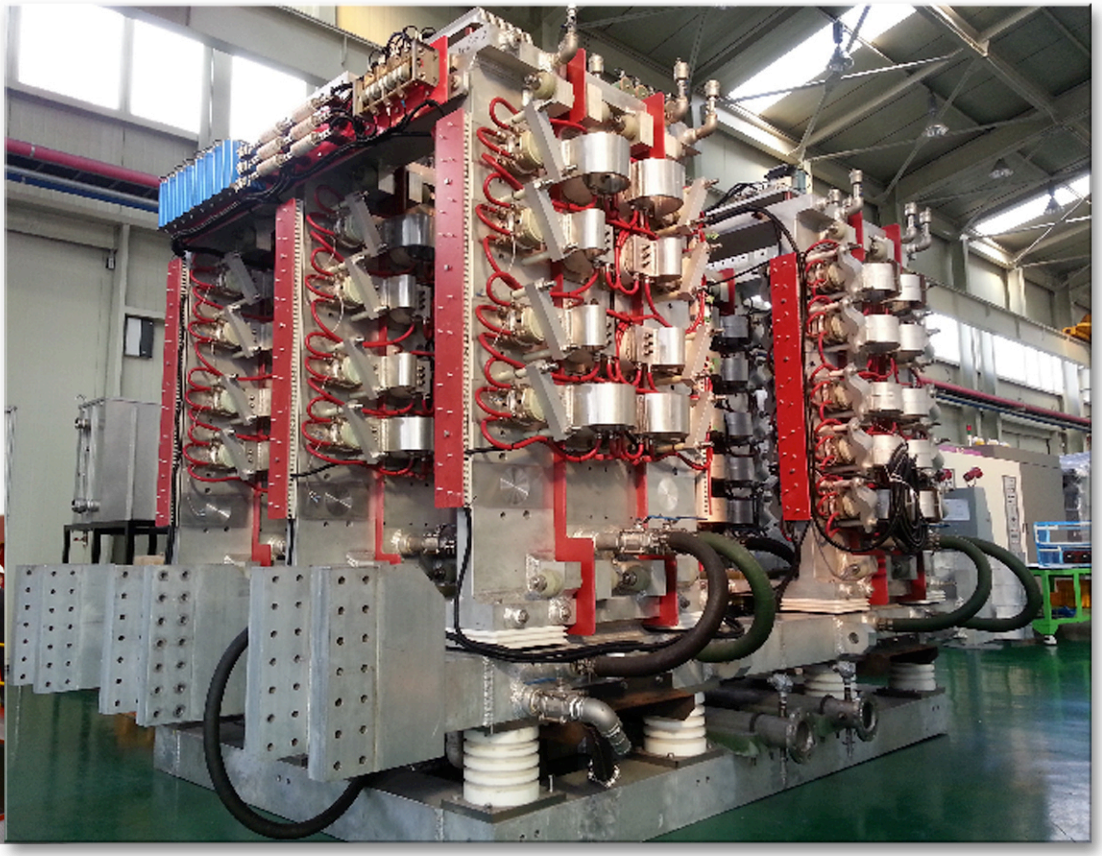
B3 Segment

TF Coil ~325 metric tons
16 m tall x 9 m wide

(Photos: JA DA)

Korea – Vacuum Vessel Segments and Power Convertor Systems

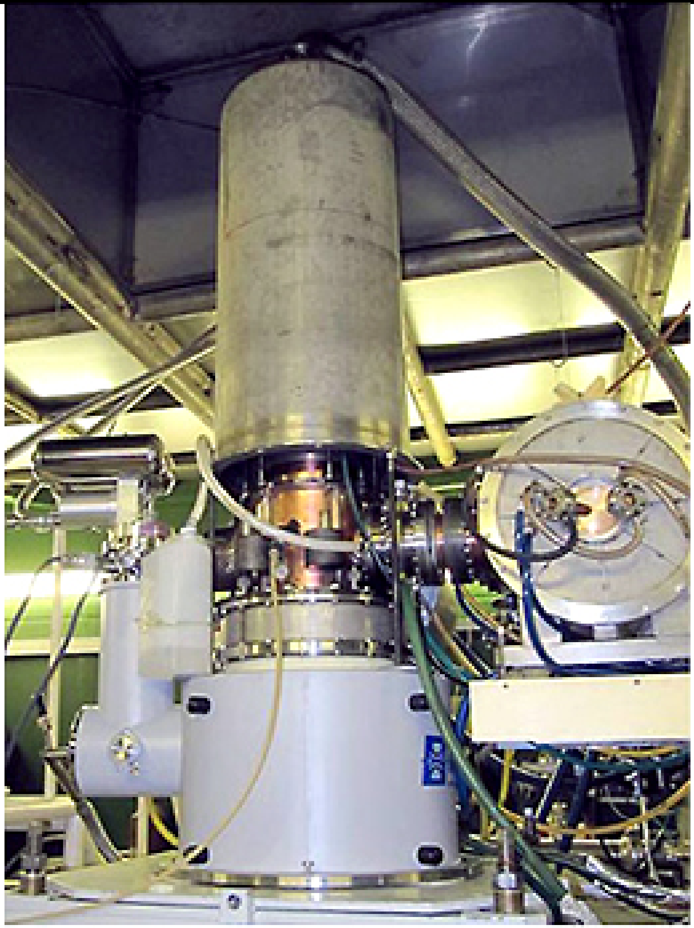
Manufacturing of an ITER vacuum vessel segment in Korea



Prototype of the AC/DC power converter for the ITER vertical stabilization coils.

(Photos: KO DA)

Russia – Poloidal Field Magnet Conductor Development and 170 GHz Gyrotron



1MW gyrotron for plasma heating and current drive plus mode suppression

A copper dummy conductor fabricated for the PF1 coil

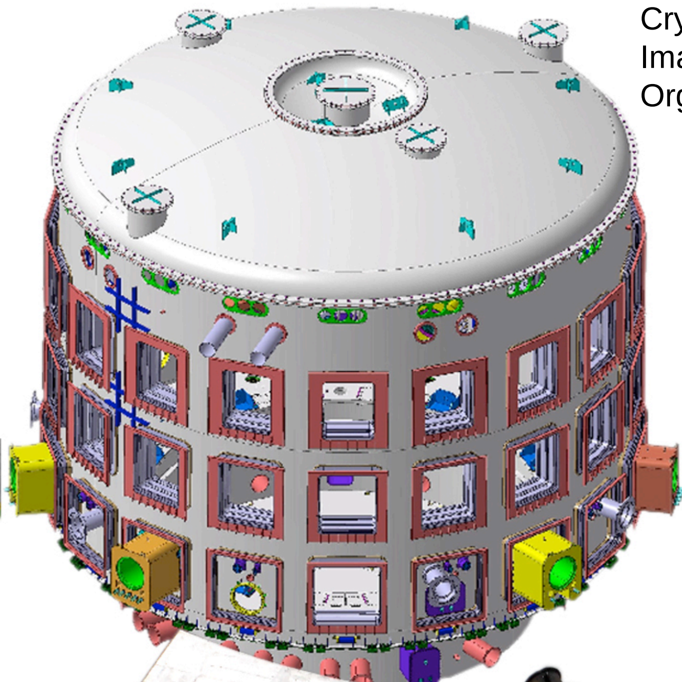
(Photos:Gycom)

China – Poloidal Field Conductor

Poloidal field dummy conductor was loaded on a ship bound for France in April 2013. Photo: CN DA

Poloidal field dummy conductor was delivered from China to the ITER site in June 2013.
Photo: ITER Organization

