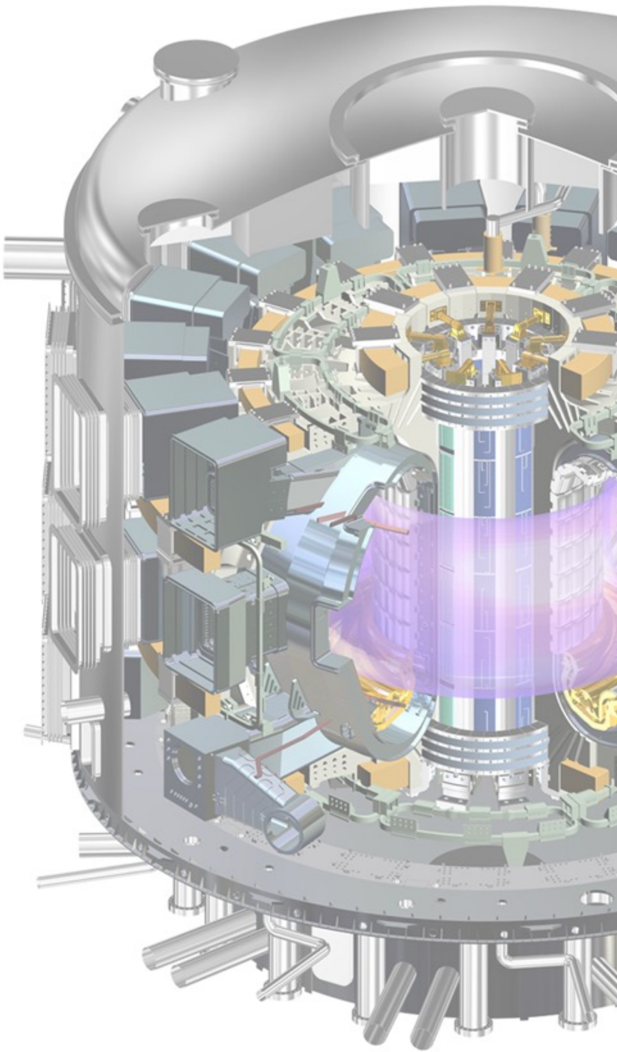
# Status of US ITER

**Kathy McCarthy**
*Project Director*



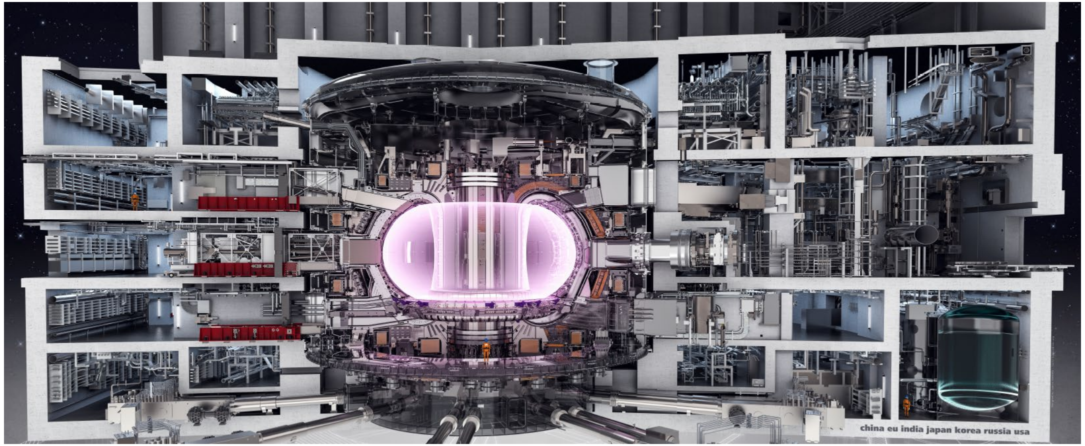
*Fusion Energy Sciences Advisory Committee*

