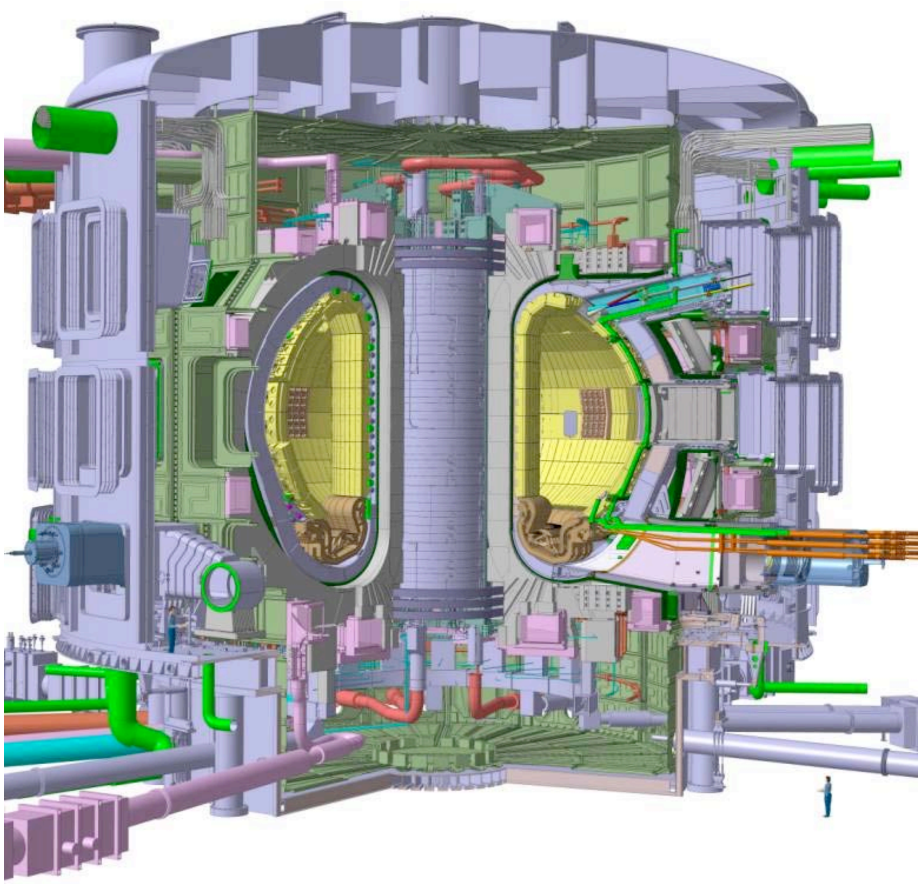
Plans for U.S. Contributions to ITER



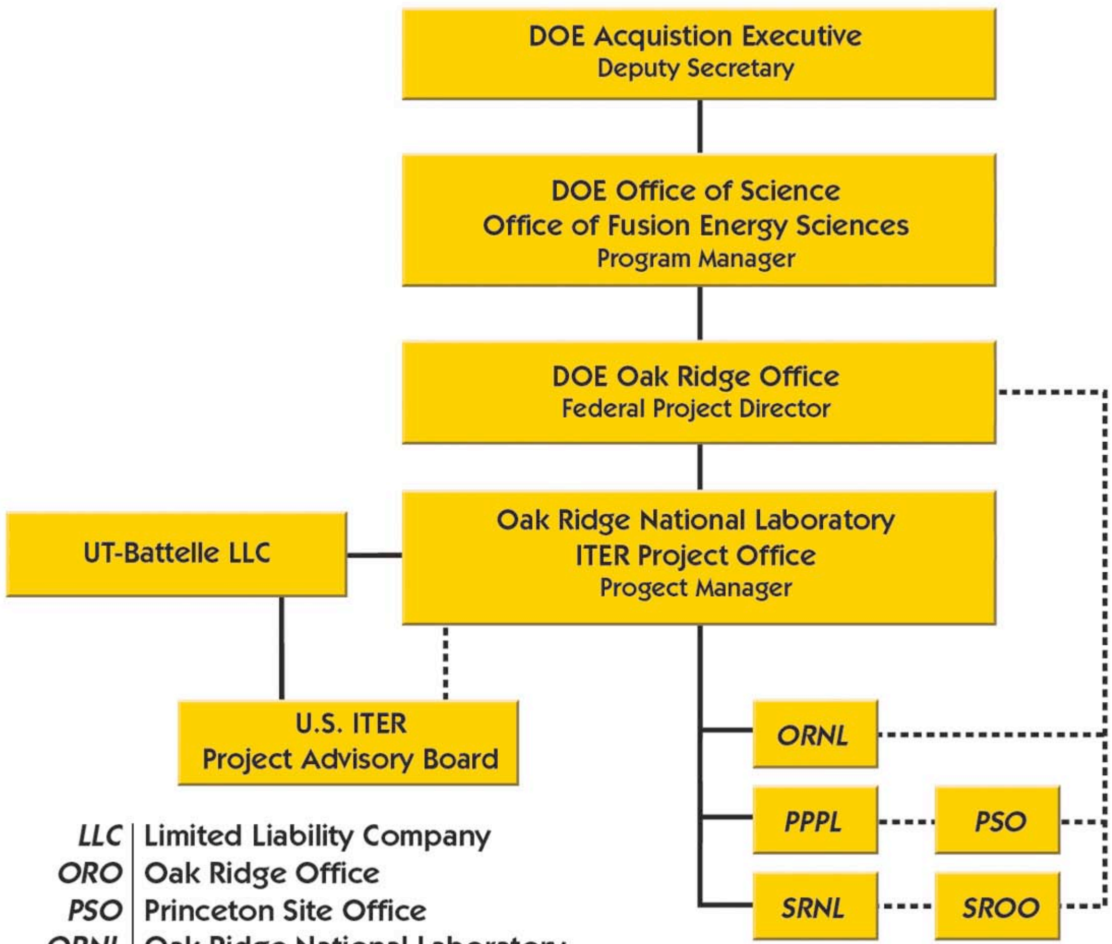
Ned Sauthoff

Director, U.S. ITER Project Office

Fusion Power Associates

December 3, 2008

U.S. ITER Organizational Structure



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

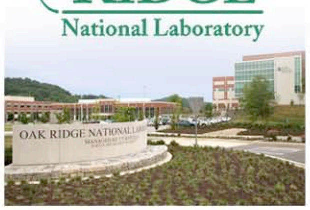
U.S. ITER Project Office

USIPO is prepared to proceed….

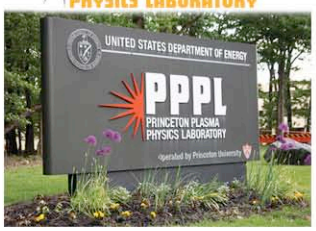
- **Project Execution Plan**
- **Resource-loaded schedule**
- **Cost-estimate range**
  - CD-1 basis cited in the President's Budget Request
  - Includes Risk-based contingency
- **Project Control tools built on Spallation Neutron Source set**
  - Work Breakdown Structure
  - Configuration Control
  - Quality Assurance and Safety Plans
  - Risk Management….
- **Contracts, Business and other capabilities from ORNL, but co-located**

U.S. Partners

Office of Science
U.S. DEPARTMENT OF ENERGY



Oak Ridge National Laboratory (Tennessee), host lab
- Project Management/Support
- International Team Support
- Magnets, Cooling Water, Blanket Shielding/Port Limiter, Vacuum Pumping & Fueling, Ion Cyclotron Heating, Electron Cyclotron Heating

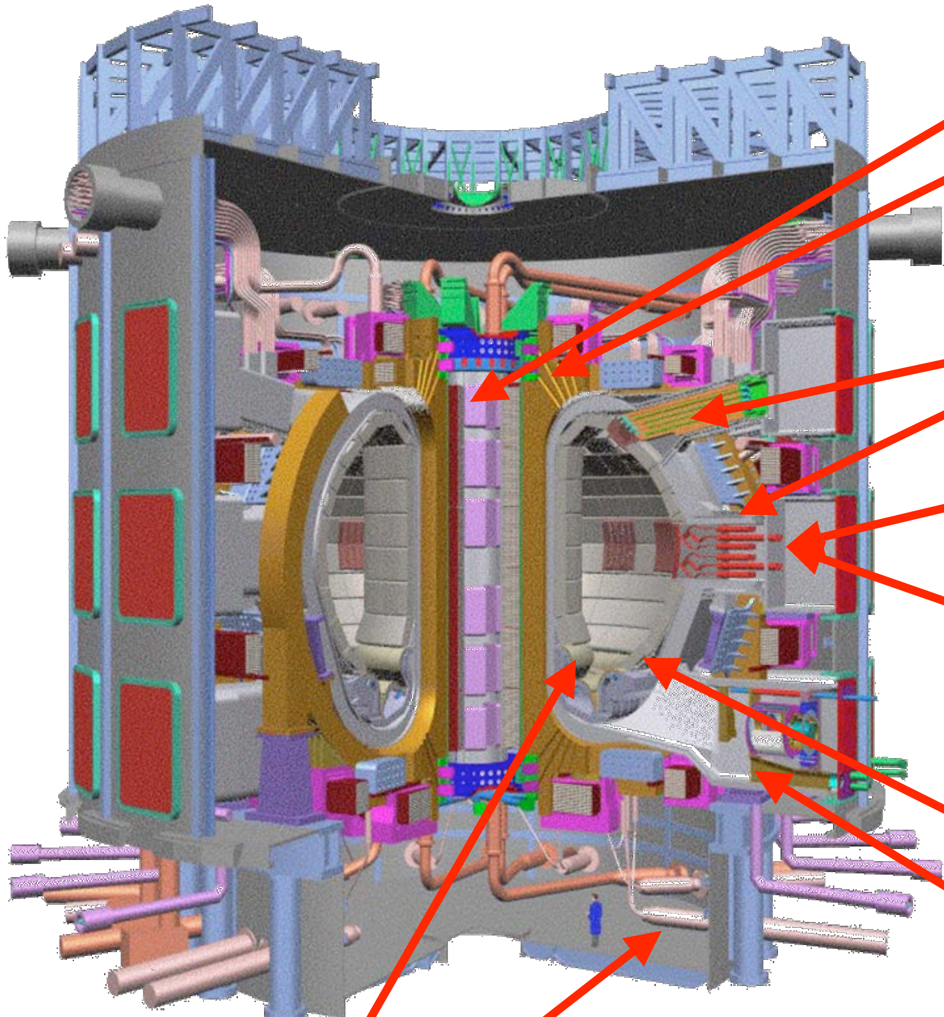


Princeton Plasma Physics Laboratory (New Jersey)
- Electric Power Systems
- Diagnostics

Savannah River National Laboratory (South Carolina)
- Exhaust Processing System: Design, fabrication, assembly, testing, shipment

U.S. iter

US ITER In-kind Hardware Contributions



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

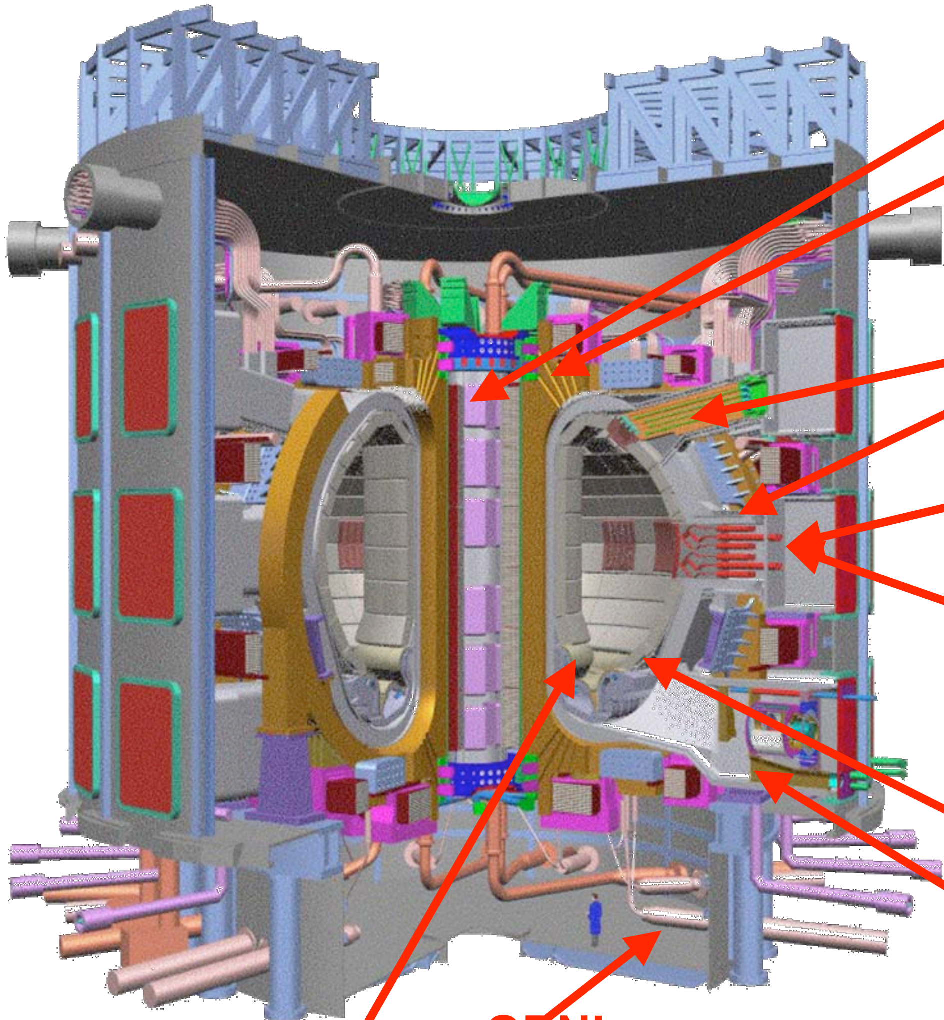
pellet injector

75% Cooling for divertor, vacuum vessel, …

Steady-state power supplies

Tokamak exhaust processing system

US ITER In-kind Hardware Contributions



ORNL 7 Central Solenoid windings

ORNL 8% of Toroidal Field conductor

PPPL 15% of port-based diagnostics

ORNL 100% Ion Cyclotron transmission lines

ORNL 100% Electron Cyclotron transmission lines

ORNL 20% Blanket/Shield

ORNL Roughing pumps, standard components

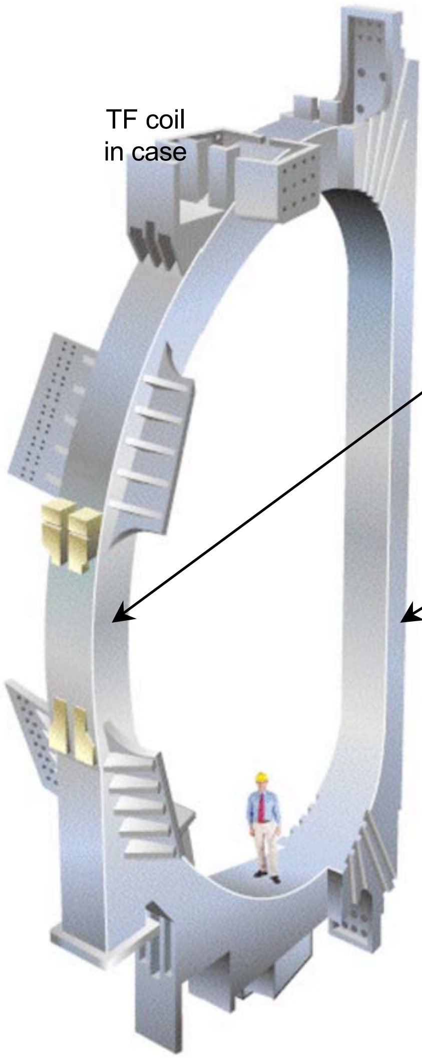
ORNL pellet injector

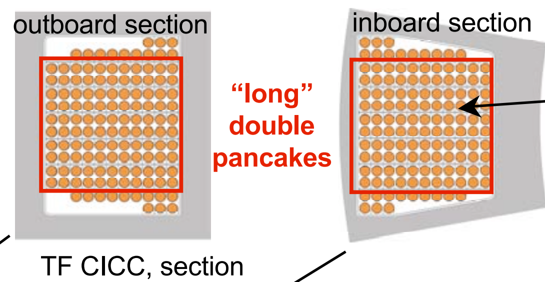
ORNL 75% Cooling for divertor, vacuum vessel, …