India – Cryostat and Diagnostic Neutral Beam

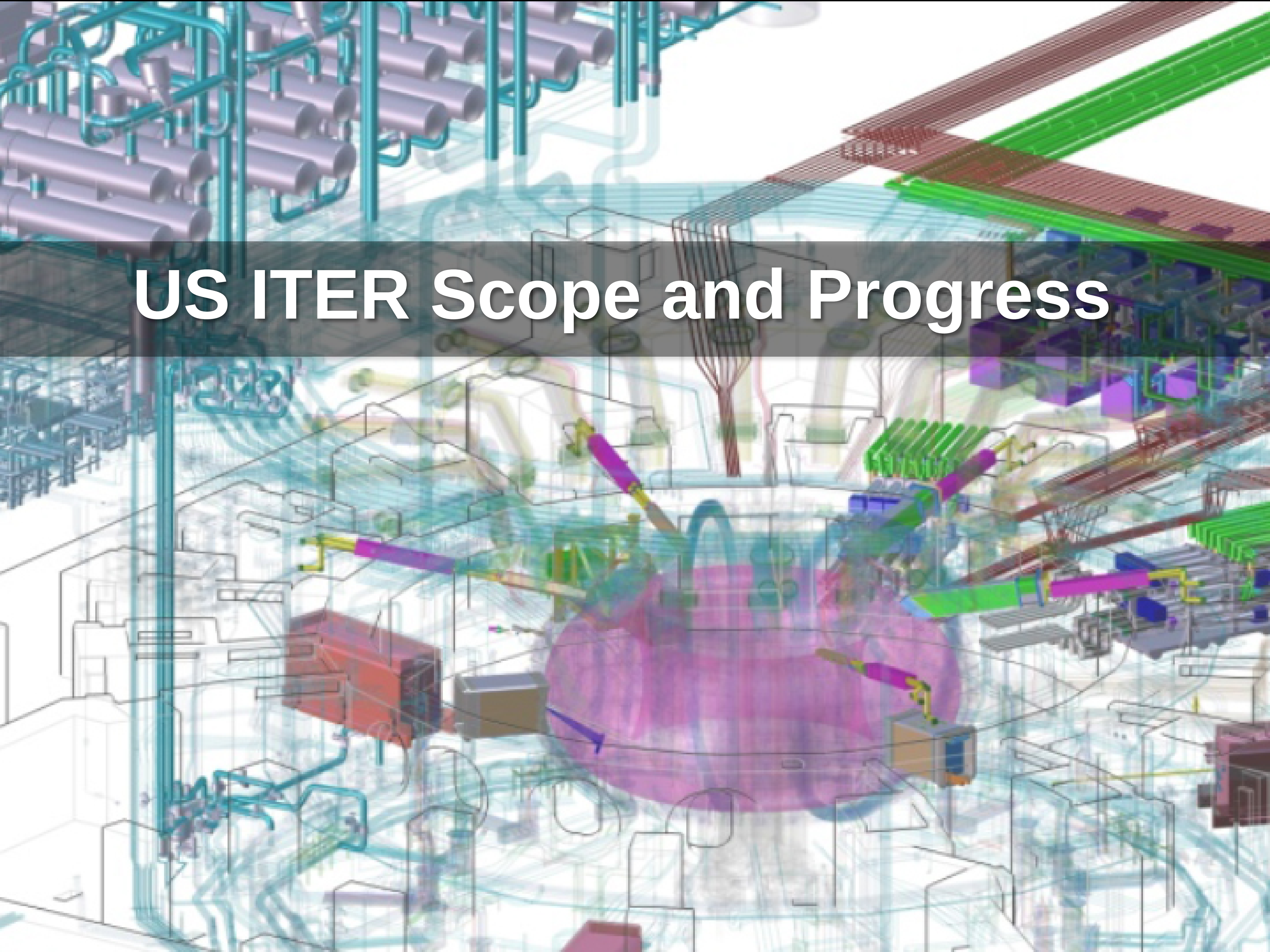


Cryostat model
Image: ITER Organization

A cryostat component full-scale mock-up. Photo: IN DA

High voltage power supply for Diagnostic Neutral Beam. Photo: IN DA

US ITER Scope and Progress



US Scope

ORNL
100% Central Solenoid (using JA conductor)

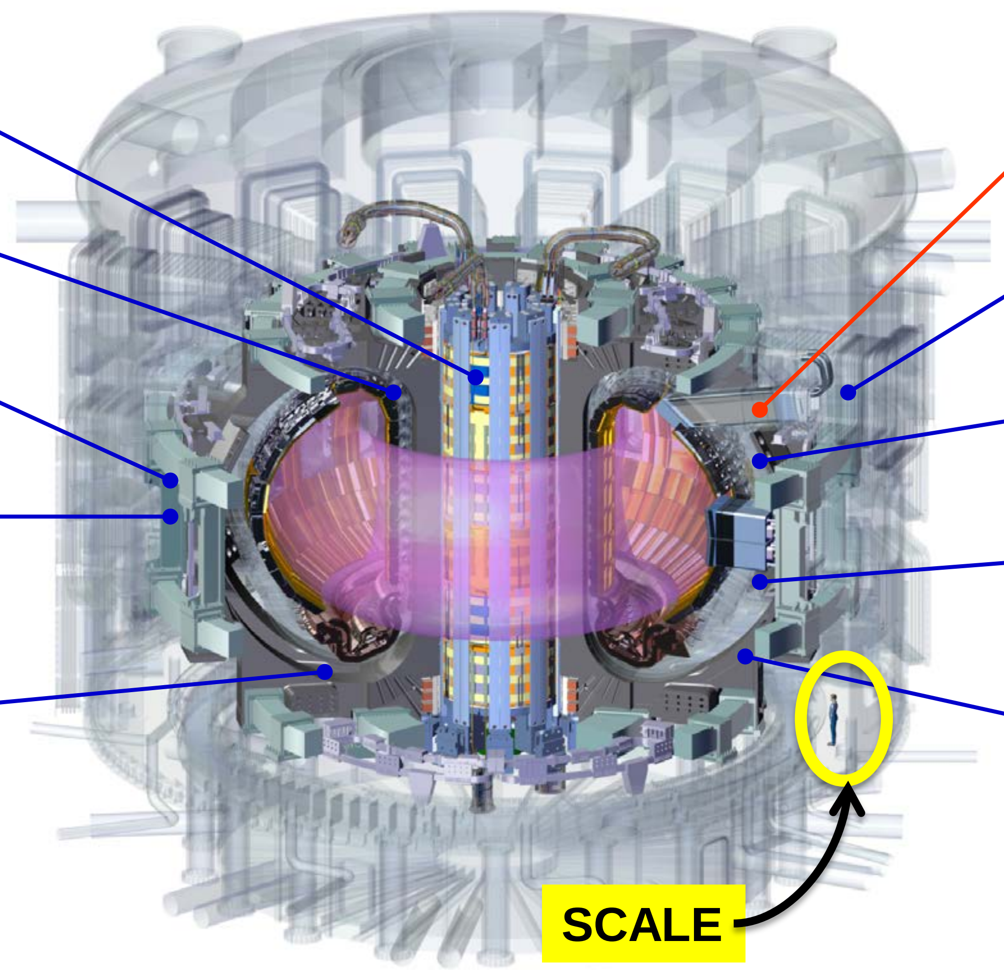
ORNL
8% of Toroidal Field Conductor

ORNL
100% Pellet Injector

ORNL
100% Disruption Mitigation (up to capped value)

ORNL
100% Tokamak Cooling Water System

PPPL
75% Steady State Electrical Network



PPPL
14% of Port-based Diagnostics

ORNL
100% Ion Cyclotron Transmission Lines

ORNL
100% Electron Cyclotron Transmission Lines

ORNL
Blanket/Shield (design support)

ORNL
100% Roughing Pumps, Vacuum Auxiliary System

SRNL
100% Tokamak Exhaust Processing System

Major Progress: US ITER

Deliveries to be Completed in 2014-2015

Major Progress: US ITER

Central Solenoid Fabrication Begins in 2014

Successful acceptance tests of CS tooling stations

Central Solenoid

Specs: 6 independent coil packs of cable-in-conduit conductor (produced in up to 910 m lengths), plus pre-compression structure

• 13 Tesla • 5.5 GJ • 30 kV • 1.2 T/s • 45 kA

ITER Partner:

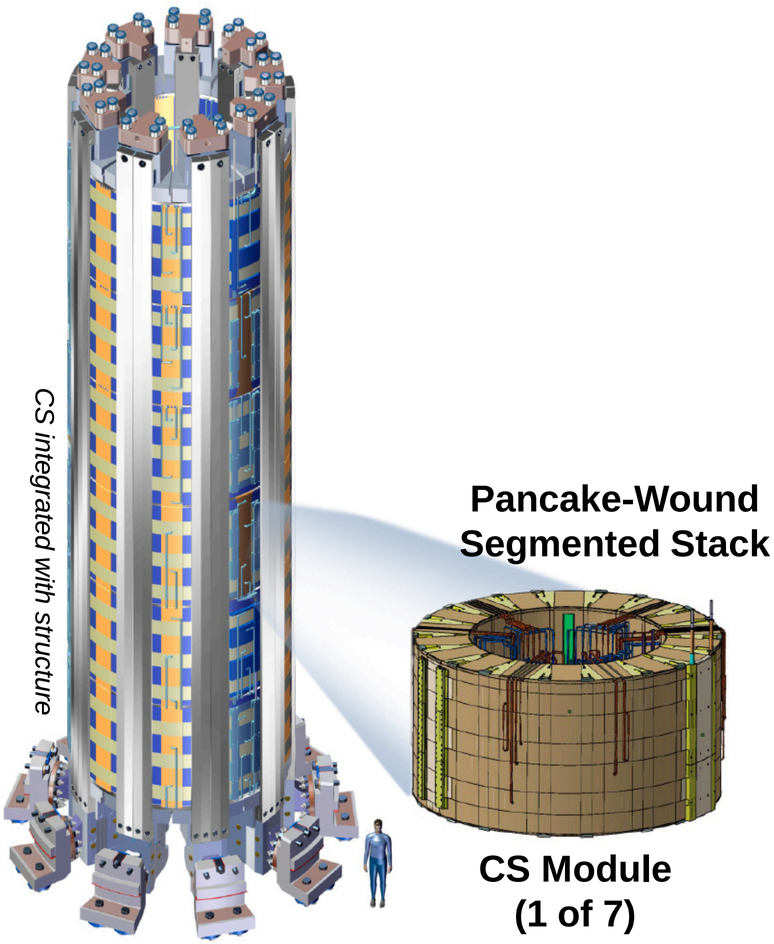
- Japan (conductor)

Status:

- Final Design Review completed
- Development and fabrication of tooling stations in process

Key Vendors:

- General Atomics (modules) with Tauring, Ridgway, Babcock Noel, Seco Warwick (tooling stations)
- G&G Steel (prototype tie plates)
- Major Tool & Machine, Inc. (prototype tie plates)