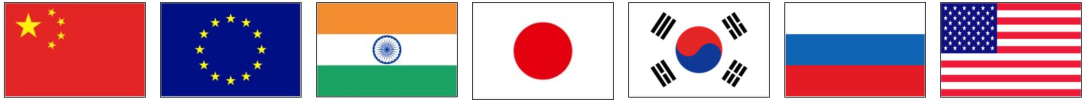
*August 31, 2021*

# Outline

- ITER Background
- Overall ITER Project Progress
- US ITER Hardware Responsibilities
- US ITER Sub-Project 1 Baseline vs. Appropriations
- Overview of US ITER Hardware Design and Delivery
- ITER's Role in the US Fusion Program
- Look-Ahead

# ITER Mission: Demonstrate the scientific and technical feasibility of fusion energy



## How does ITER contribute to the path to fusion energy?

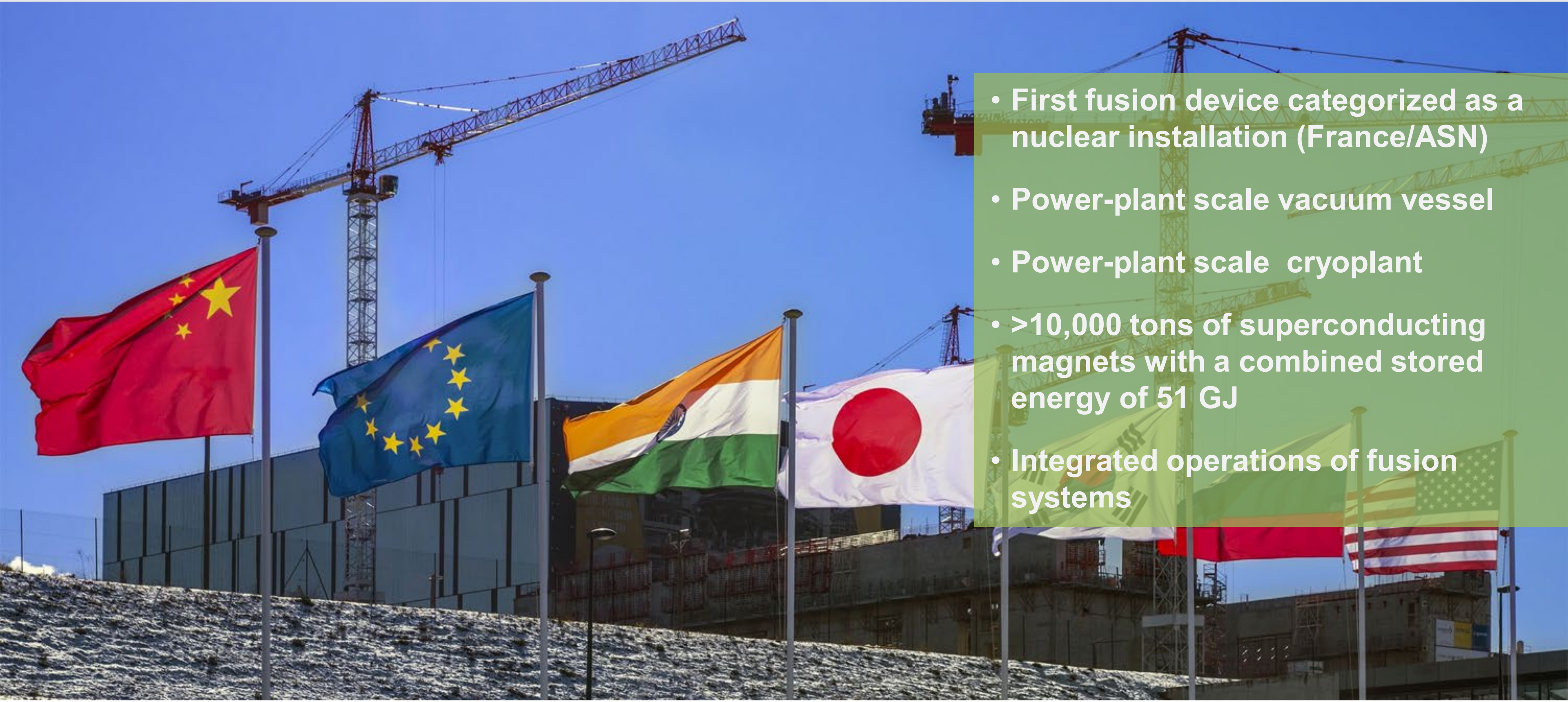
ITER will:

- Achieve a deuterium-tritium plasma in which the reaction is self-sustained through internal heating (“Burning Plasma” facility)
- Produce 500 MW of fusion power for pulses of 400 seconds
- Demonstrate the integrated operation of technologies for a reactor-scale fusion power plant
- Test/demonstrate Tritium fuel breeding
- Demonstrate the safety characteristics of a fusion energy device

**U.S. contributes ~9% for 100% of ITER science and intellectual discovery**

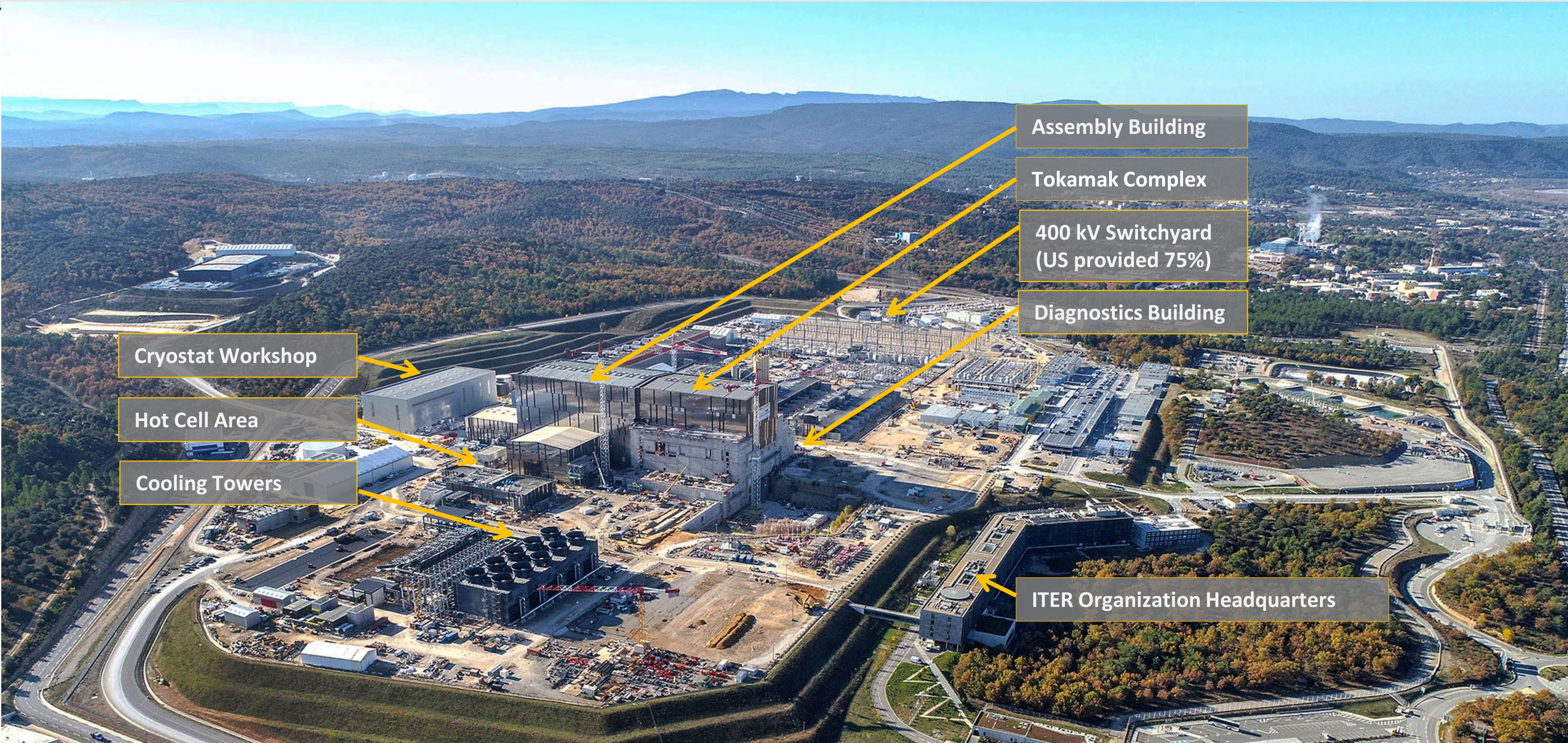
During the construction phase the U.S will pay 9.09%; the U.S. will pay a 13% cost share during the operations phase.