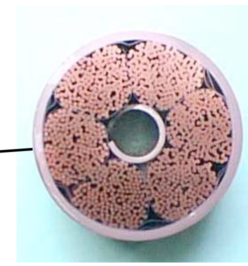
PPPL Steady-state power supplies

SRNL Tokamak exhaust processing system

Toroidal Field Coil Conductor



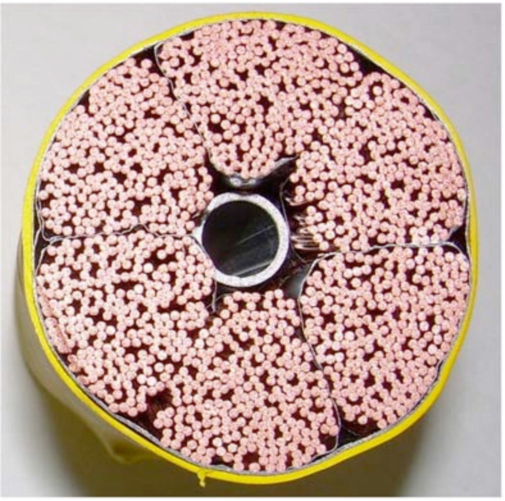




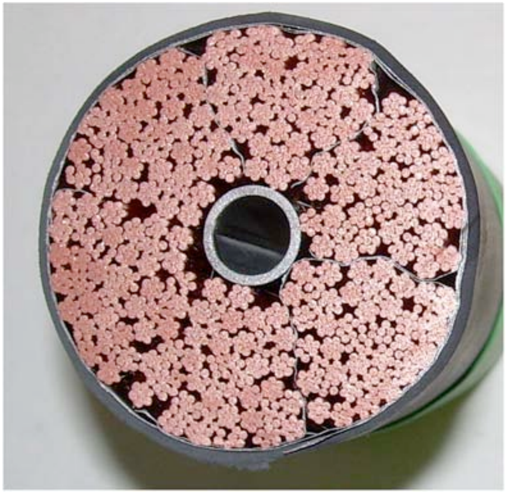
U.S. will supply 40 tons of Niobium$_3$-Tin superconducting wire

Cable pattern & strand support

Baseline geometry 3-based



Alternate geometry 6+1 based



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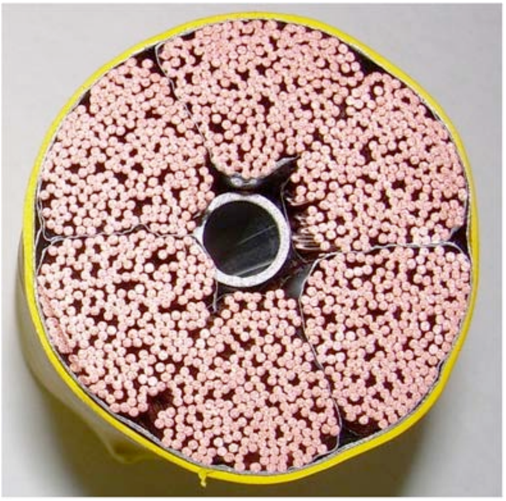

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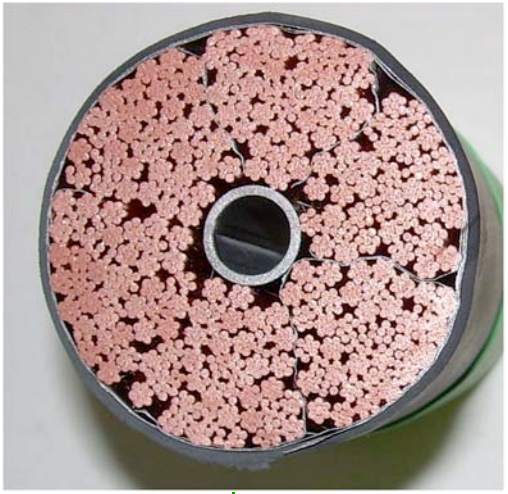


Alternate geometries substantially stiffer than baseline.

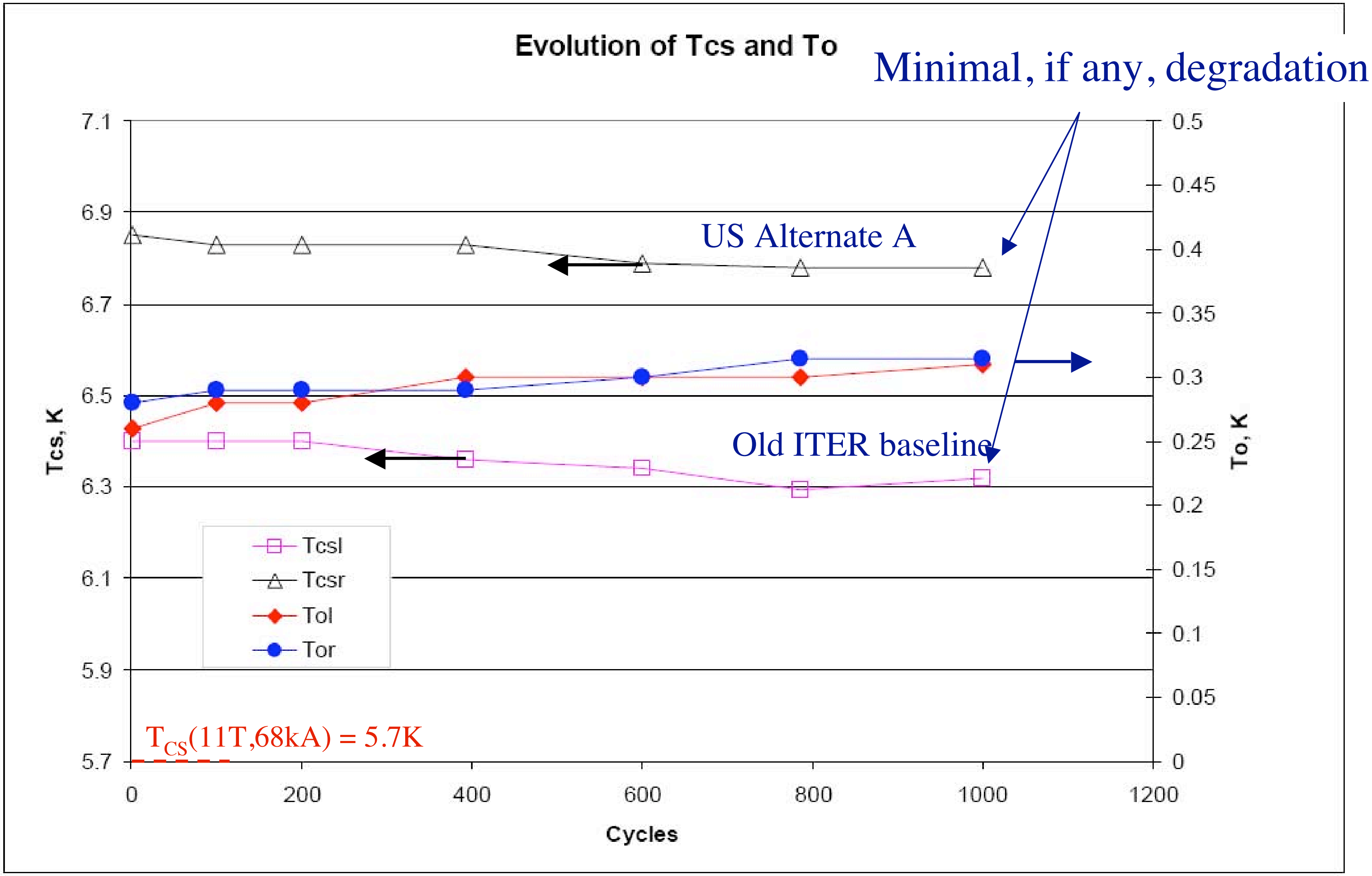
Better strand support?

Sultan Test Samples

Sultan Test Facility
Photo courtesy CRPP/PSI

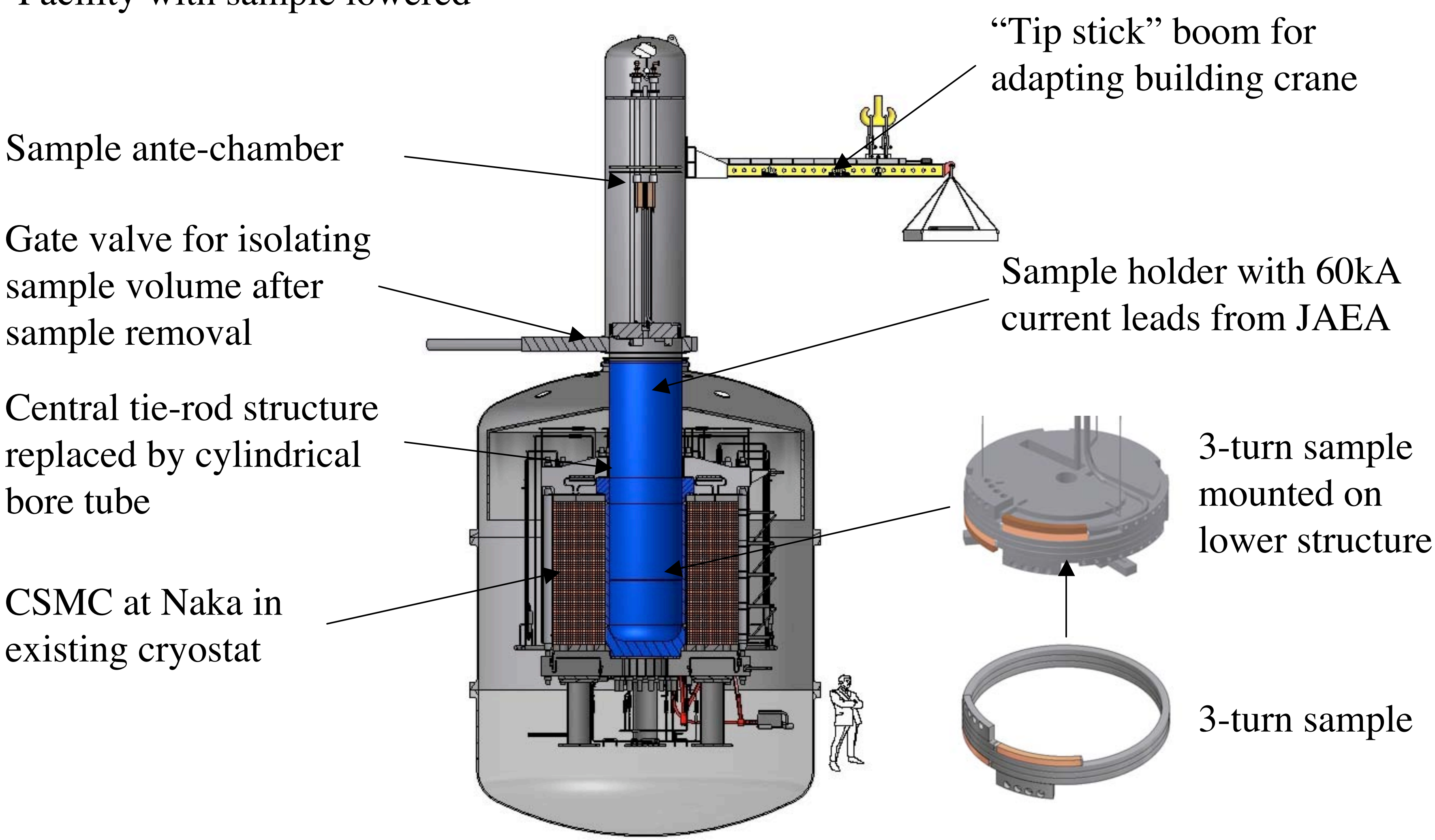
- **All superconducting strands for the Toroidal Field Coils (TF) have to pass a Qualification Procedure.**
- **These tests are performed at the Superconductor Test Facility SULTAN, Located at the Paul Scherrer Institute in Villigen, Switzerland.**
- **EU dipole and perhaps the CSMC (or KO) facility will be used in the future too.**