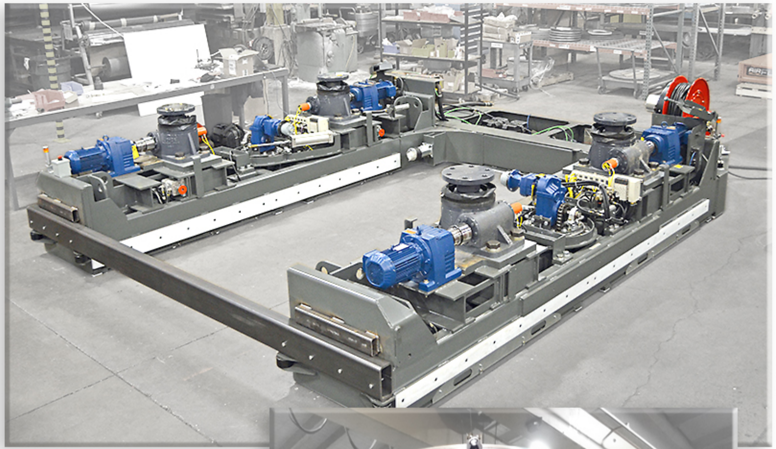


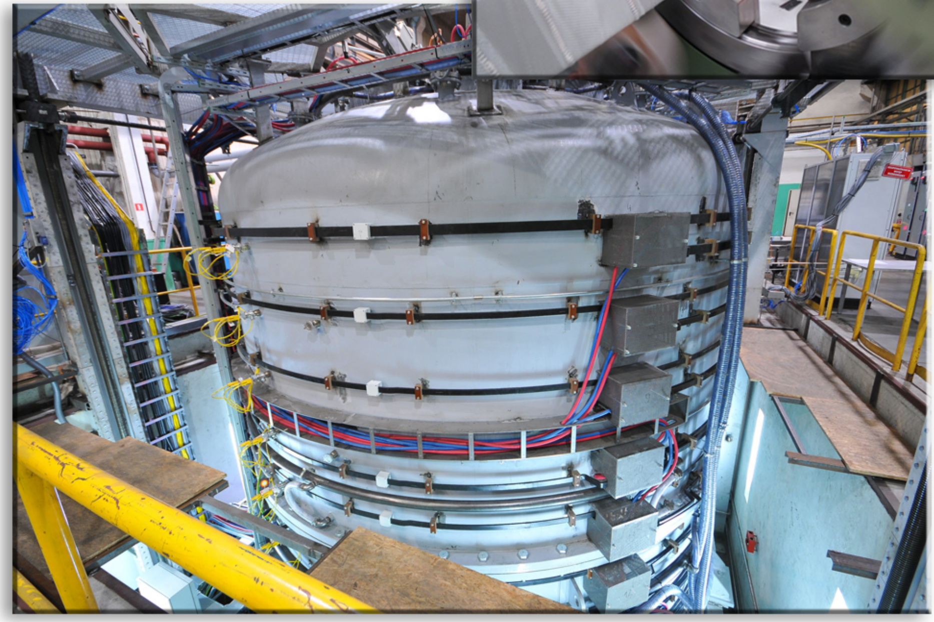
General Atomics is Fabricating the Central Solenoid Modules

GA is Leading Tooling Station Development for CS Fabrication

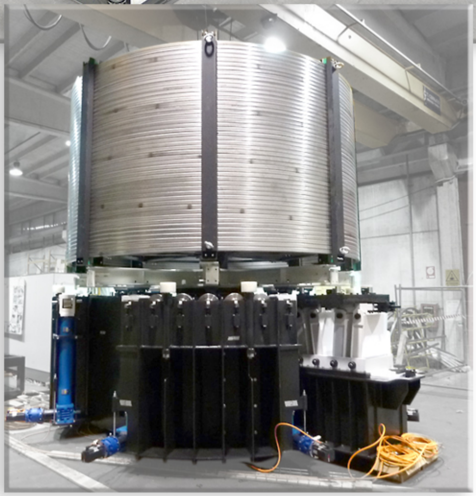
Automated machine wrapping of conductor bars at General Atomics (Poway, CA)

Coil transport tool at Airfloat (Decatur, IL)





Heat treatment furnace at Seco Warwick Corp. (Meadville, PA)



Conductor winding equipment at Tauring (Torino, Italy)

GA is Leading Tooling Station Development for CS Fabrication

Conductor winding station at Tauring (Torino, Italy) during factory acceptance testing.
Photo: US ITER

Toroidal Field Conductor

Specs:

- US contribution includes over 4 miles of conductor, which is constructed from 40 tons/over 4000 miles of niobium-tin superconducting strand
- 18 toroidal field coils being produced by partners
  - Total magnetic energy of 41 gigajoules
  - Maximum magnetic field of 11.8 tesla

Status: In Fabrication

Strand

- Production completed

Cabling

- Dummy cable completed
- 1st production cable completed

Jacketing

- 800 m dummy conductor completed
- Preparation for shipment is under way with shipment planned for April 2014

Key Vendors:

- Luvata Waterbury, Inc.
- Oxford Superconducting Technologies
- New England Wire Technologies, Inc.
- High Performance Magnetics

Strand at Luvata Waterbury, Inc. (Waterbury, CT)

Toroidal Field Conductor

Completed batch of production cable at New England Wire Technologies (Lisbon, NH)

Completed 800 m dummy conductor at High Performance Magnetics (Tallahassee, FL)

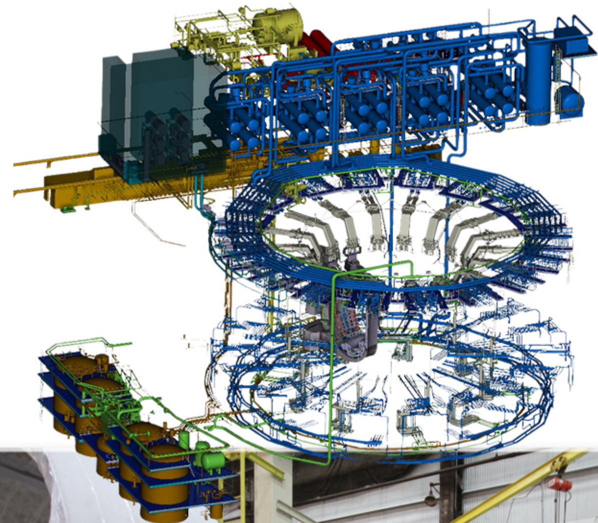
Tokamak Cooling Water System

Configuration:
36 km (22 mi) of piping, ~108 major industrial components

Status:
In fabrication: Drain tanks
In design: Integrated system and 230 pieces of equipment

Key Partner: ITER Organization

Key Vendors: AREVA Federal Services (design, Title III) with Joseph Oat Corporation and ODOM Industries (drain tank manufacture)



Drain tank assembly is underway at Joseph Oat, Corp. (Camden, NJ).

Drain tank heads from Odom Industries (Milford, OH) were delivered to Joseph Oat, Corp. for tank fabrication.

Tokamak Cooling Water System

Recent Achievements:

- Drain tank fabrication progressing and scheduled for completion in 2014
- Arrangements between US ITER and the ITER Organization to complete the final TCWS design, and procure and pre-fabricate piping on behalf of US ITER
- Completed the design documentation review and transferred a hierarchical set of documents into a searchable database that shows the implementation requirements

Drain tank heads and shells are being fitted and assembled at Joseph Oat Corporation (Camden, NJ). Photo: US ITER

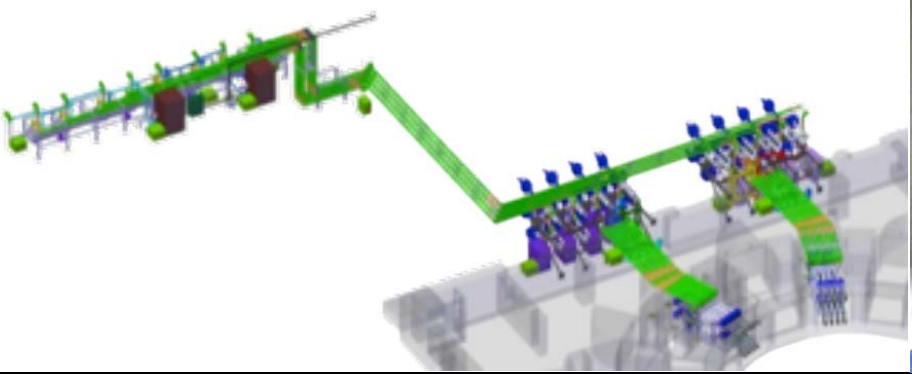
Ion Cyclotron Transmission Lines

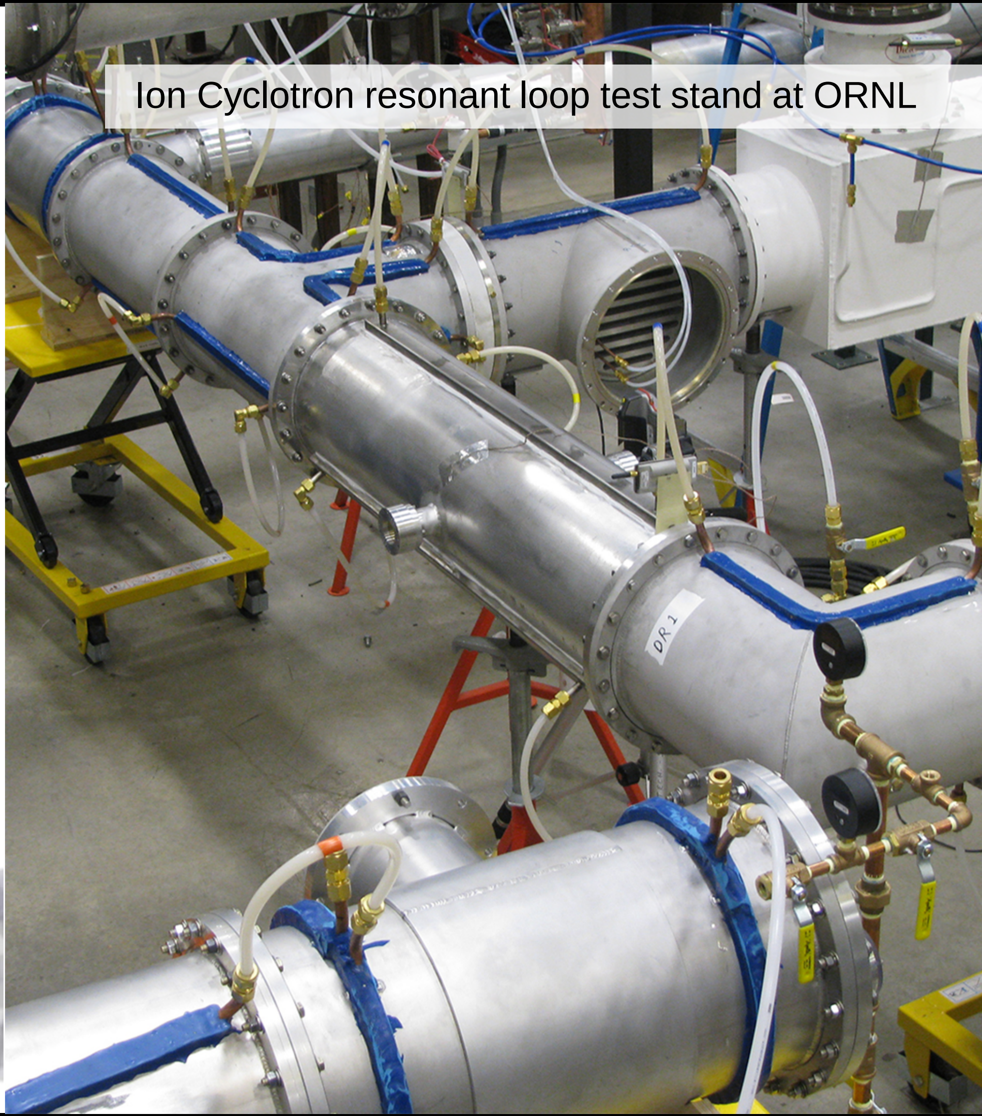
Specs:

- Deliver up to 6 MW per transmission line from 8 transmitters to 2 power launchers
- Load-tolerant tuning over 40-55 MHz
- 1.5 km of transmission line

Status: In Preliminary Design

Key Vendors: Mega, Dielectric, Comet, General Atomics, National Instruments, Cincinnati Fan



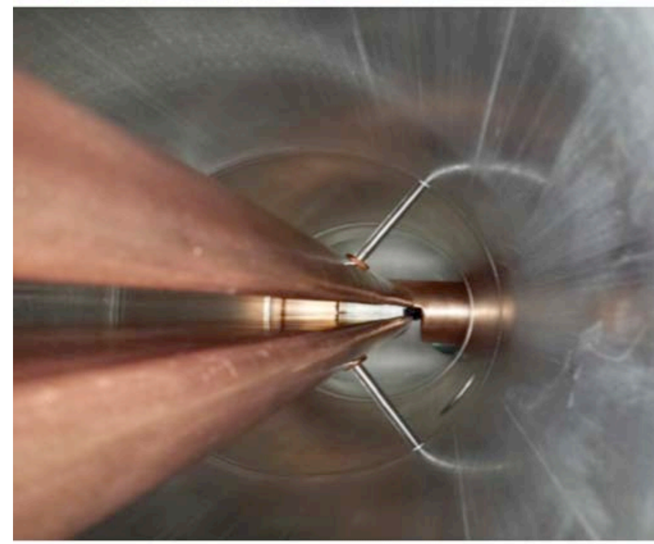


Ion Cyclotron resonant loop test stand at ORNL

Ion Cyclotron Transmission Lines and Matching System

Recent Achievements:

- Successful test of cooling the inner conductors with circulating air at 3-atmosphere pressure
- Successful tests at high-voltage (40 kV) and long-pulse (1 hour) for two candidate straight transmission lines
- Successful test of one candidate gas barrier at high-voltage (40 kV) and long-pulse (1 hour)
- Successful performance verification test of 50/50 hybrid power splitter
  - The power splitter enables passive tolerance to plasma ELM events



Four-port 50/50 power splitter on the test bench. Internal view of outer conductor (aluminum) and inner conductors (copper) of the power splitter (Mega Industries, Portland, ME).

Electron Cyclotron Transmission Lines

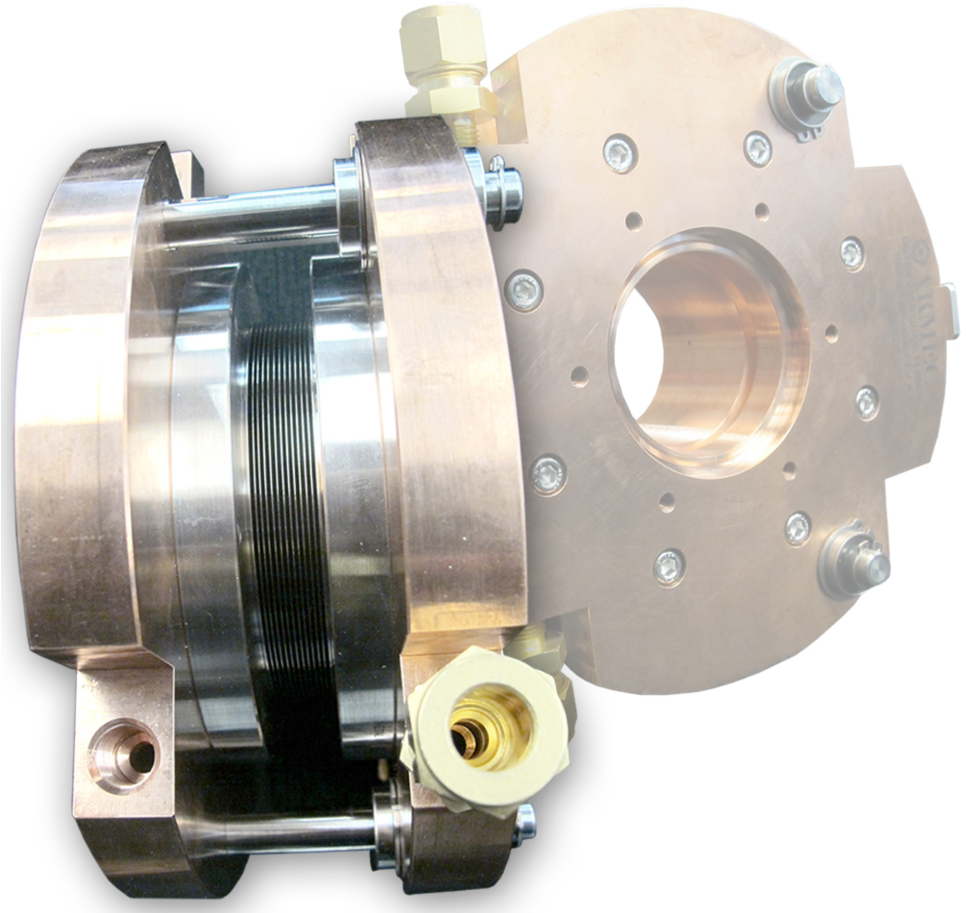
Specs:

- Provide efficient power transfer from 170 GHz gyrotron sources to launchers
- Provide 20 MW of plasma heating power
- 4 km of transmission line, with 24 sources to 56 feeds

Status: In Final Design

Key Vendors:

- General Atomics
- Dymenso
- Calabazas Creek
- ARMEC

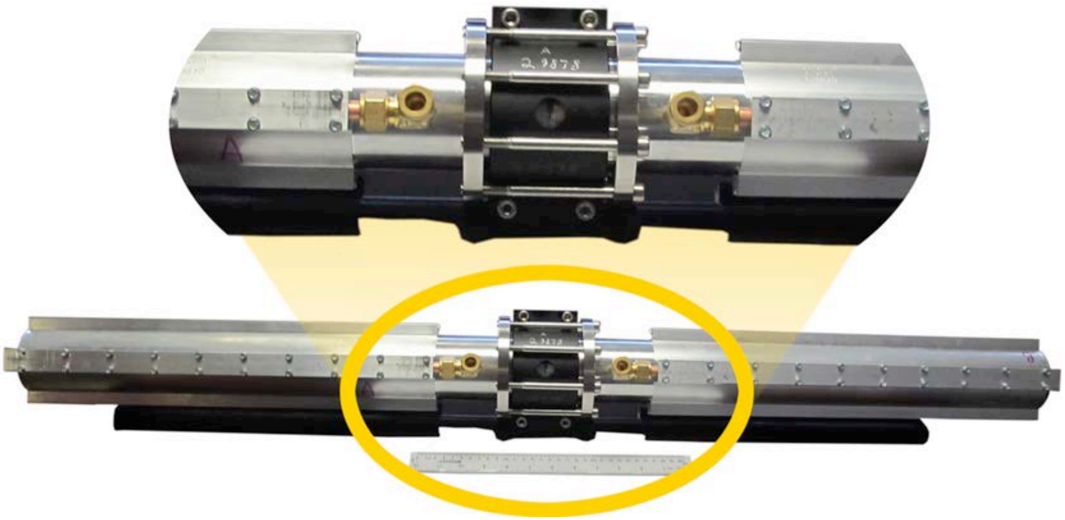


A waveguide short gap expansion unit prototype permits expansion and contraction during cycles

Electron Cyclotron Transmission Lines and Support System

Recent Achievements:

- Fabrication of test articles for waveguide switch, thermal expansion system and high accuracy waveguide joint
- Thermal/mechanical modeling of waveguide components and associated water cooling requirements
- Modeling analysis of mode conversion and ohmic power losses for waveguide components and overall integrated system losses