# ITER fusion "firsts"



- First fusion device categorized as a nuclear installation (France/ASN)
- Power-plant scale vacuum vessel
- Power-plant scale  cryoplant
- >10,000 tons of superconducting magnets with a combined stored energy of 51 GJ
- Integrated operations of fusion systems

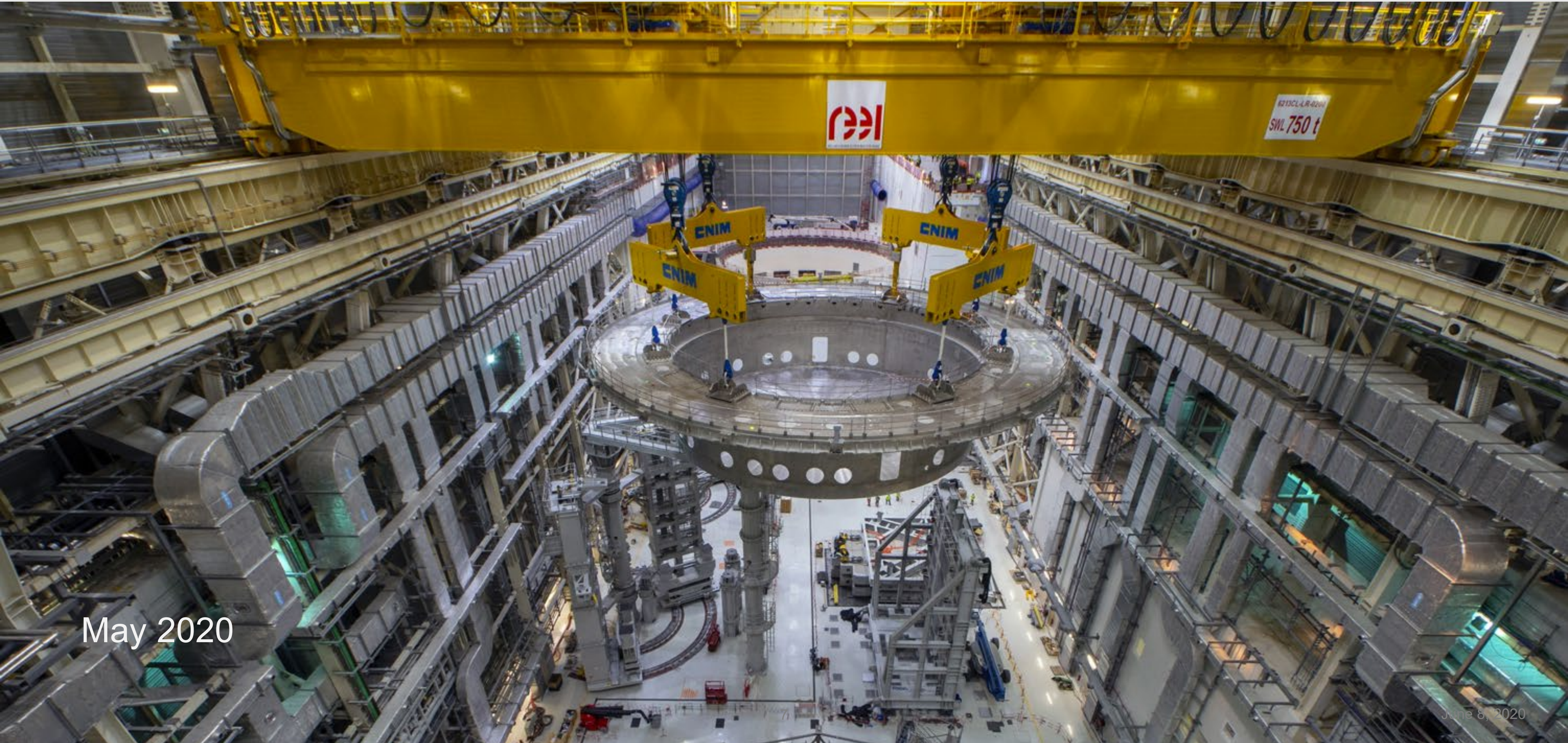
# ITER Project is ~78% complete for First Plasma site construction and components



# ITER celebrated the start of assembly in July 2020

French President Emmanuel Macron served as host for the international virtual event on July 28, 2020.