US TF Conductors have qualified twice



Possible conductor test facility

Facility with sample lowered



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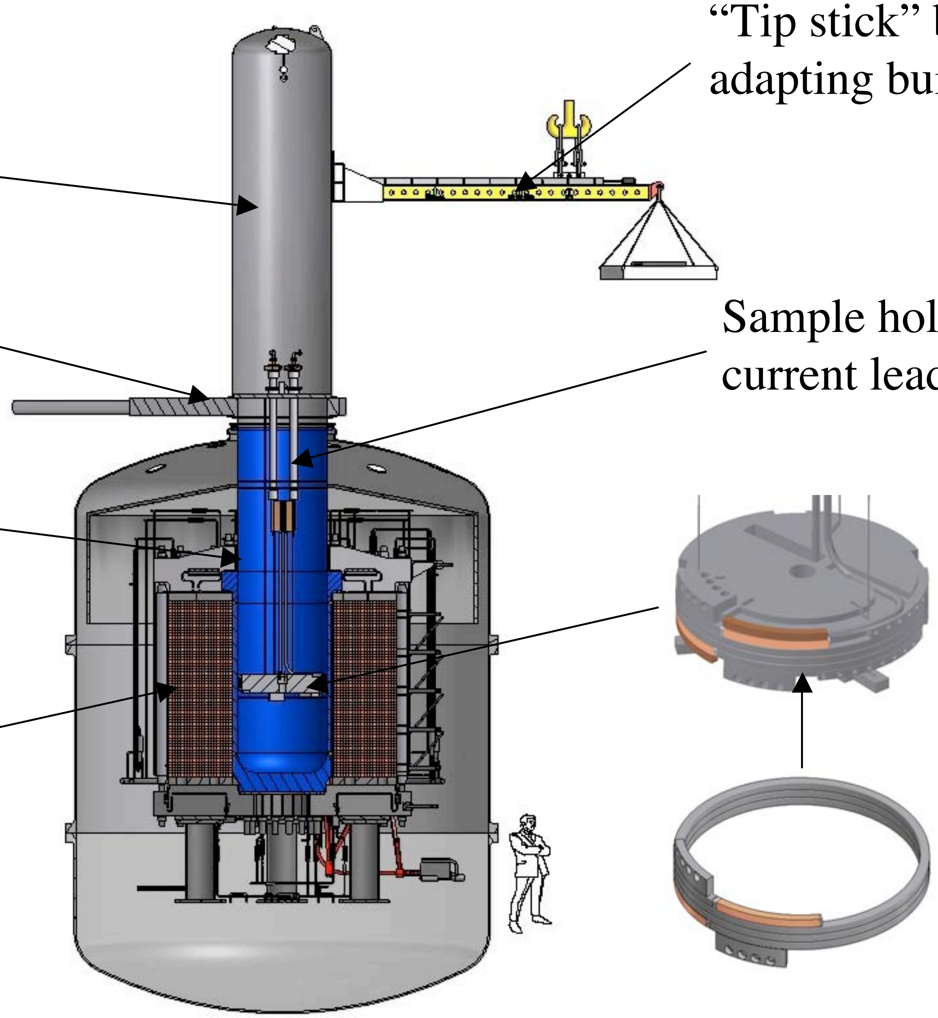


Central Solenoid Options

Reference Design, external structure based on inner & outer tie plates

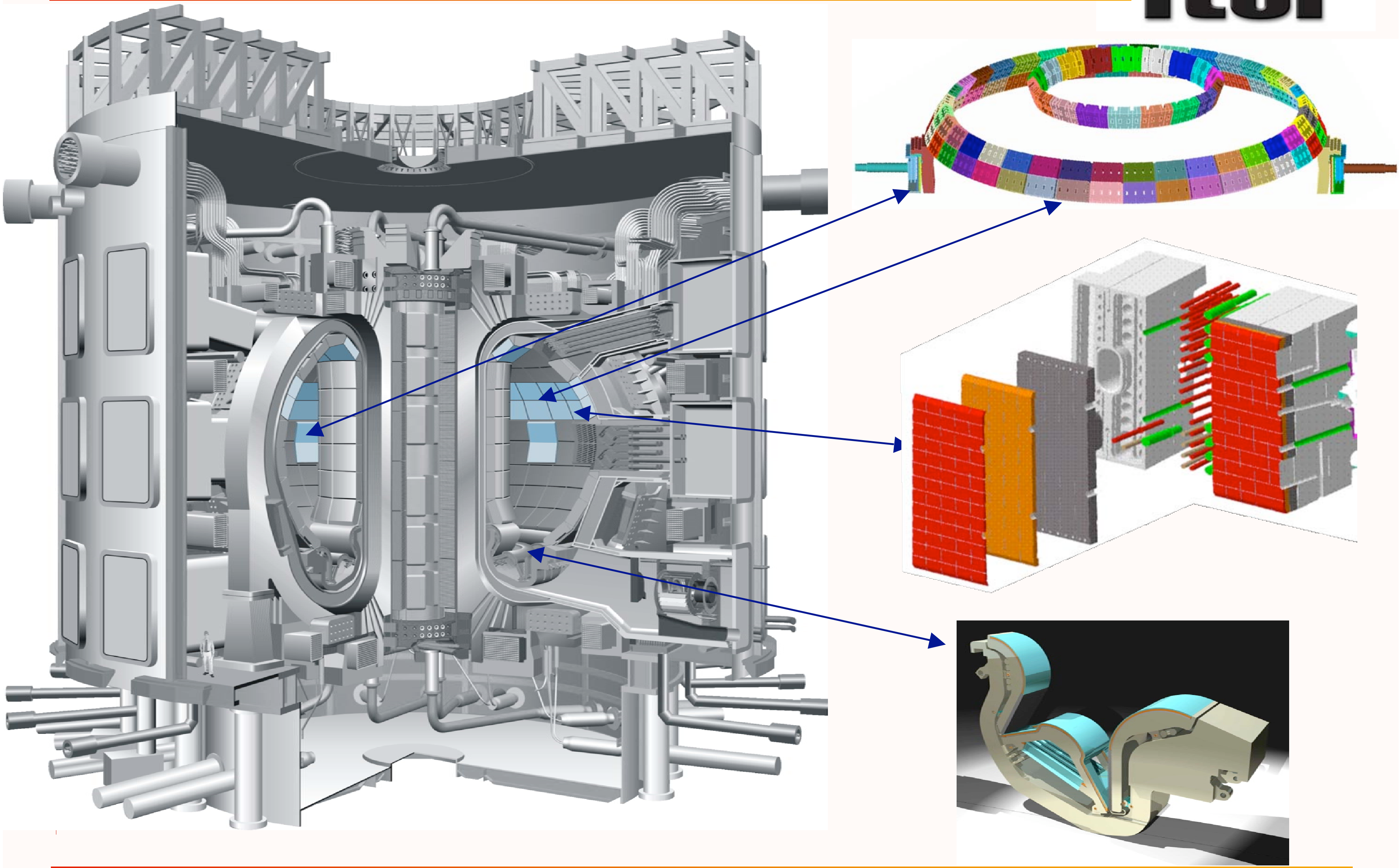
Central Solenoid Options

Reference Design, external structure based on inner & outer tie plates

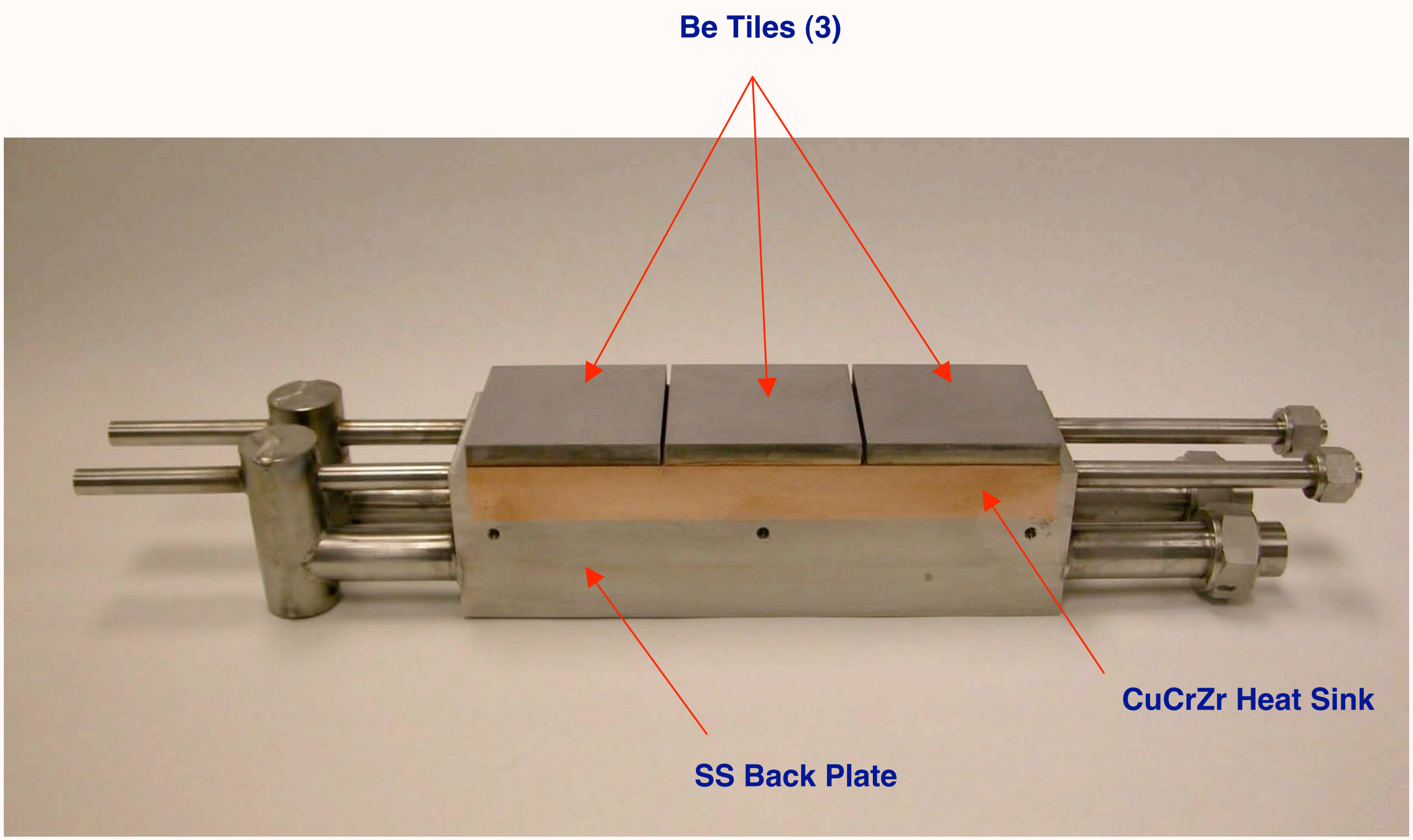
Alternate Design, external structure based on central tie rods and rigid end caps