High alignment accuracy waveguide joint

Aluminum waveguide and spiral corrugation tool

Vacuum Auxiliary and Roughing Pump Systems

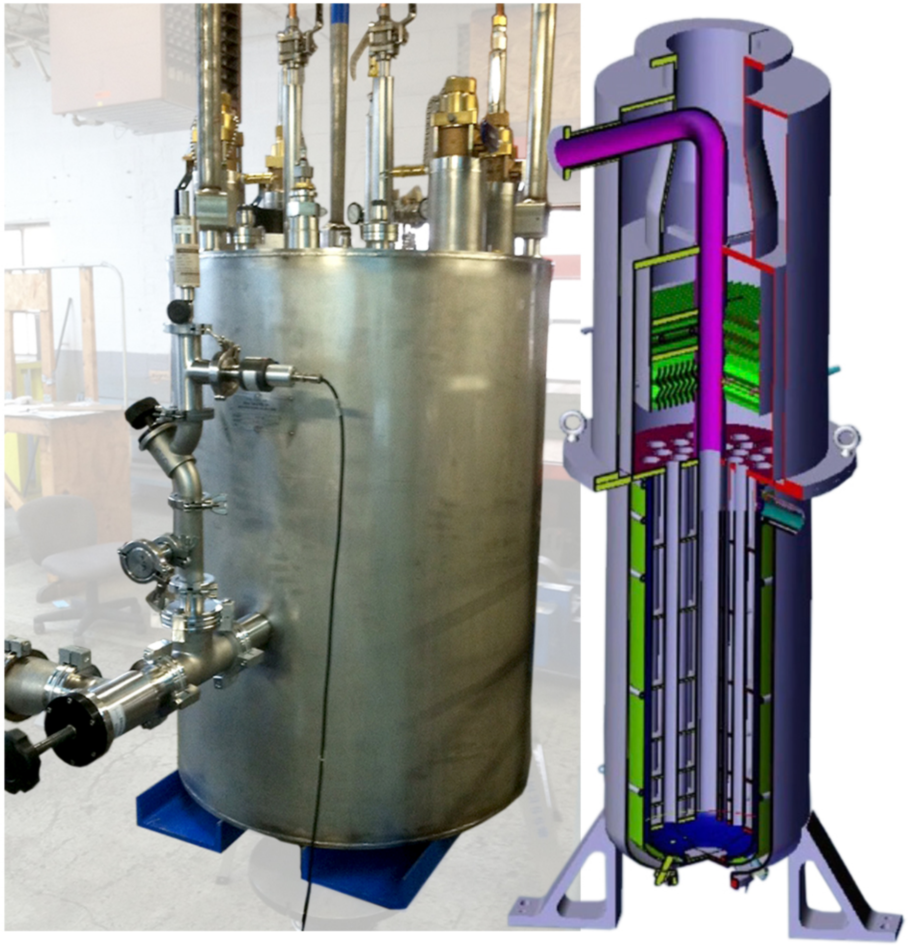
Specs: Vacuum auxiliary system (VAS) servicing ~ 5000 clients and continuous Protium, Deuterium, Tritium, and Helium gas roughing pumps (RPs)

Status: In Preliminary/Final Design

- Delivered test equipment
- Prototype pumps in fabrication and being tested

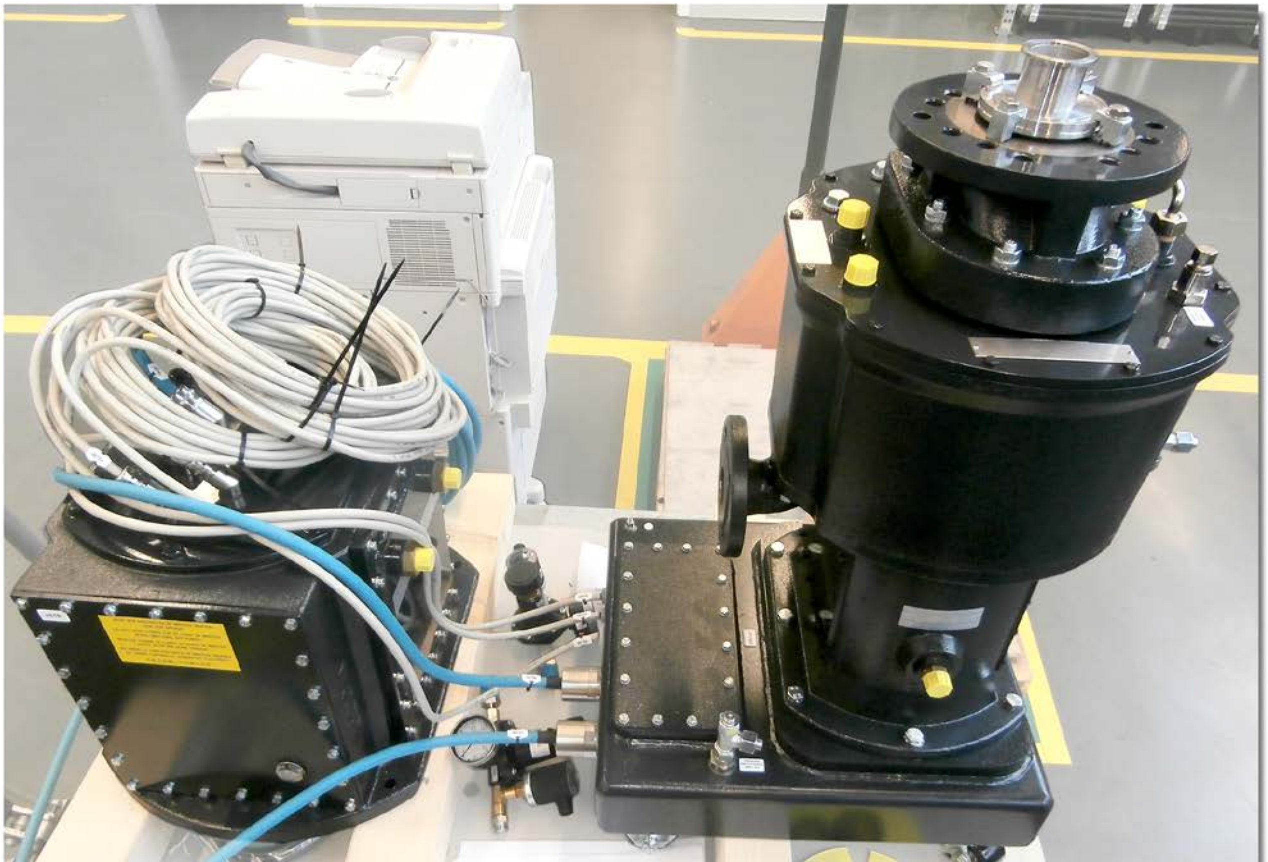
Key Vendors:

- SIHI Pumps, Inc.
- Major Tool & Machine
- Pfeiffer Vacuum, Inc.



Cryogenic Viscous Pump prototype (left) and concept for 1st stage rough pumping.

Vacuum Auxiliary and Roughing Pump Systems



Screw pump from SIHI (Grand Island, NY). Photo: US ITER

CVC pump inner tube bundle
Photo: US ITER

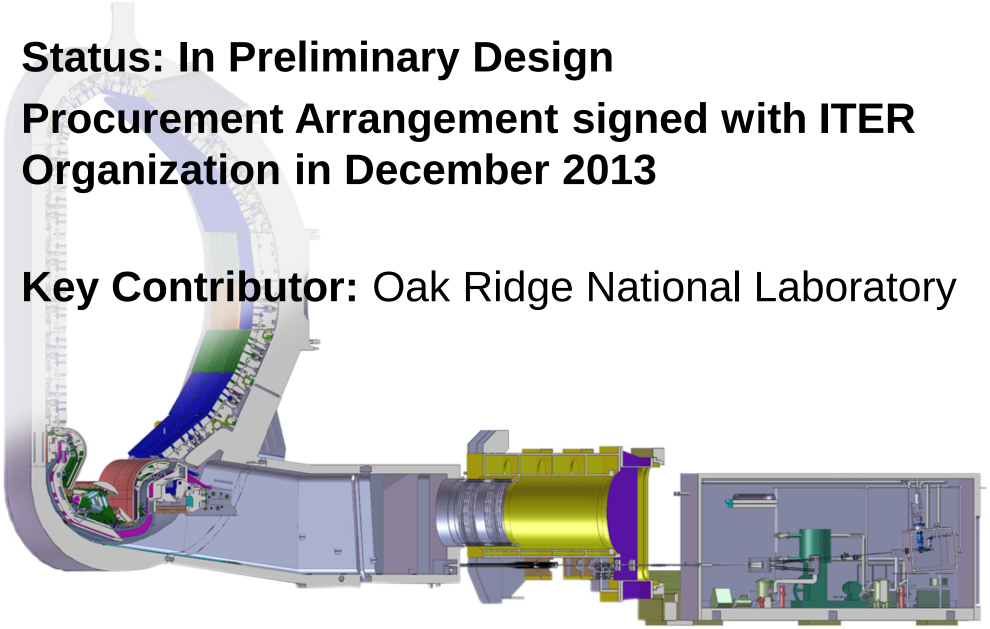
Pellet Injection System

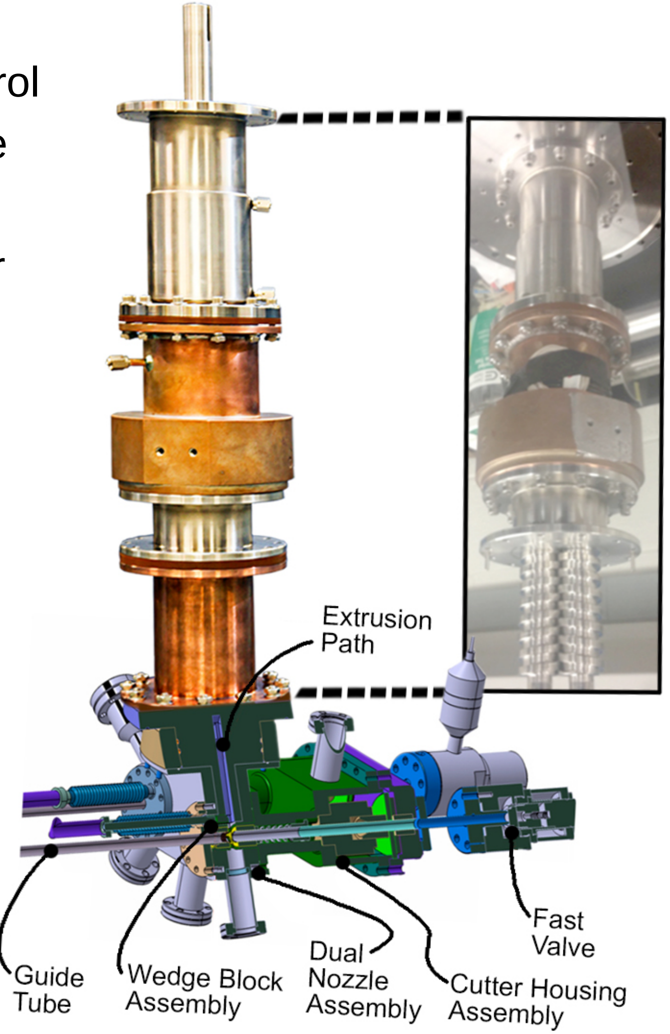
Specs:
- Continuous and reliable H/D/T fueling and mode control
- Frozen hydrogen pellets accelerated by high pressure gas
- Extruder nozzle produces adjustable length pellets for fueling or mode triggering

Status: In Preliminary Design

Procurement Arrangement signed with ITER Organization in December 2013

Key Contributor: Oak Ridge National Laboratory

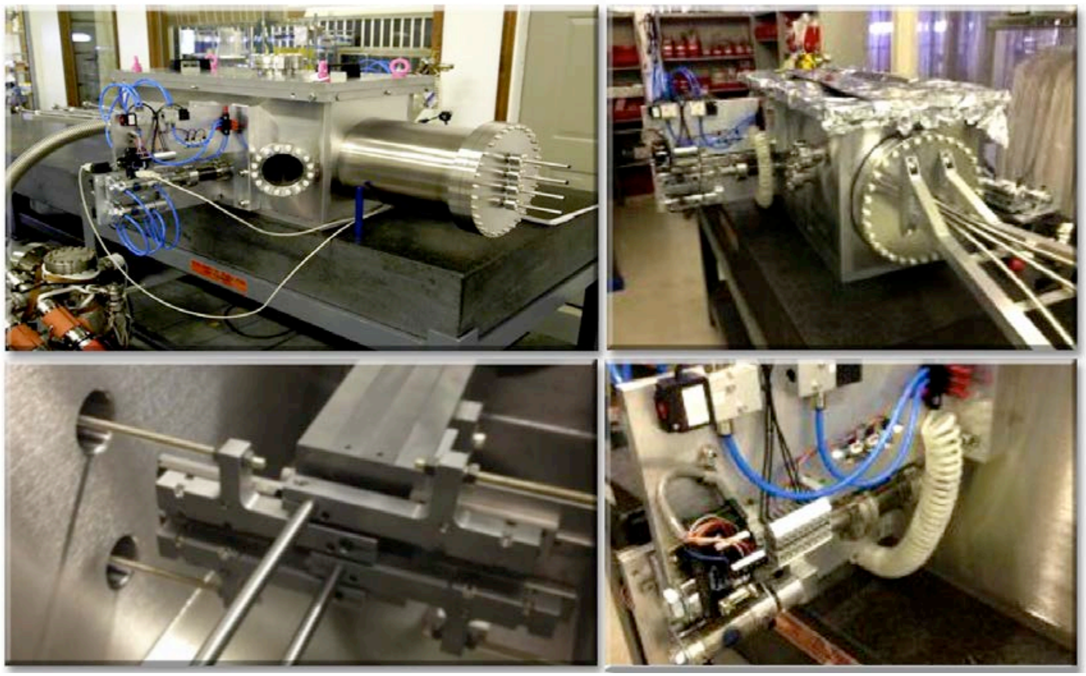




Pellet Injection System

Recent Achievements:

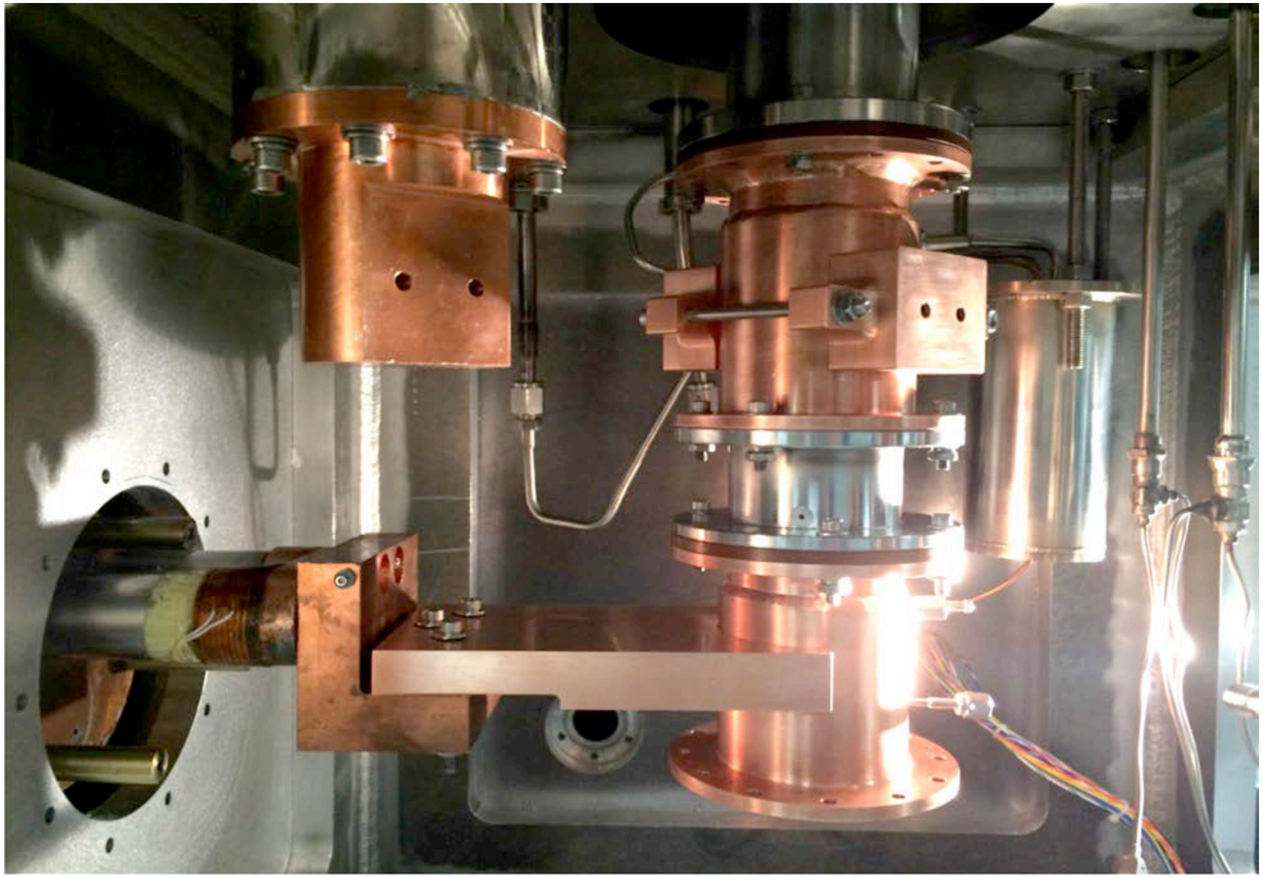
- Fabrication of test articles for extruder and guide tube selector
- Long-term reliability tests of tritium compatible piston pump for recirculation loop
- Demonstration on DIII-D of pellet ELM pacing at 12 X natural rate and associated 12 X reduction in ELM intensity



Pellet guide tube selector with internal views of actuators for routing pellets for multiple inputs to multiple outputs.

Pellet Injection System

Prototype Extruder Development



Pellet injector deuterium gas liquefier, solidifier and extruder assembly inside vacuum cryostat. Photo: US ITER

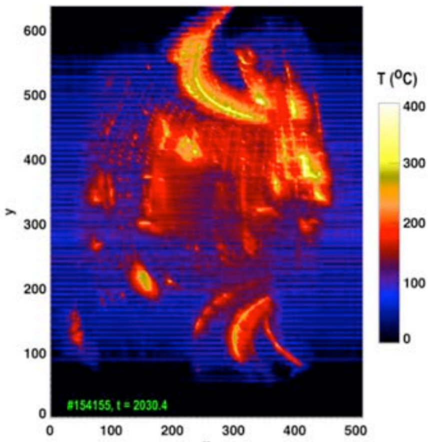
Disruption Mitigation

Specs: Massive gas injection and shattered pellet injection will be used to limit impacts of plasma current disruptions and suppress the formation and deleterious effects of high-energy runaway electrons.

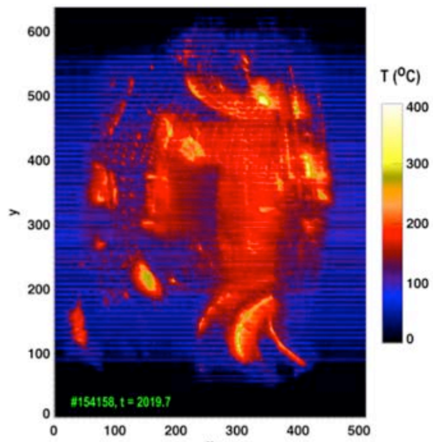
Status: In Preliminary Design

- Massive gas injection developed and tested on ASDEX-U, C-Mod, DIII-D and JET
- Radiation asymmetry characterized
- Large valve developed for JET being redesigned for ITER use
- Shattered pellet injection tested on DIII-D
- Multiple barrel design being developed for ITER use
- ITER environment, delivery distance and required reliability and response time is a design challenge

Experiment on DIII-D: Massive gas injection (MGI) results in reduction in upper strike point wall temperature and more uniform heat distribution on main chamber walls.