Especially suited to JA request for 316LN CS conductor jacket

Blanket, Port Limiter and Divertor Systems

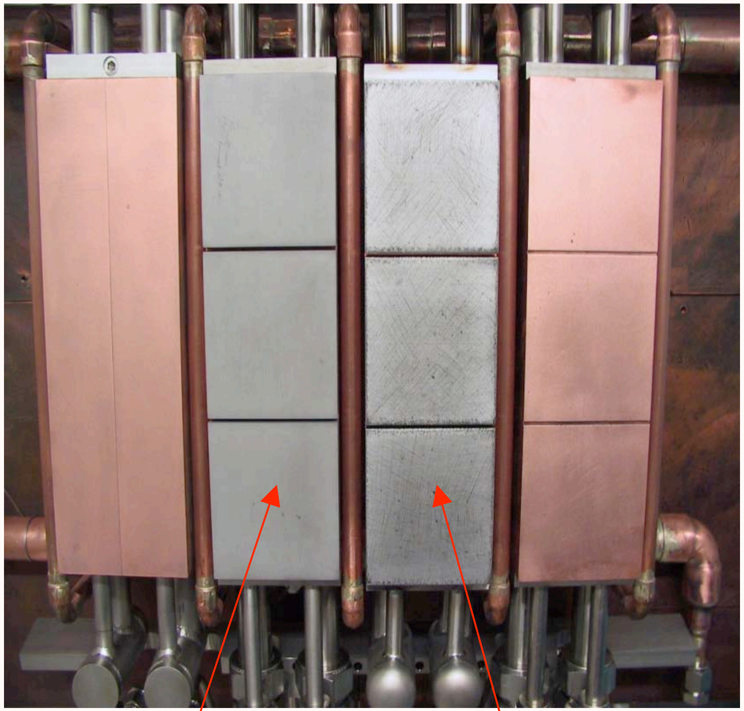


First Wall Qualification Mockup



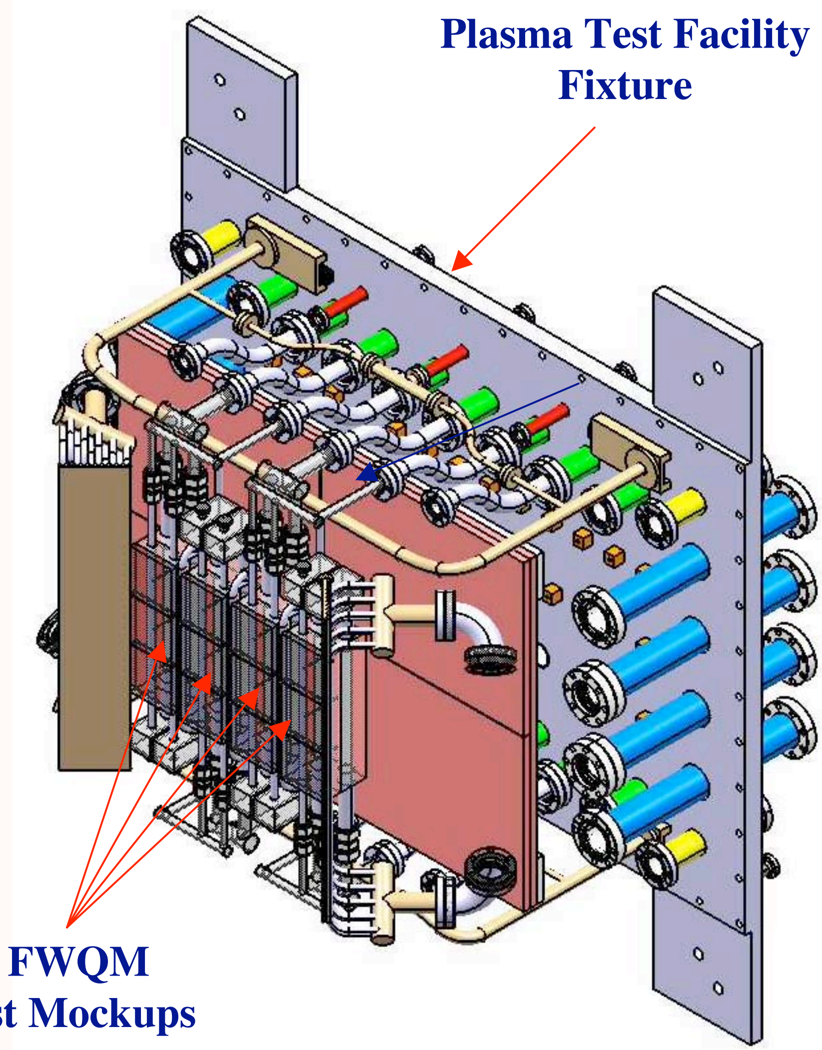
First Mockup
FWQM US-1

FWQM Test Facility - SNL



US FWQM Mockup

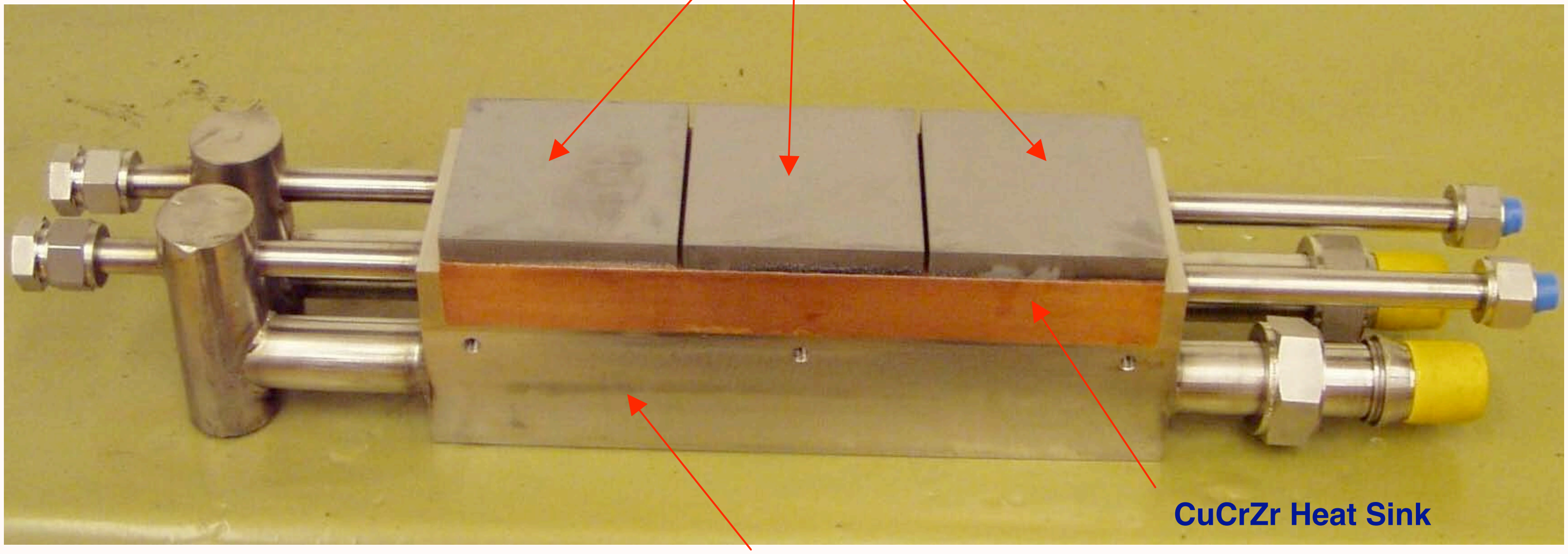
EU FWQM Mockup



Plasma Test Facility Fixture

4 FWQM Test Mockups

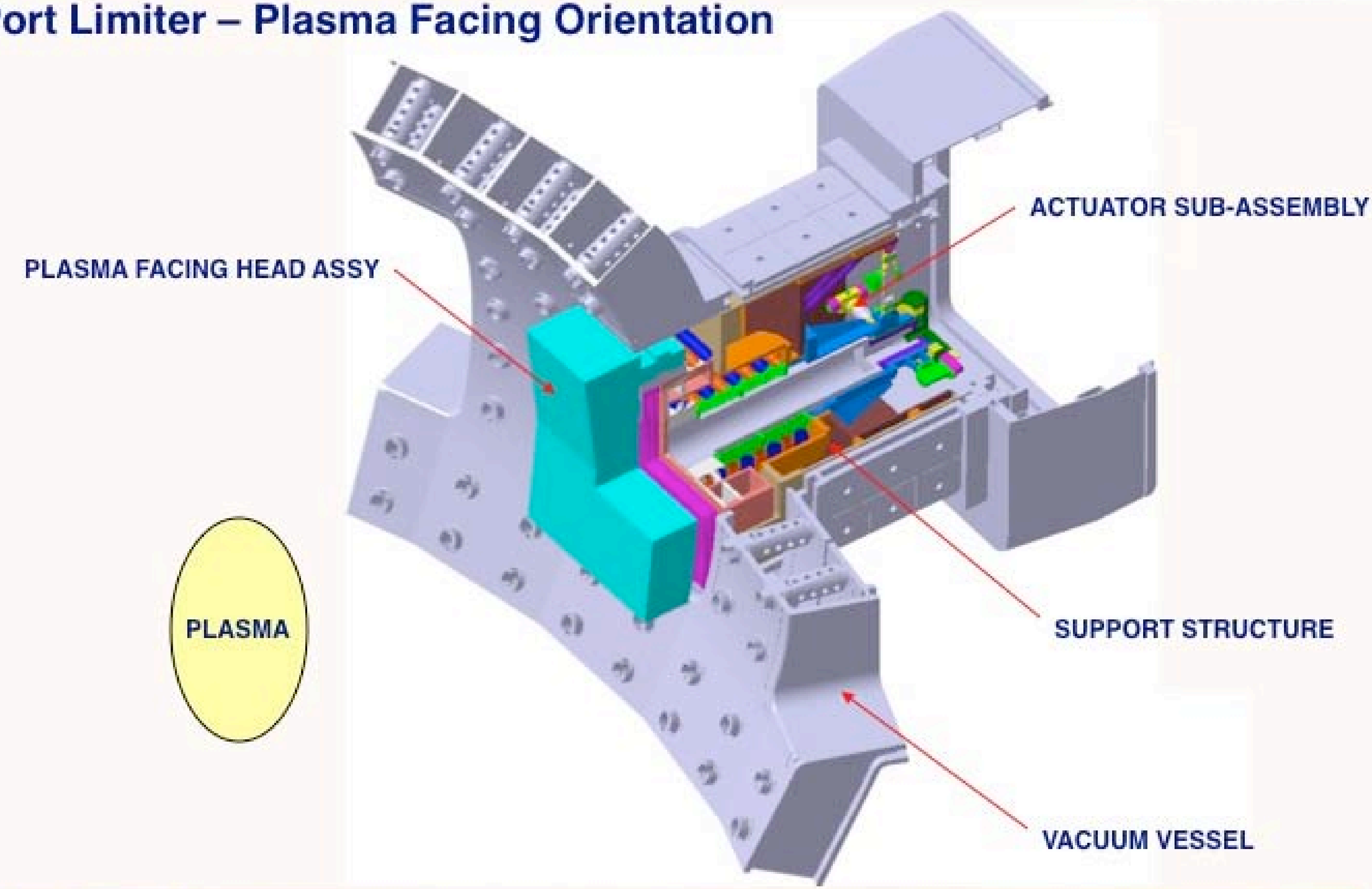
First Wall Qualification Mockup for EU test



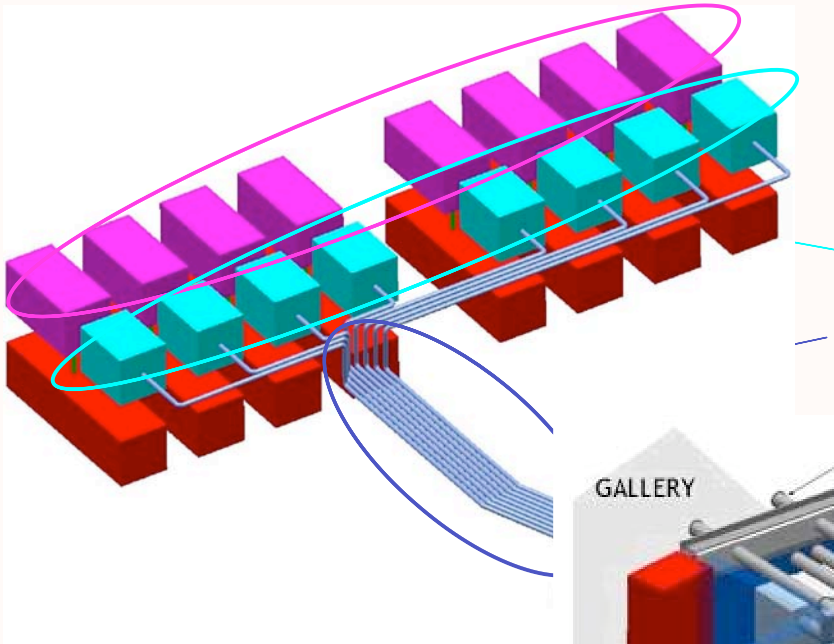
Second Mockup
FWQM US-2

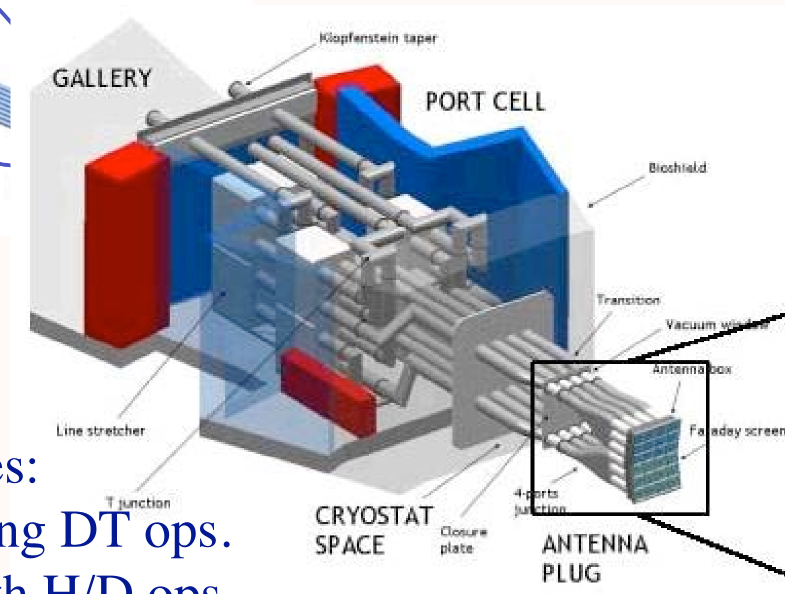
Port Limiters on hold

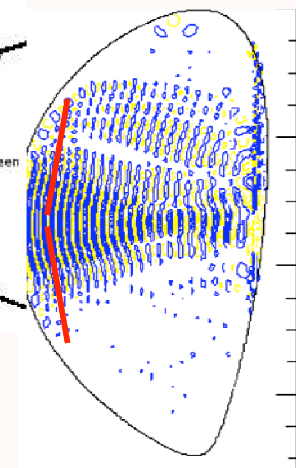
Port Limiter – Plasma Facing Orientation



Ion Cyclotron System



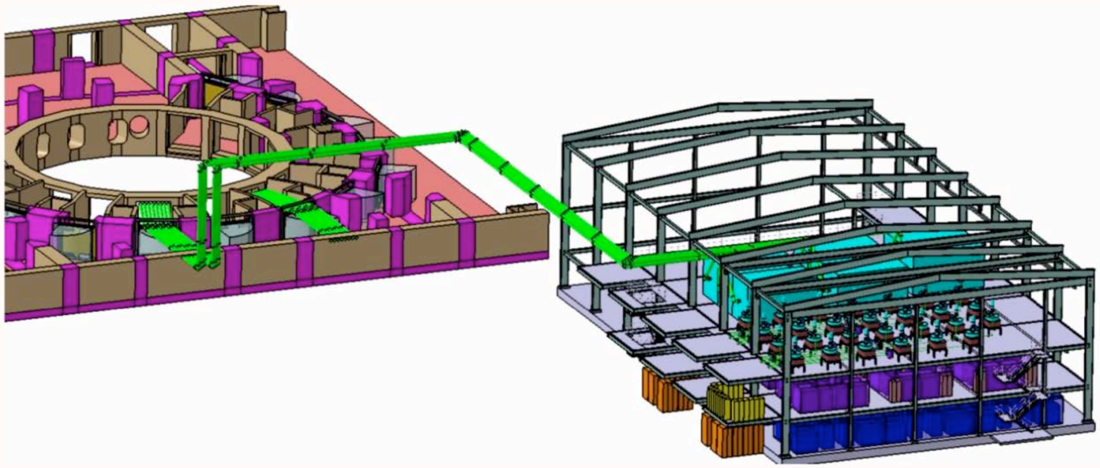


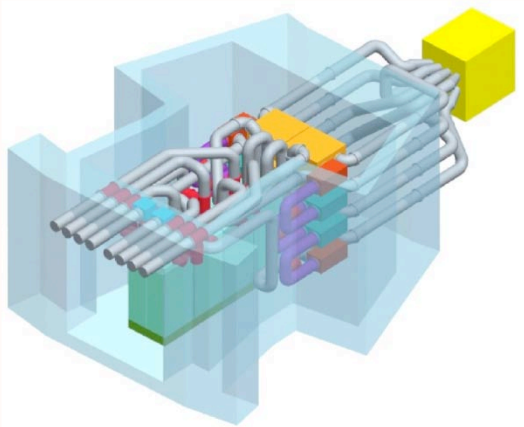


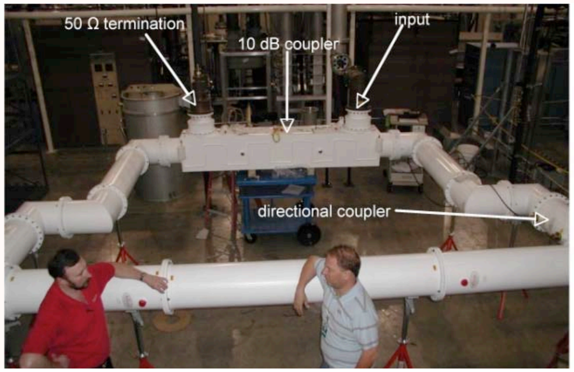
40-55 MHz ICRF provides:
- Tritium ion heating during DT ops.
- Minority ion heating with H/D ops.
- Sawtooth stabilization
- Central current drive for AT ops.

ICH Transmission lines and Tuning/Matching System

5 MW transmission air cooled lines from the sources to the antenna
3 dB ELM tolerant matching connected to 24 strap antenna array





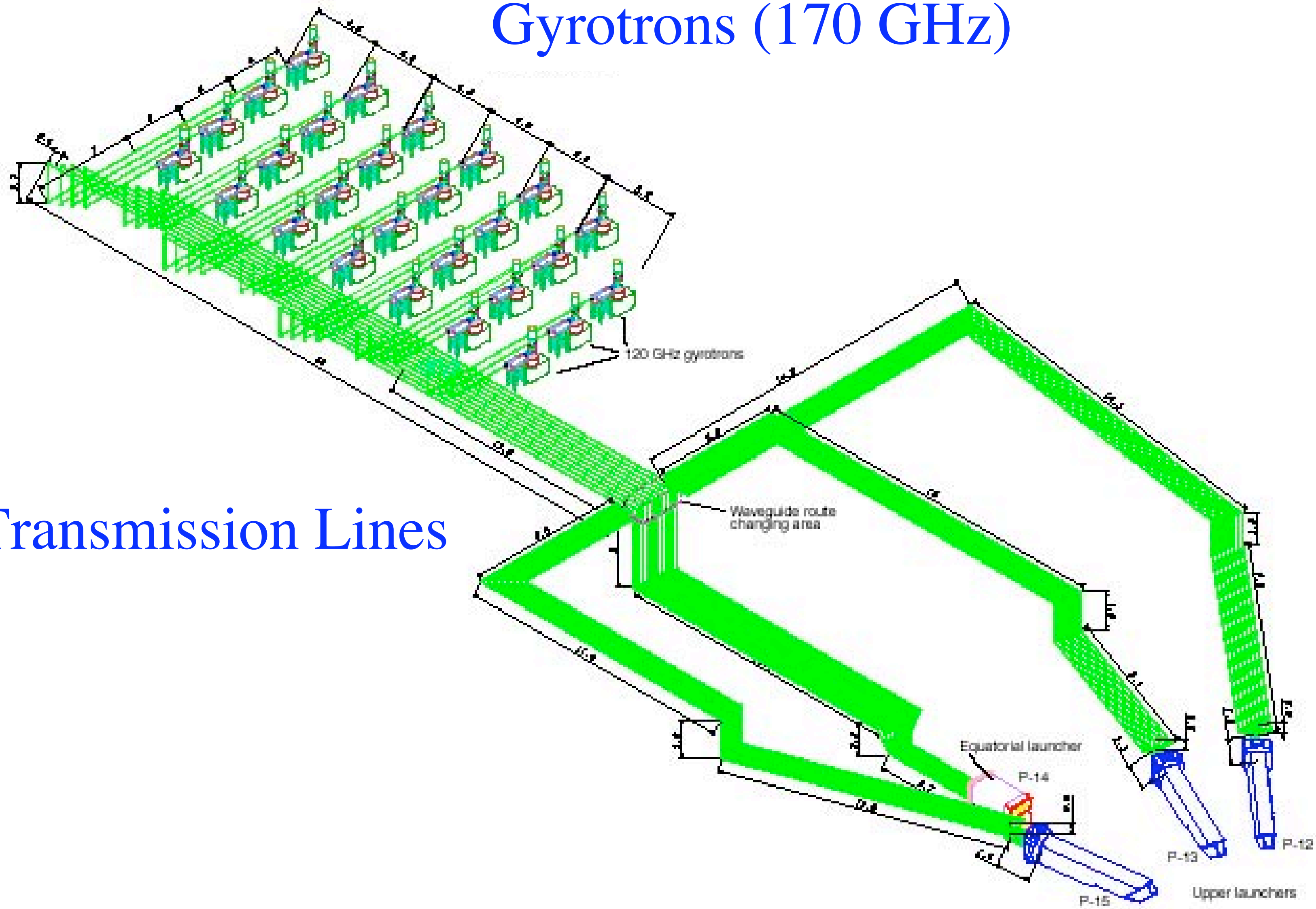


Long pulse; High power resonant ring tests components to > 5 MWs (ORNL)

Electron Cyclotron System

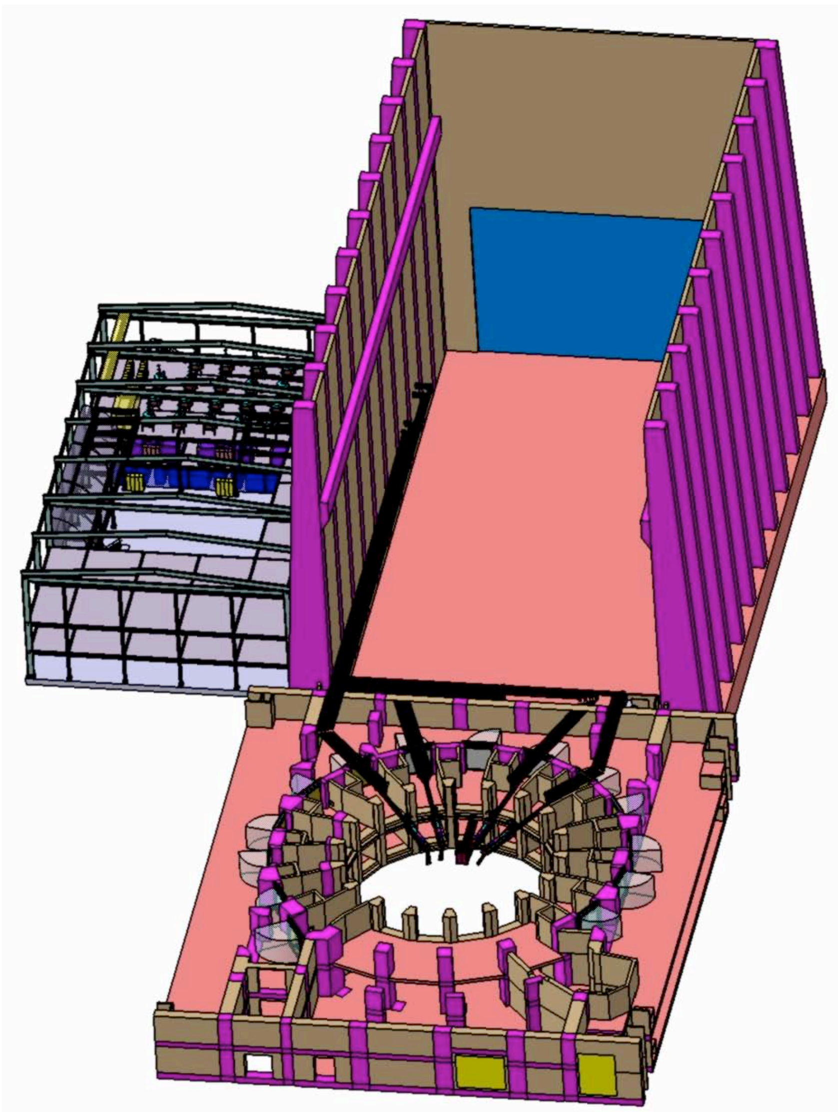
Gyrotrons (170 GHz)

Transmission Lines

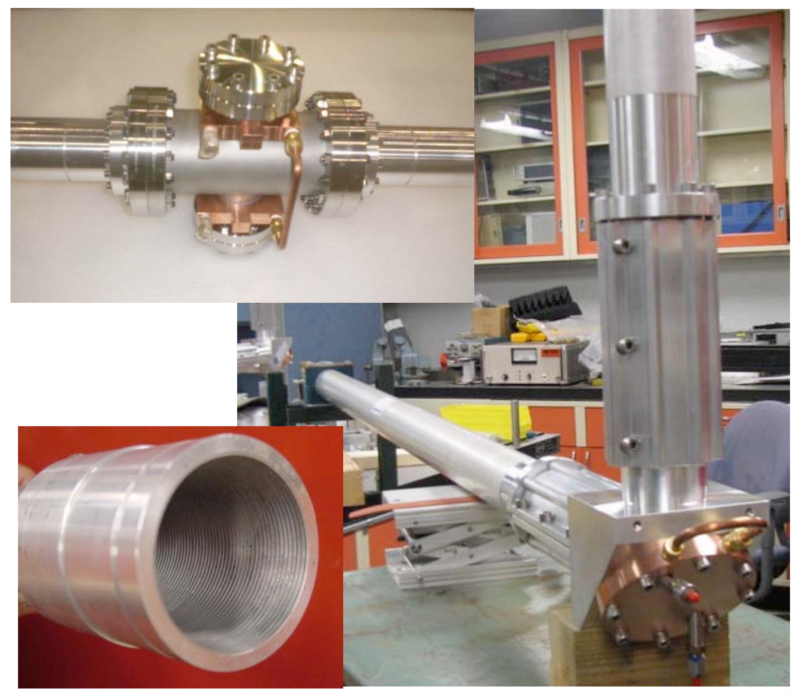


Launchers

WBS 1.5.2. Scope - ECH Transmission line and Mode Control

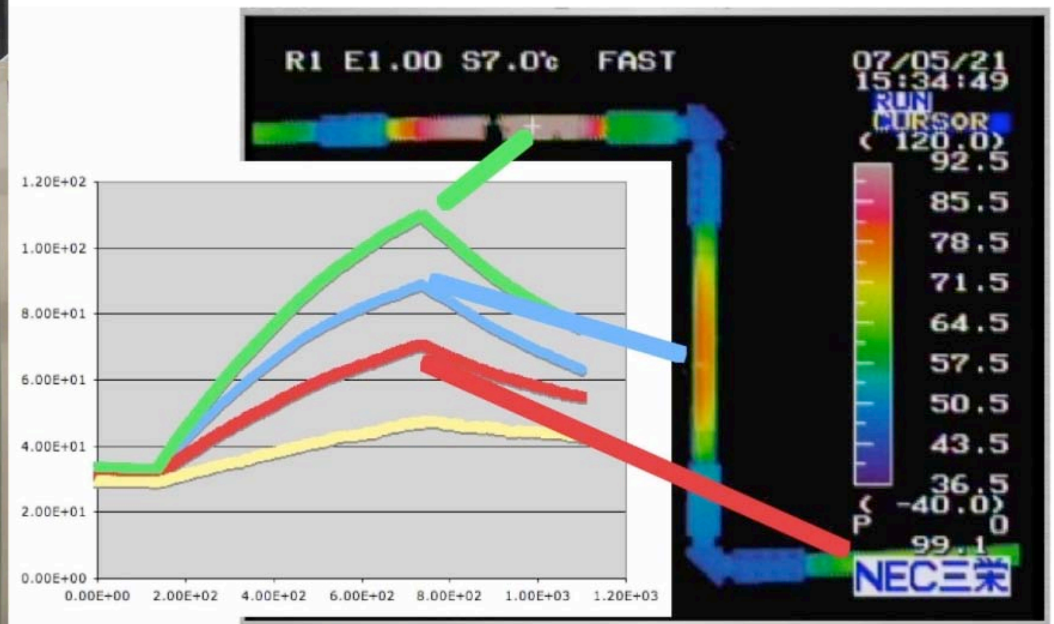


- 1-2 MW water cooled T-lines from the gyrotrons to the launchers
- 24 lines to the equatorial launchers
- 32 lines to the upper launchers
- Mode and polarization control are major technical challenges



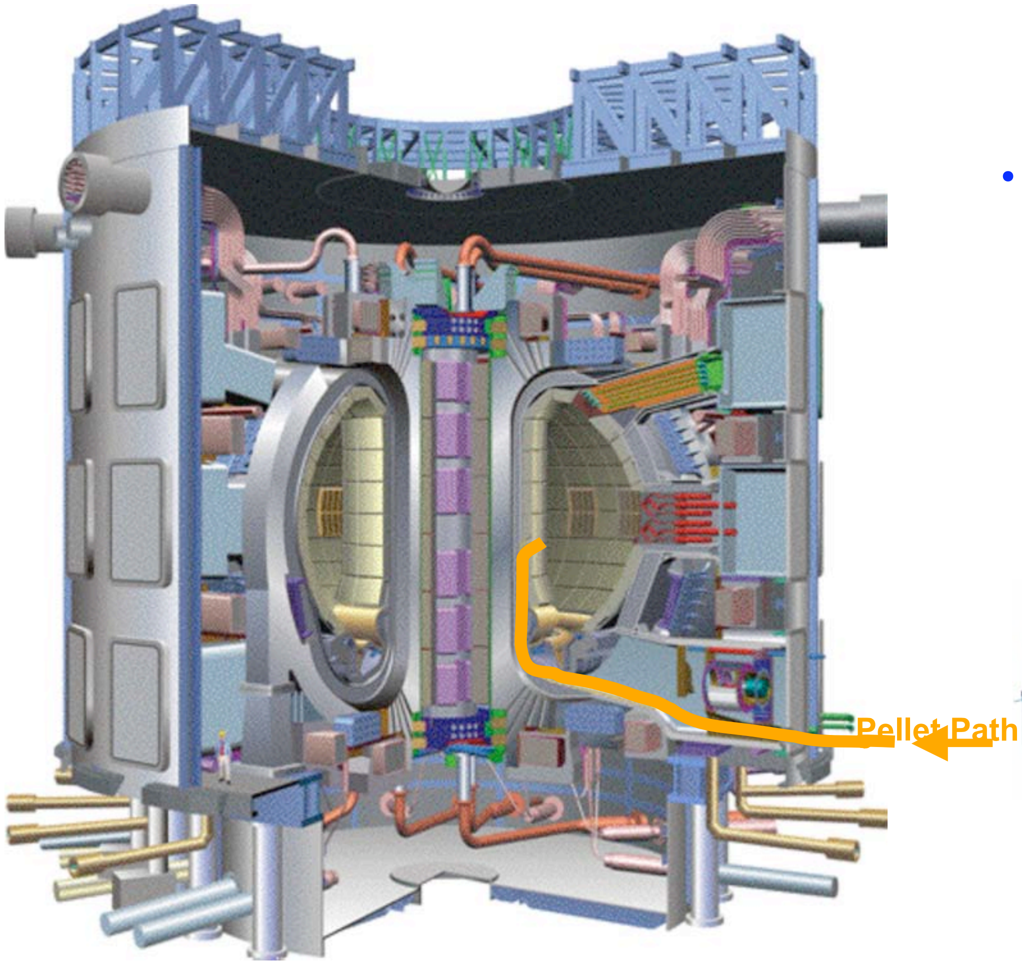
140/170 GHz test stands used to develop and qualify components

Long pulse; High power resonant ring tests components to > 2 MWs (ORNL)