Unmitigated upward vertical displacement event (VDE)



Upward VDE mitigated with MGI 10 ms before VDE thermal quench time

Disruption Mitigation

Prototype 3-Barrel Shattered Pellet Injector

A prototype 3-barrel shattered pellet injector with 16 mm barrels is under development at ORNL. Shown here installed in vacuum chamber. Photo: US ITER

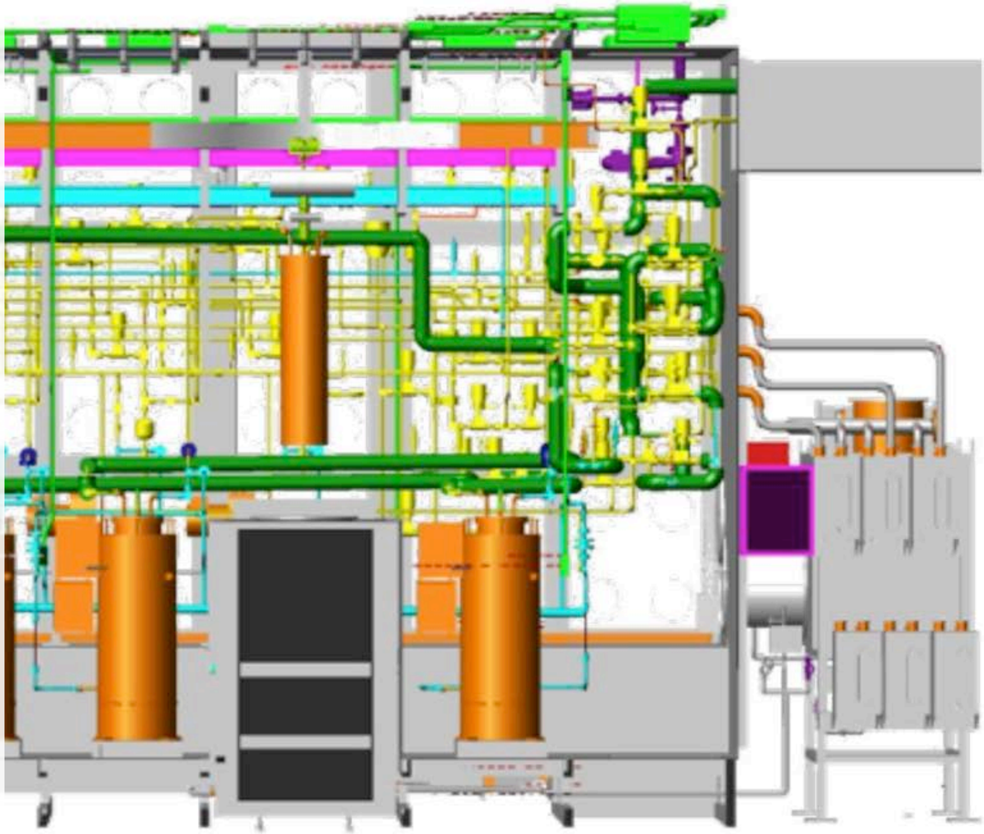
Tokamak Exhaust Processing

Specs:

- Separates hydrogen isotopes from non-hydrogen in the gas exhaust system
- Delivers hydrogen isotopes to EU's hydrogen isotope separation system

Status: In Preliminary Design

Key Contributor: Savannah River National Laboratory



Steady State Electrical Network

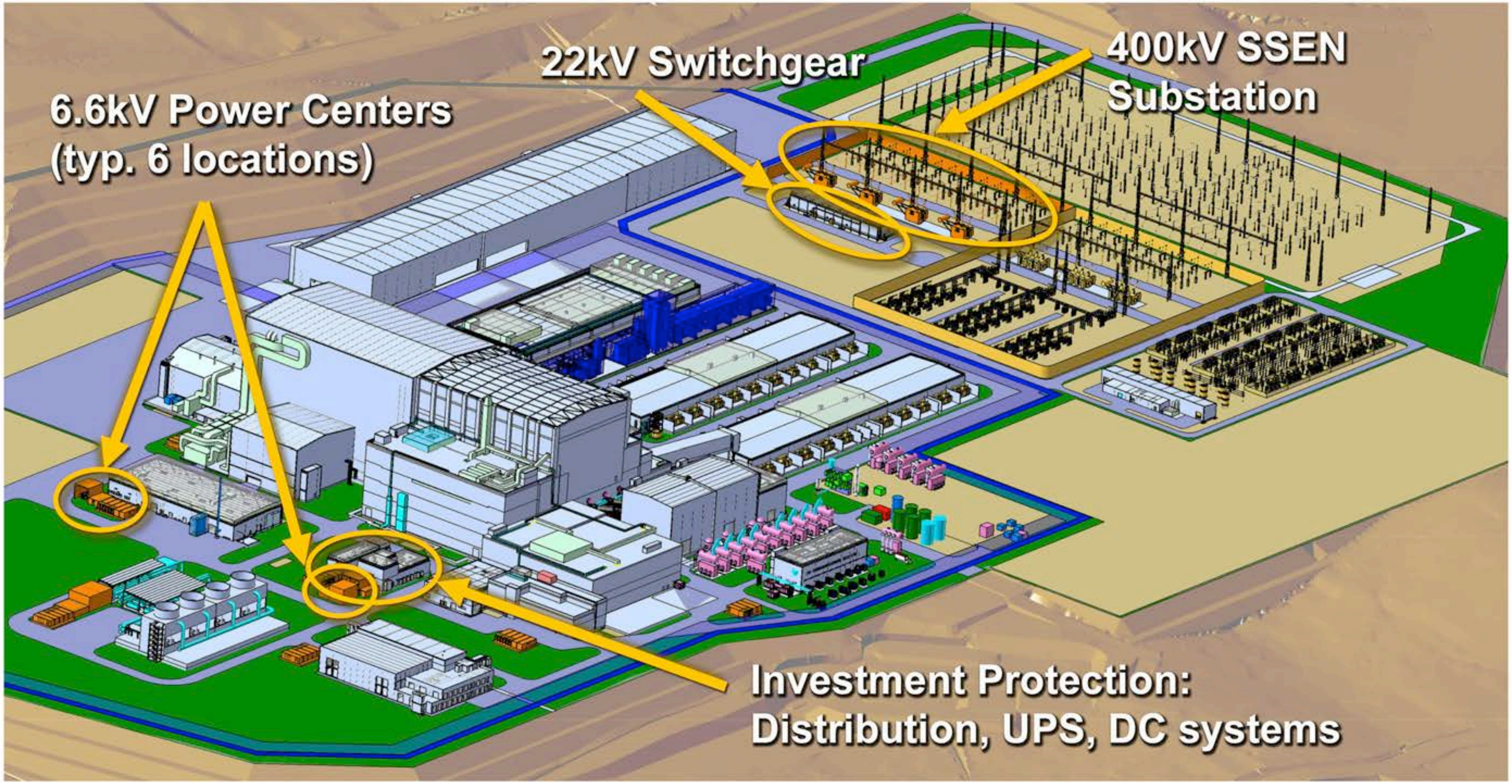
Scope: 75% of the equipment used to supply electrical power to all conventional (steady state) loads in ITER facility, including

- HV Disconnect Switches
- HV Circuit Breakers
- HV Current Transformers
- HV Potential Transformers
- HV Surge Arresters
- HV Substation Transformers
- HV Substation Hardware
- HV Control & Protection
- Earthing Resistors
- 22kV Switchgear

Status: In Fabrication

Key Vendors:
Hyundai Corporation (USA)
Eaton Corporation
ABB, Inc.
Siemen's Industry, Inc.

Steady State Electrical Network Scope



Equipment provided by US noted above (~ $30M).

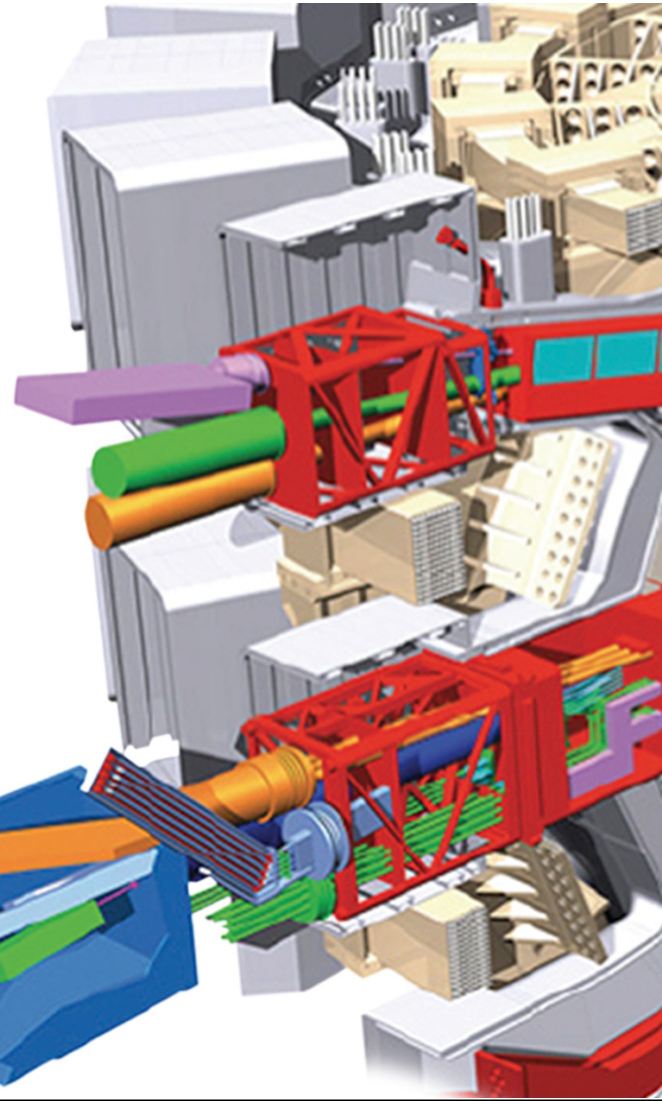
(Design, installation, and 25% of equipment provided by EU.)