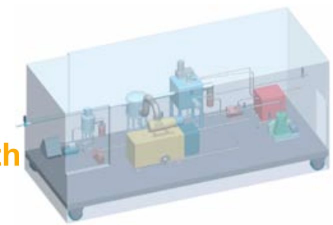


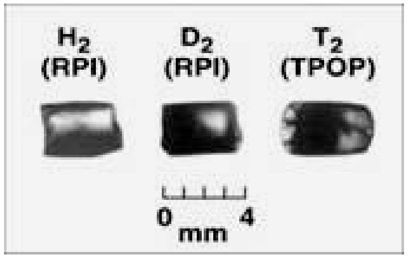
Infrared imaging shows ohmic & mode conversion hot spots (JAEA)

Pellet Fueling of ITER



- **Pellet injection to achieve efficient core tritium fueling**

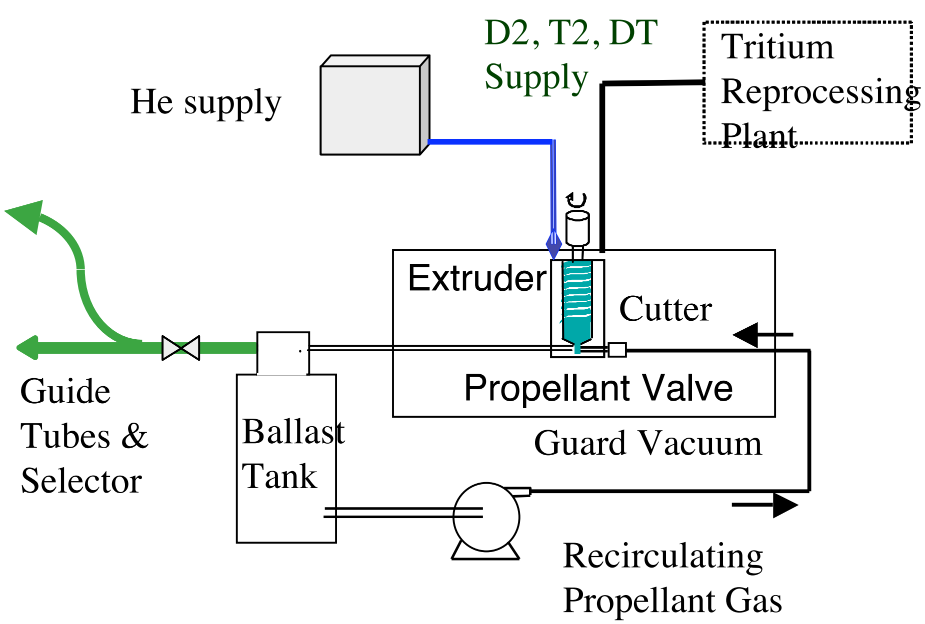


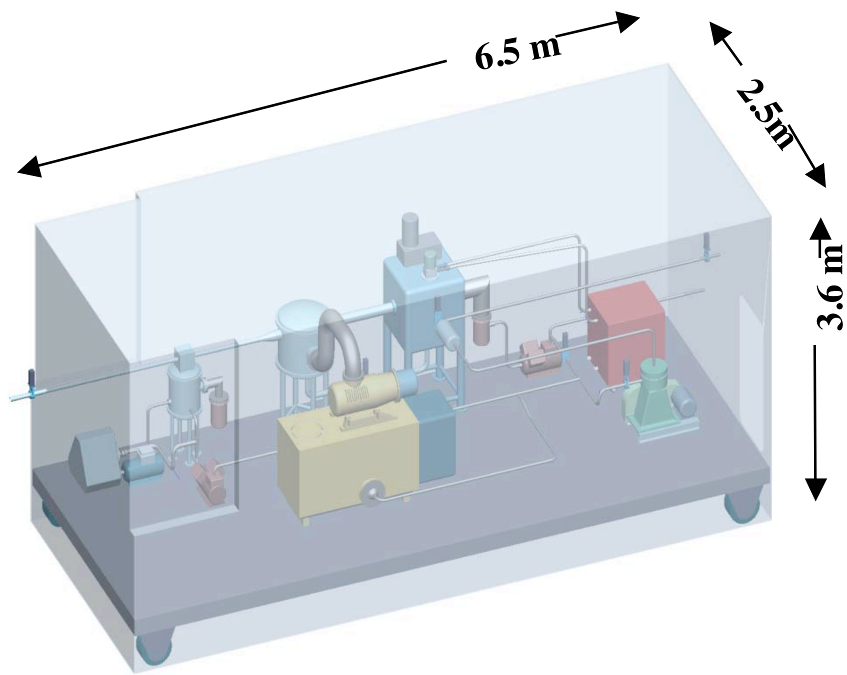


Hydrogen, Deuterium and Tritium Pellets @ 14° Kelvin

Pellet Injector R&D to develop extruder, gas recirculation and injector reliability

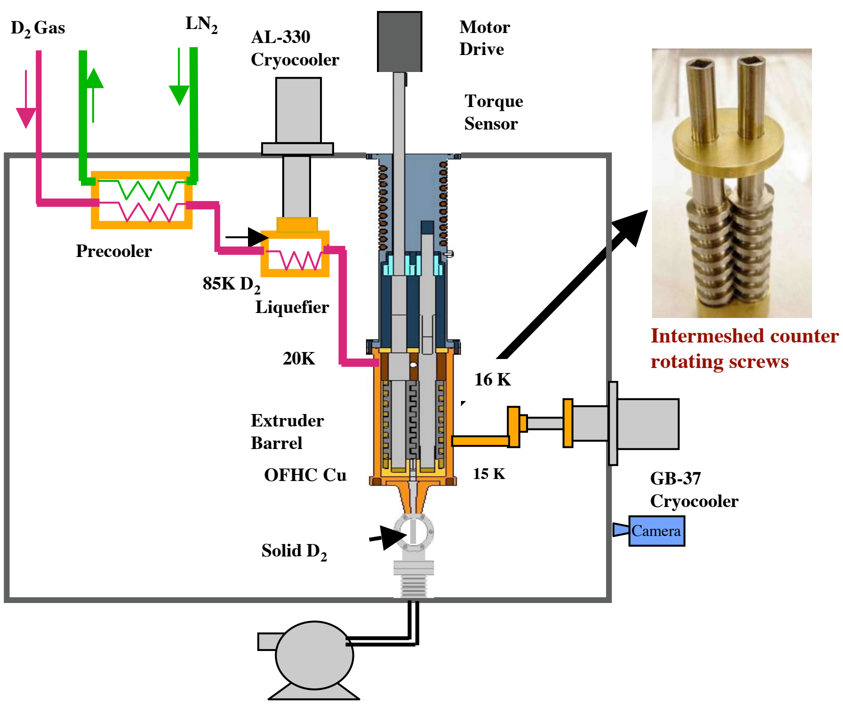
- **Technical challenges**
  - Extruder throughput and reliability (FY07-10)
  - Propellant gas recirculation to minimize impact on tritium plant (FY09-10)
  - Gas gun prototype (FY09-11)
  - Pellet survivability in guide tubes and guide tube selector (FY09-11)

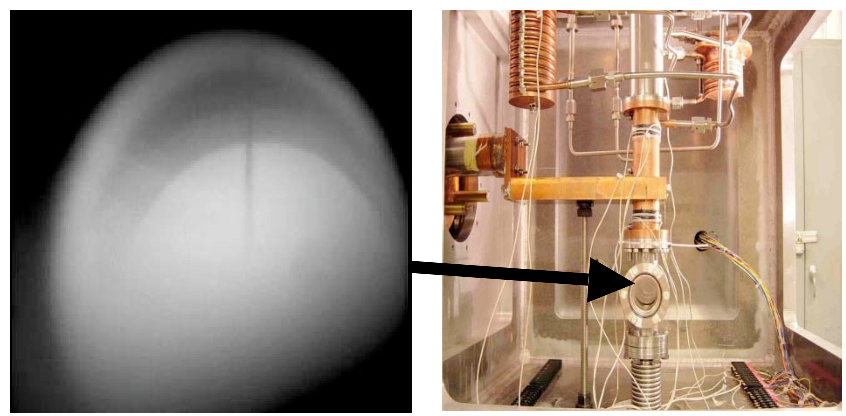




Twin Screw Extruder Prototype R&D is making good progress towards goals

- Pellet injector twin screw extruder prototype has successfully produced solid deuterium extrusions for up to 30 minutes
  - Achieved 10% of the ITER required flow rate.
  - Further optimization will be undertaken to increase the flow rate up to the prototype's design value of 30% of the ITER requirement.
  - Recirculating fuel loop will be added as the next step.

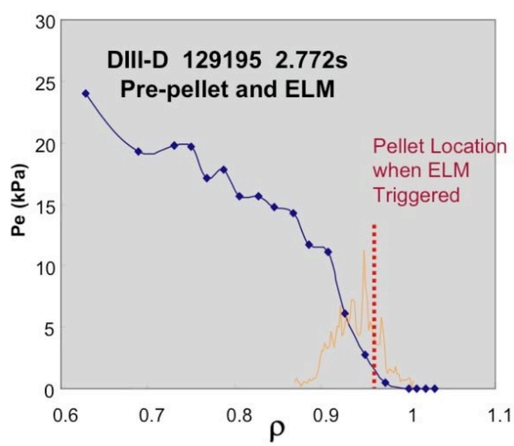


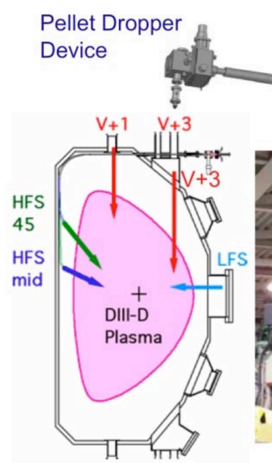


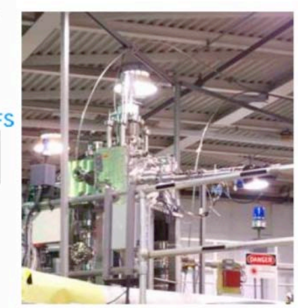
3mm D_2 Extrusion

Pellet Pacing for ELM mitigation

- ELMs need to be limited to 1 MJ/event
- ELM pellet pacing frequency of 20-40 Hz is needed
- 4mm (cylindrical) pellet required to reach the 4 keV pedestal
- Recent experiments indicate shallower penetration with smaller pellets (~ 1 mm) may suffice
- High rep rate pellet dropper experiments underway at DIII-D







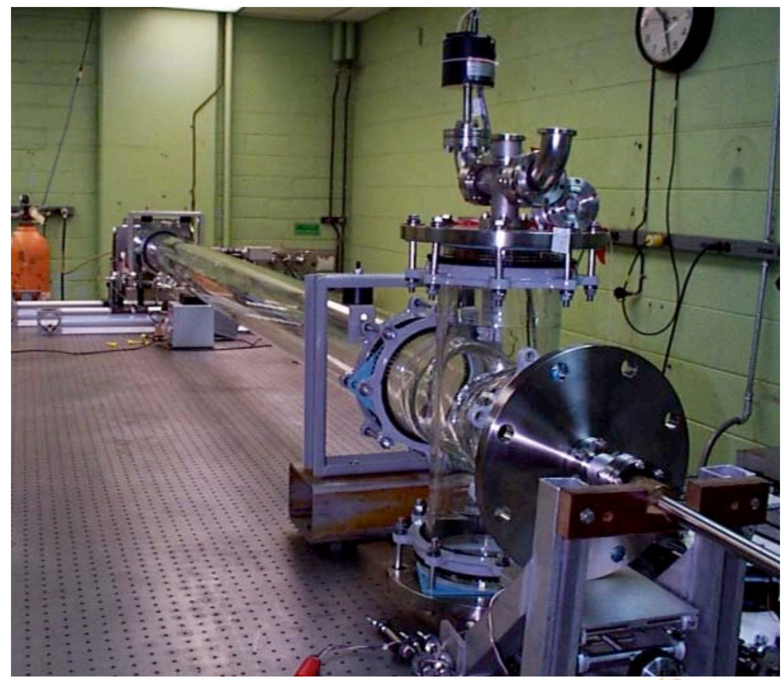
- Will require at least 2 additional pellet injection systems to meet increased requirements

Disruption Mitigation
(possible new/additional scope)

- Massive gas puff not likely to scale to ITE

- Large pellets may be required
  (wine cork size)

- Liquid jets have also been considered



Design Review and STAC issues

- **Design Review**
  - Completed September 2007
  - U.S. provided roughly 25% of the professional person years provided by the parties
- **Resolution of issues identified by the Science and Technology Advisory Committee**
  - U.S. provided 36% of the professional person years provided by the parties

Current and future directions

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  - "Product teams"
    - can increase the resources available for the work,
    - expedites simplification of interfaces,
    - optimizes the distribution of the roles and functions, and
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    - can increase the resources available for the work,
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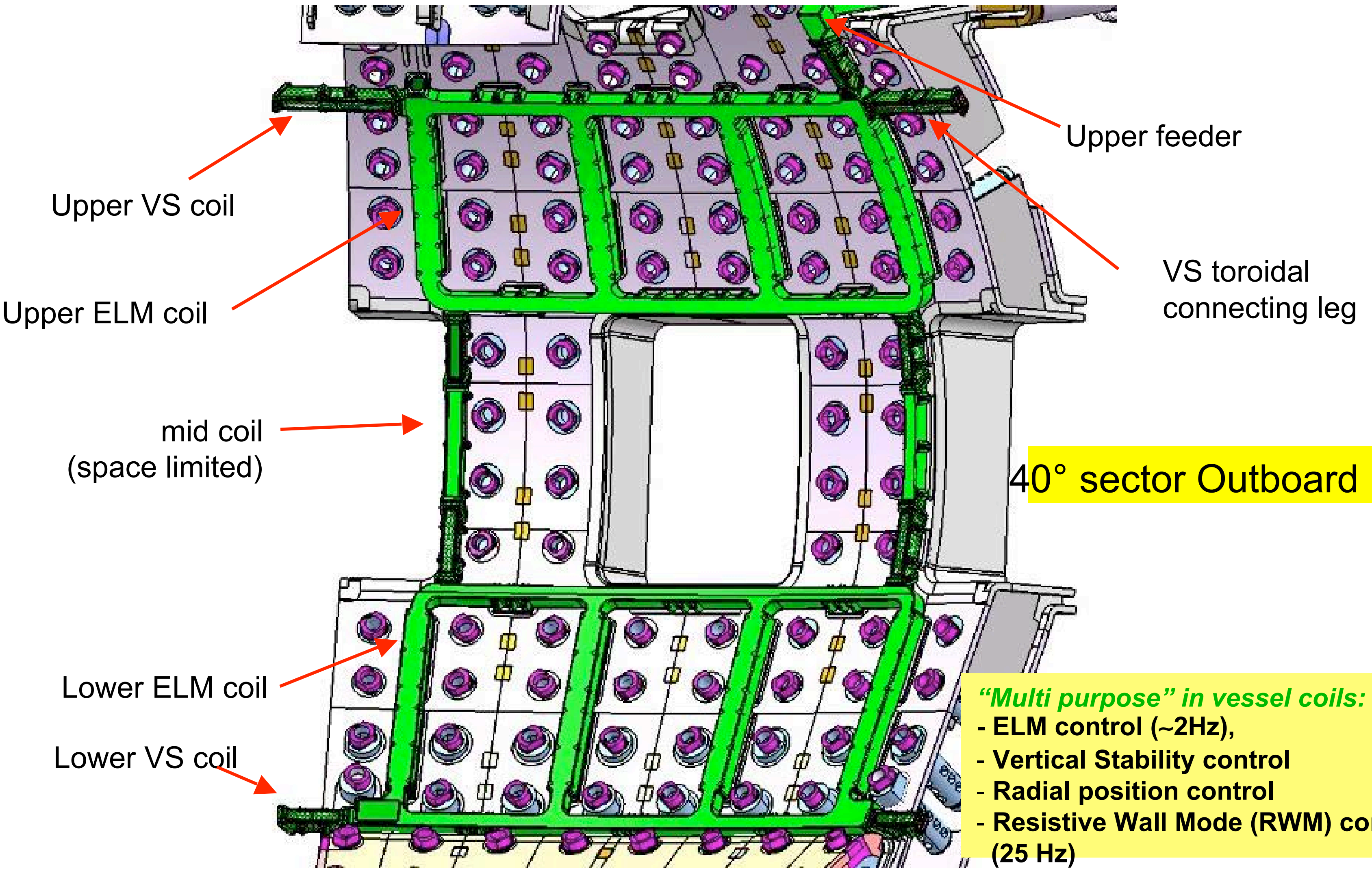
  - “Phased Procurement Arrangements” to complete design and engage industry

The US is designing, costing and scheduling the ELM & VS coils

~~VAC-02 - 3 rows – 9 coils~~



"Multi purpose" in vessel coils:
- **ELM control (~2Hz),**
- **Vertical Stability control**
- **Radial position control**
- **Resistive Wall Mode (RWM) control (25 Hz)**

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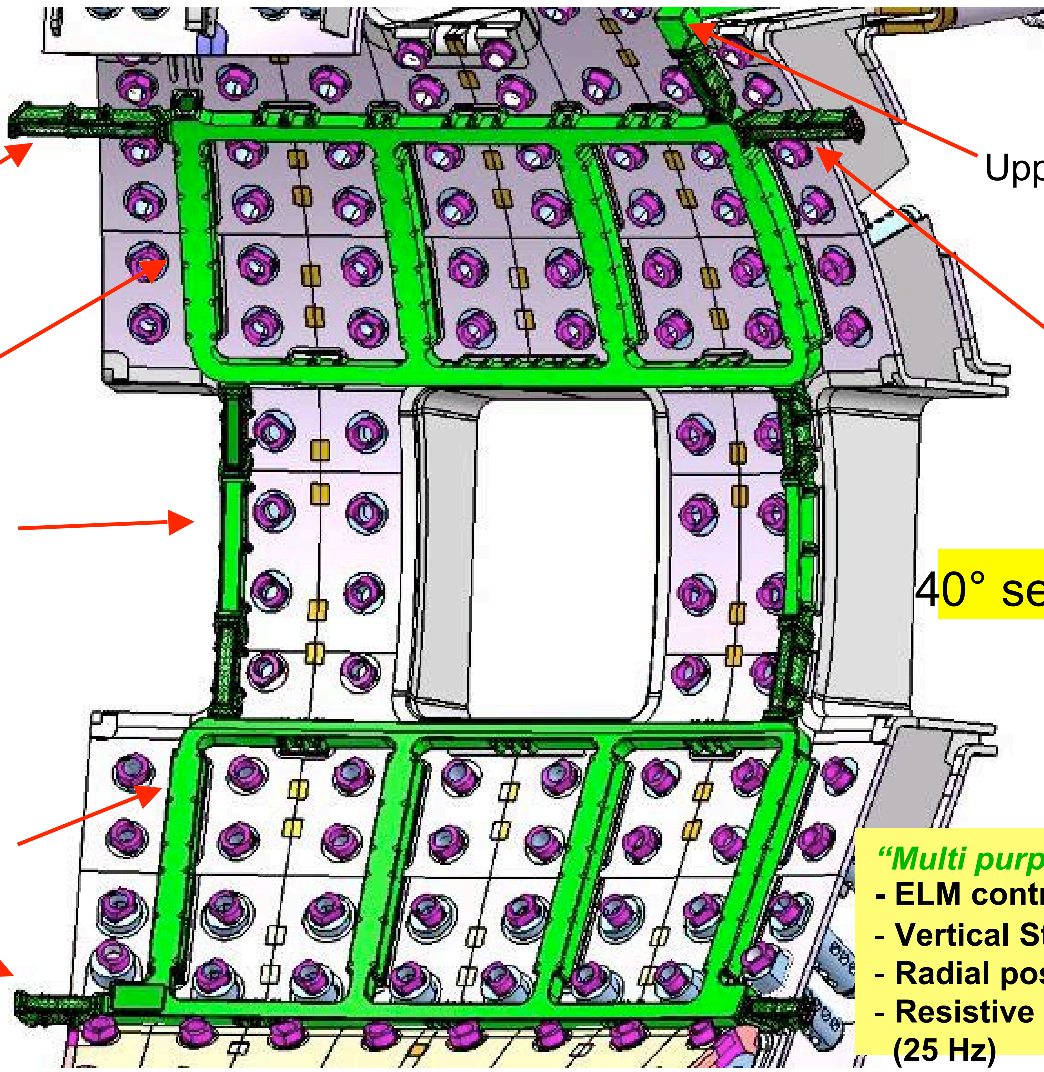

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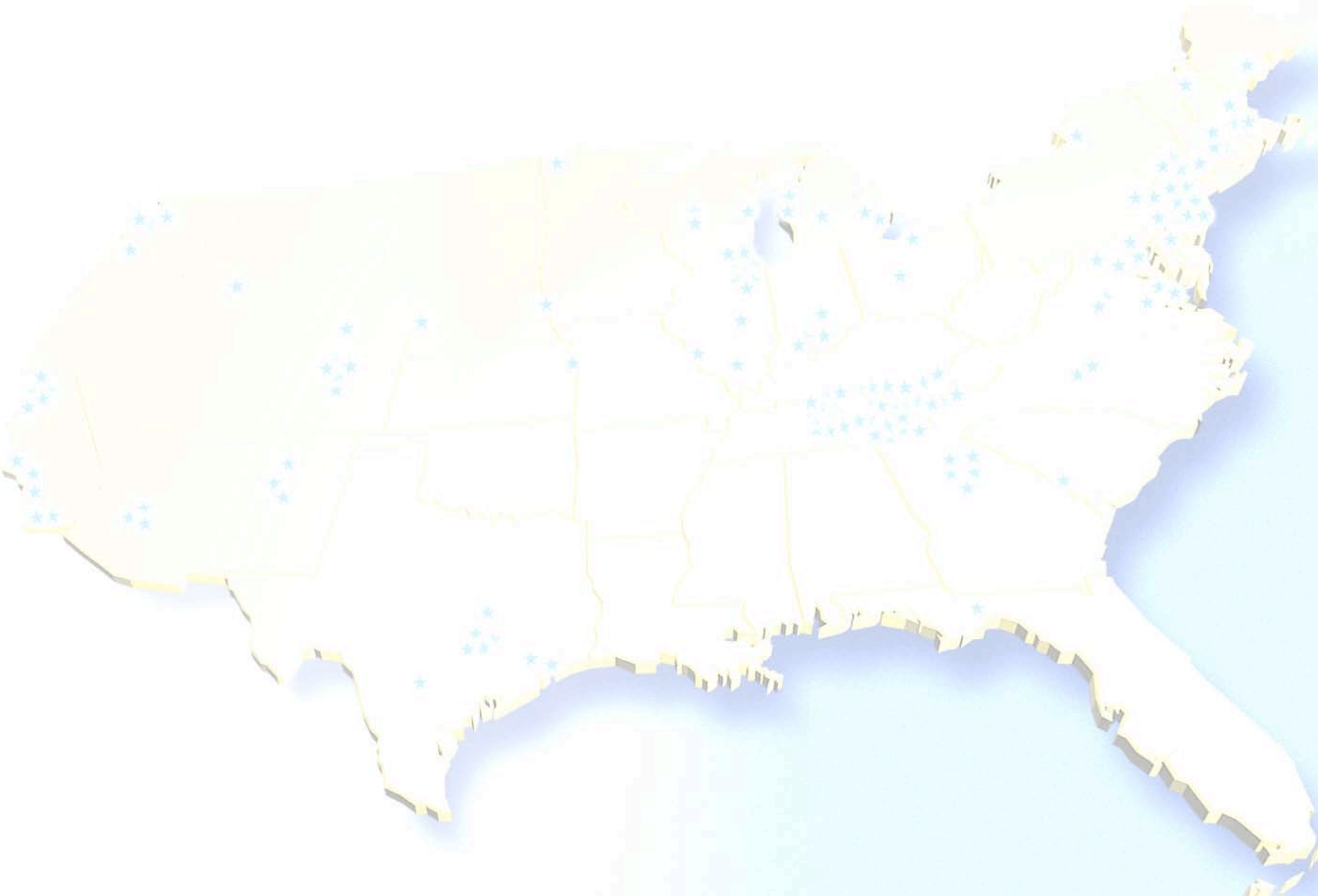
US fabrication of ELM coils would modify the US procurement allocations

Next Steps



Next Steps

- **Engage US industry in design completion and optimization**
  - Incorporate industrial experience
  - Assure ITER design is compatible with US manufacturing methods
  - Focus on early-delivery / high-risk systems
    - superconducting magnets
    - plasma-facing components
    - power handling
    - diagnostic instrumentation

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    - superconducting magnets
    - plasma-facing components
    - power handling
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- **Place long-lead procurements for materials for early-systems**
  - Superconducting strand (for schedule reasons)
  - Stainless steel (as a cost-risk mitigation measure)

Bottom Lines

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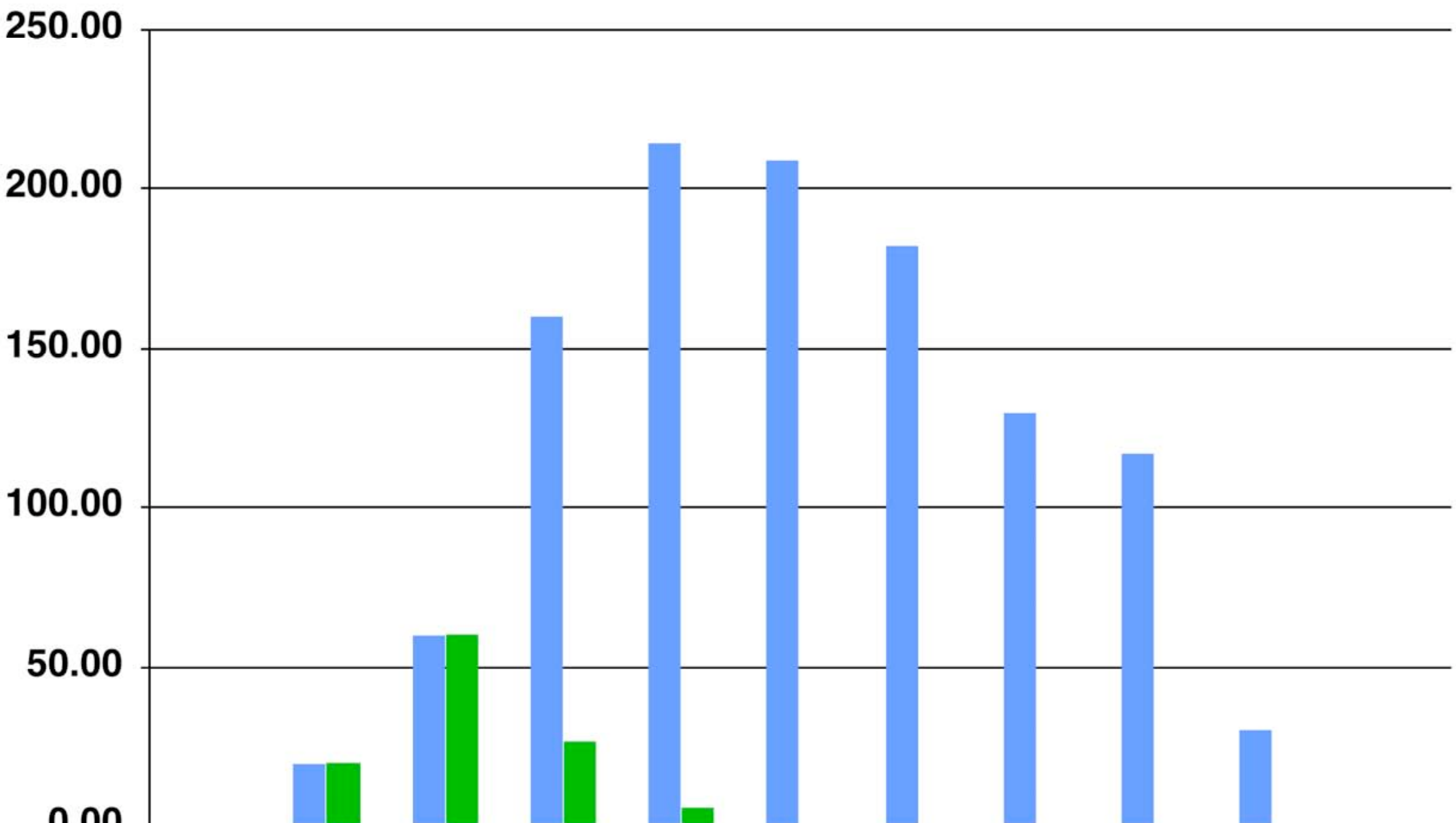
- The US is working with the ITER Organization on project management
- Next US steps involve significantly greater industrial participation (creating jobs) when additional funds are available