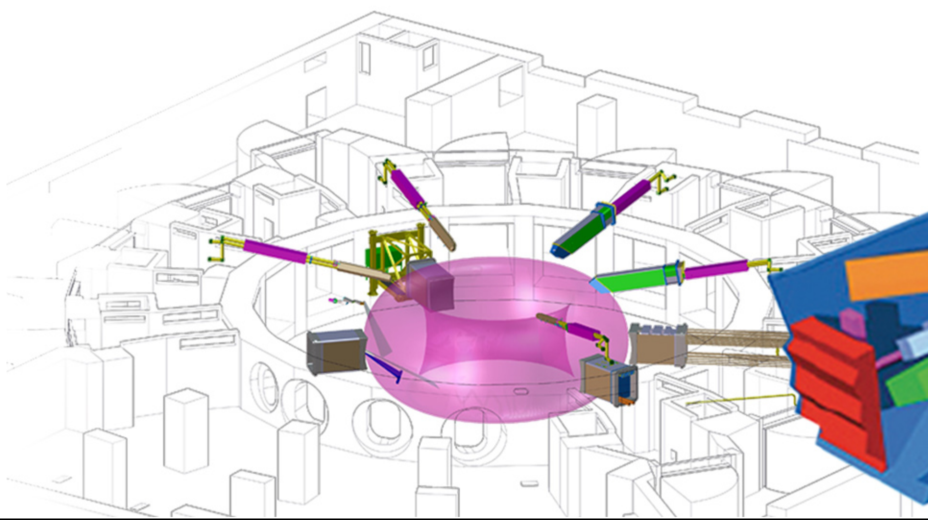
Diagnostics

Scope: 14% of port-based diagnostic systems, including integration of 4 diagnostic ports, plus 7 instrumentation systems

Status: In Preliminary and Conceptual Design

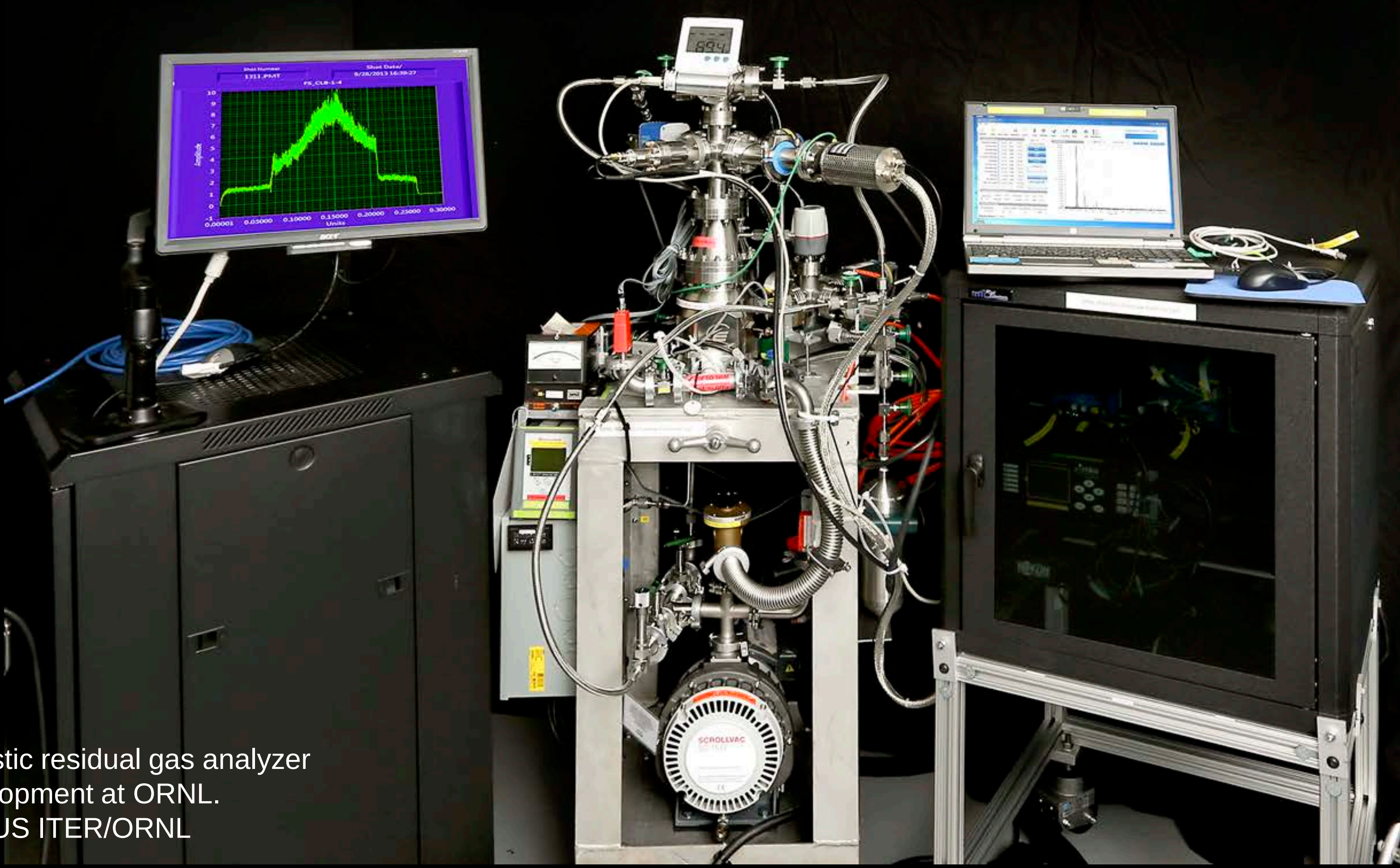
Key Contributors: PPPL, ORNL, LLNL, UCLA, U Texas, U Maryland, MIT, UC Davis, Nova Photonics, General Atomics





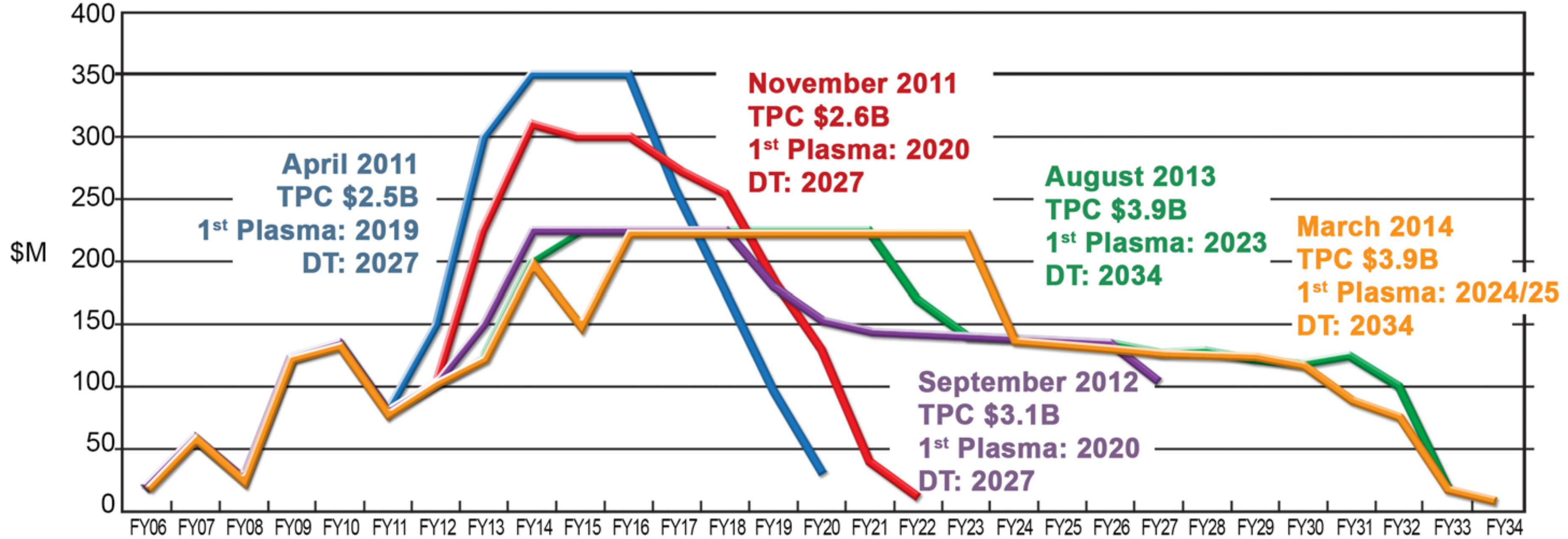
Diagnostics

Diagnostic residual gas analyzer will be installed for first plasma.



Diagnostic residual gas analyzer
in development at ORNL.
Photo: US ITER/ORNL

US ITER Funding Profile History



Four major factors driving changes:

1. Downward pressure on US ITER budget
2. Extended risk exposure increasing requirements for contingency funds
3. Delay of 3-4 years at IO with our estimate of ~ $1B increase in IO cost
4. Reduced buying power due to operations cost included under US ITER budget ceiling

Conclusion: US ITER is Strongly Positioned for Continuing Progress

- US is working closely with the ITER Council and the ITER Organization to further evolve the ITER partnership for success.
- US technical challenges encountered to date have been overcome; no “show-stoppers” foreseen.
- US 1st plasma scope is sufficiently firm to proceed with fabrication at acceptable risk.
- 1st plasma deliverables have been on schedule.
  - If $150M appropriated in FY 2015, schedule will slip again and total program cost will increase.

US ITER is strongly positioned to accelerate schedule and reduce risk with adequate appropriations.