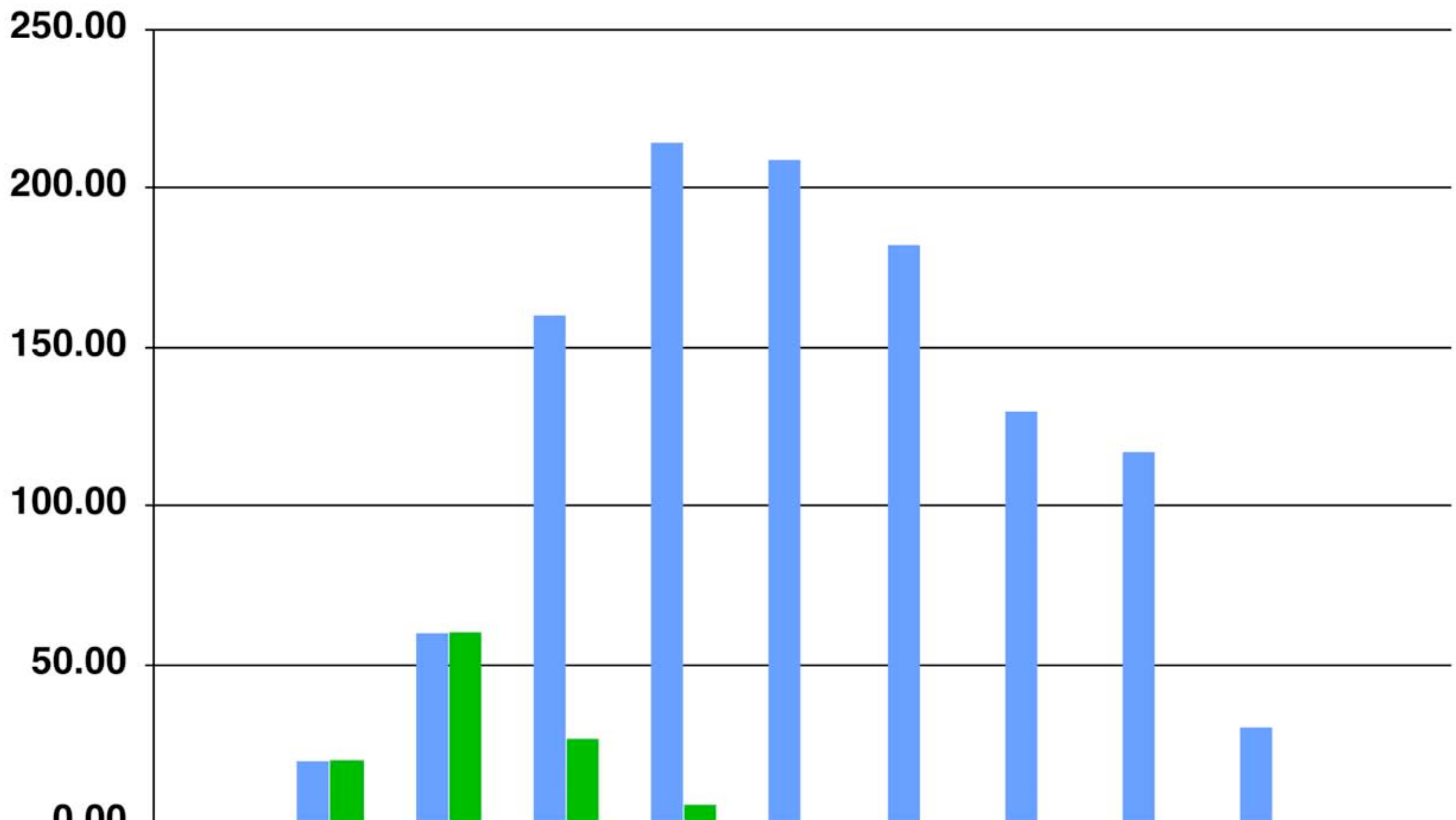
U.S. ITER Project Office

US ITER Budget Request [original profile] & Actuals ($M)



	FY05	FY06	FY07	FY08	FY09	FY10	FY11	FY12	FY13	FY14	FY15
Budget request	0.00	19.32	60.00	160.00	214.50	209.32	181.96	130.00	116.90	30.00	0.00
Appropriated	0	19.32	60	26.1	5.3						

US ITER Budget Request [original profile] & Actuals ($M)



	FY05	FY06	FY07	FY08	FY09	FY10	FY11	FY12	FY13	FY14	FY15
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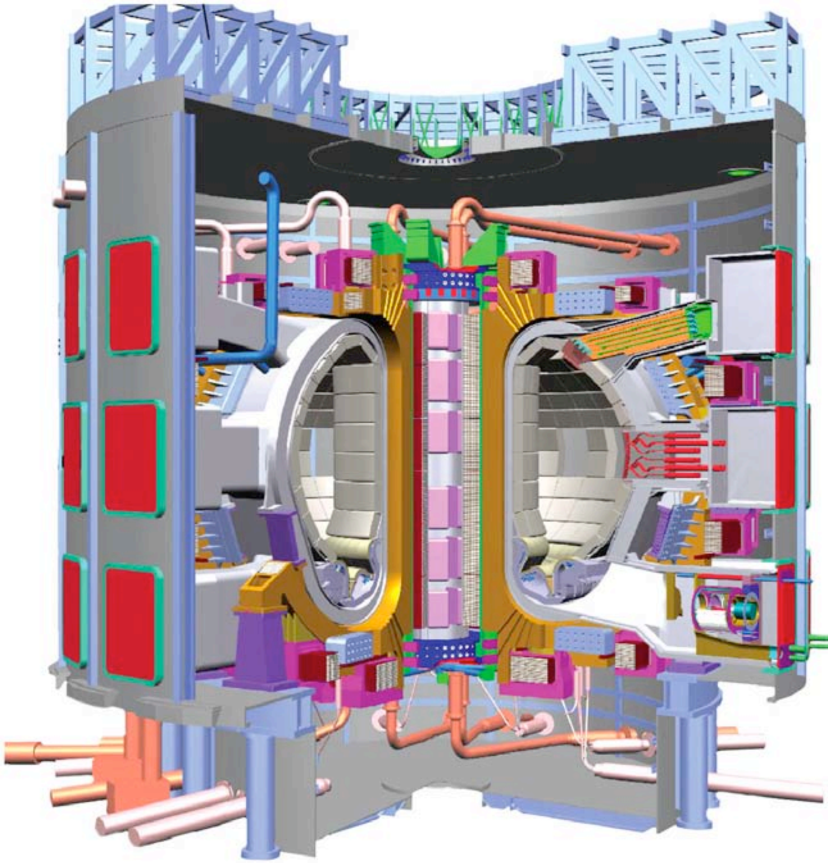
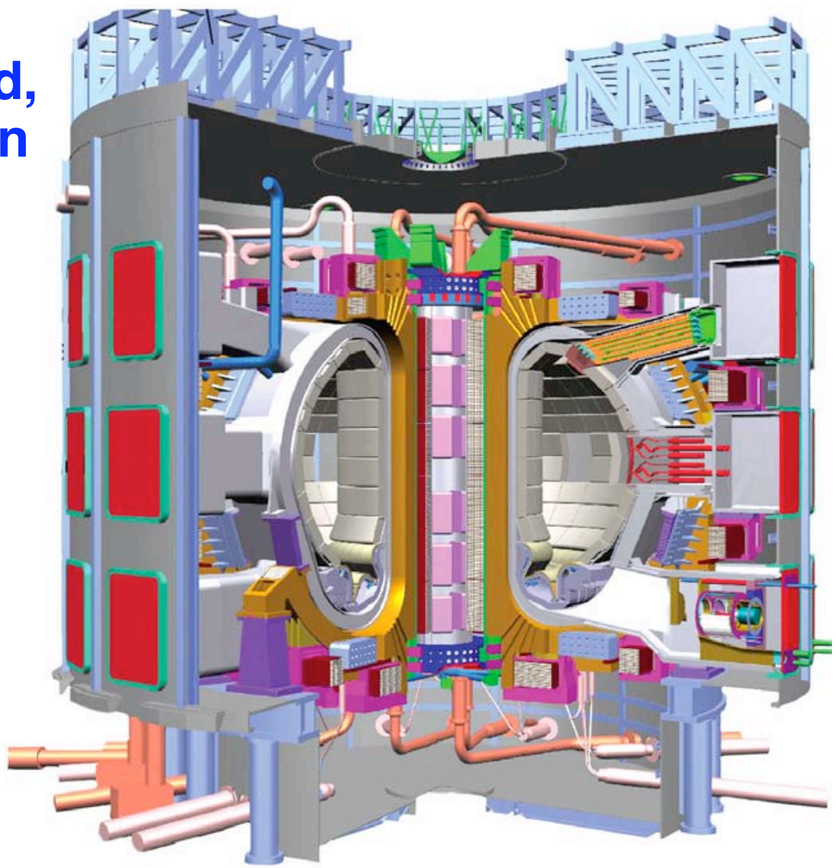
[new range: $1.45B-$2.2B]

What ITER means for the U.S. [1 of 2]



What ITER means for the U.S. [1 of 2]

- **Science of “Burning Plasmas”: The next major step: Create, understand, and control a reactor-prototypical fusion plasma**
  - New dynamics of self-heating
  - Size-scaling of phenomena at reactor scale
  - Effects of “faster-than-light” particles



What ITER means for the U.S. [1 of 2]

- **Science of "Burning Plasmas": The next major step: Create, understand, and control a reactor-prototypical fusion plasma**
  - New dynamics of self-heating
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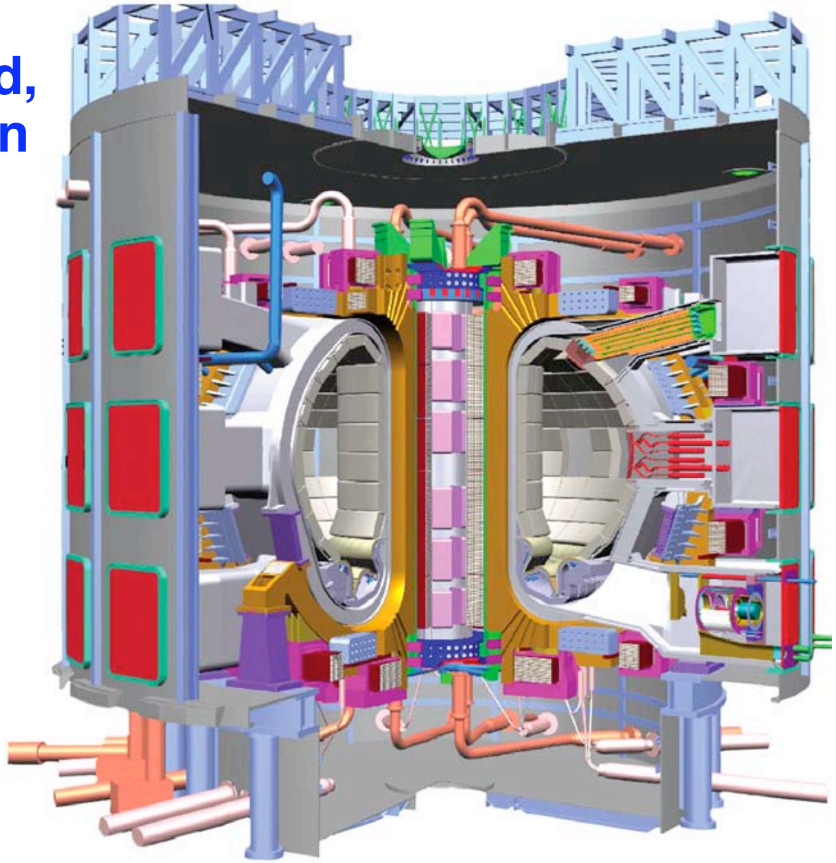
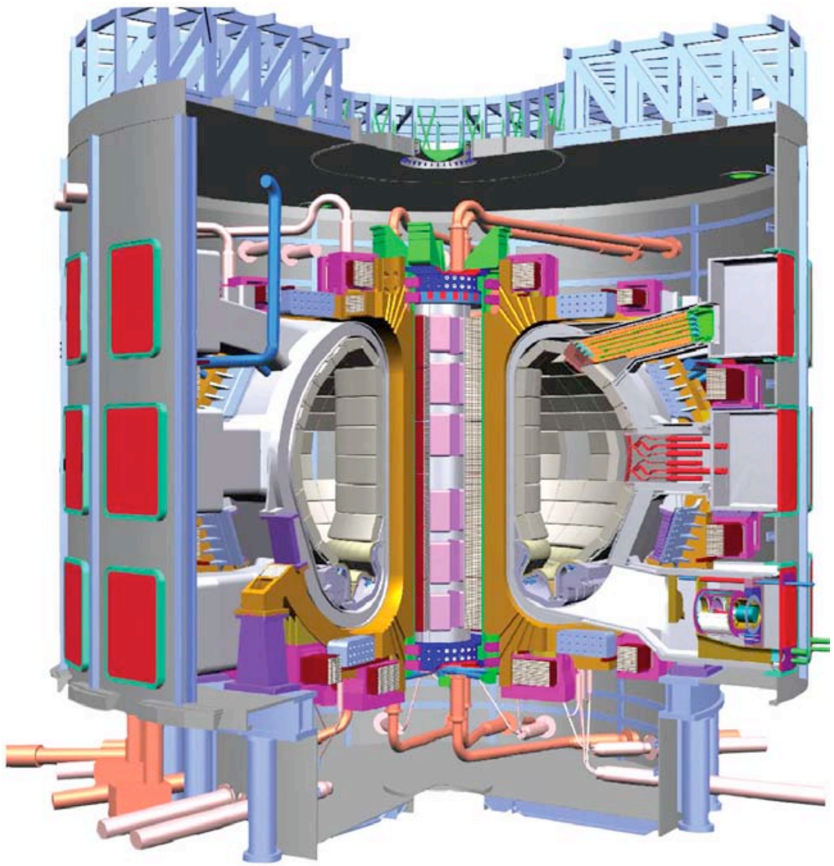
- **International partnership**
  - Refine a model for international partnership on large-science projects
  - Improve understanding and effective joint-work between ITER parties



What ITER means for the U.S. [2 of 2]



What ITER means for the U.S. [2 of 2]

- **Energy**
  - Demonstrate the scientific and technological feasibility of an energy source with
    - virtually-unlimited geographically-dispersed fuel
    - no CO_2 or acid-rain gases
    - no high-level-radioactive waste
  - U.S. Jobs and work in US industry
  - Position the US to develop and provide fusion-reactor technology