# Tokamak assembly began in May 2020

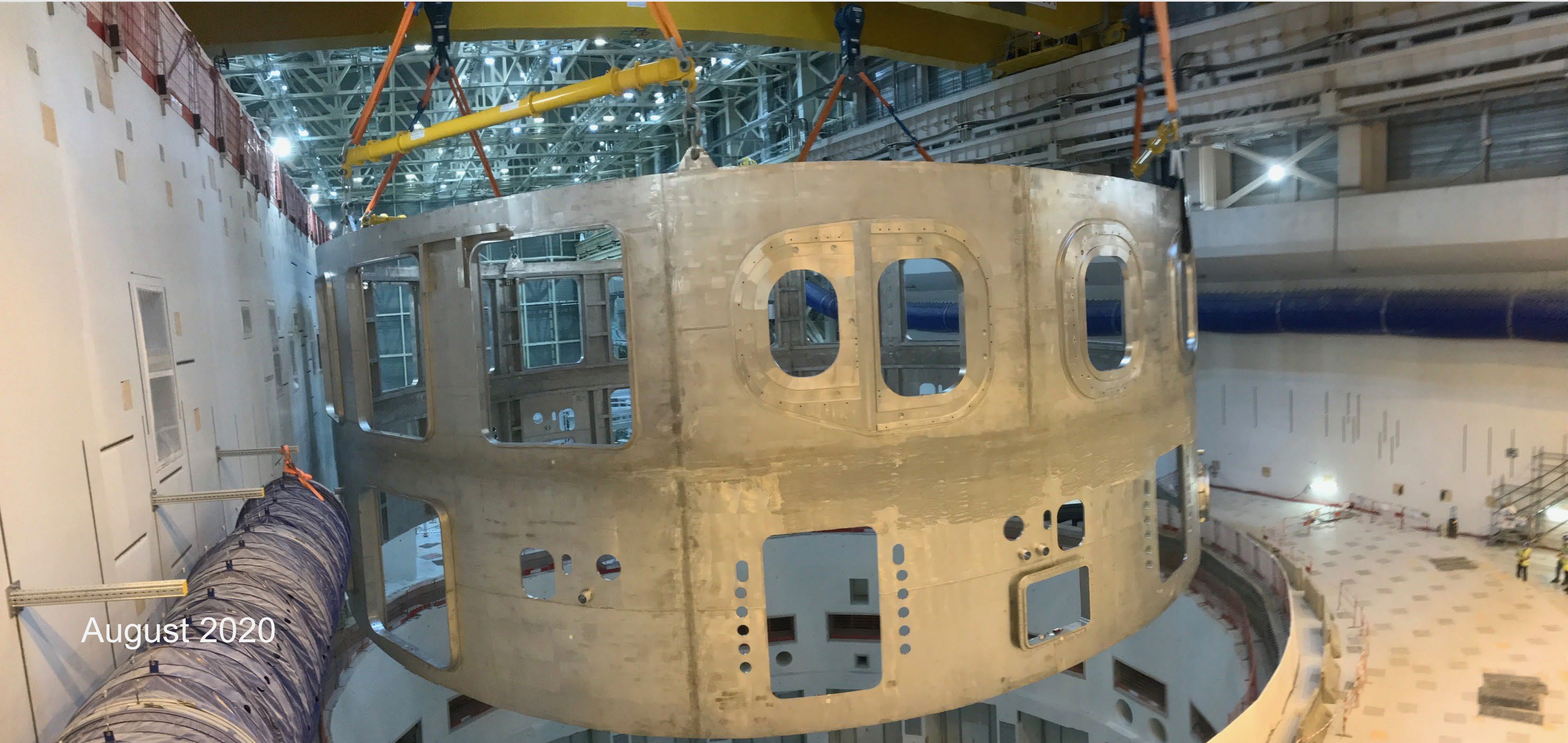



May 2020

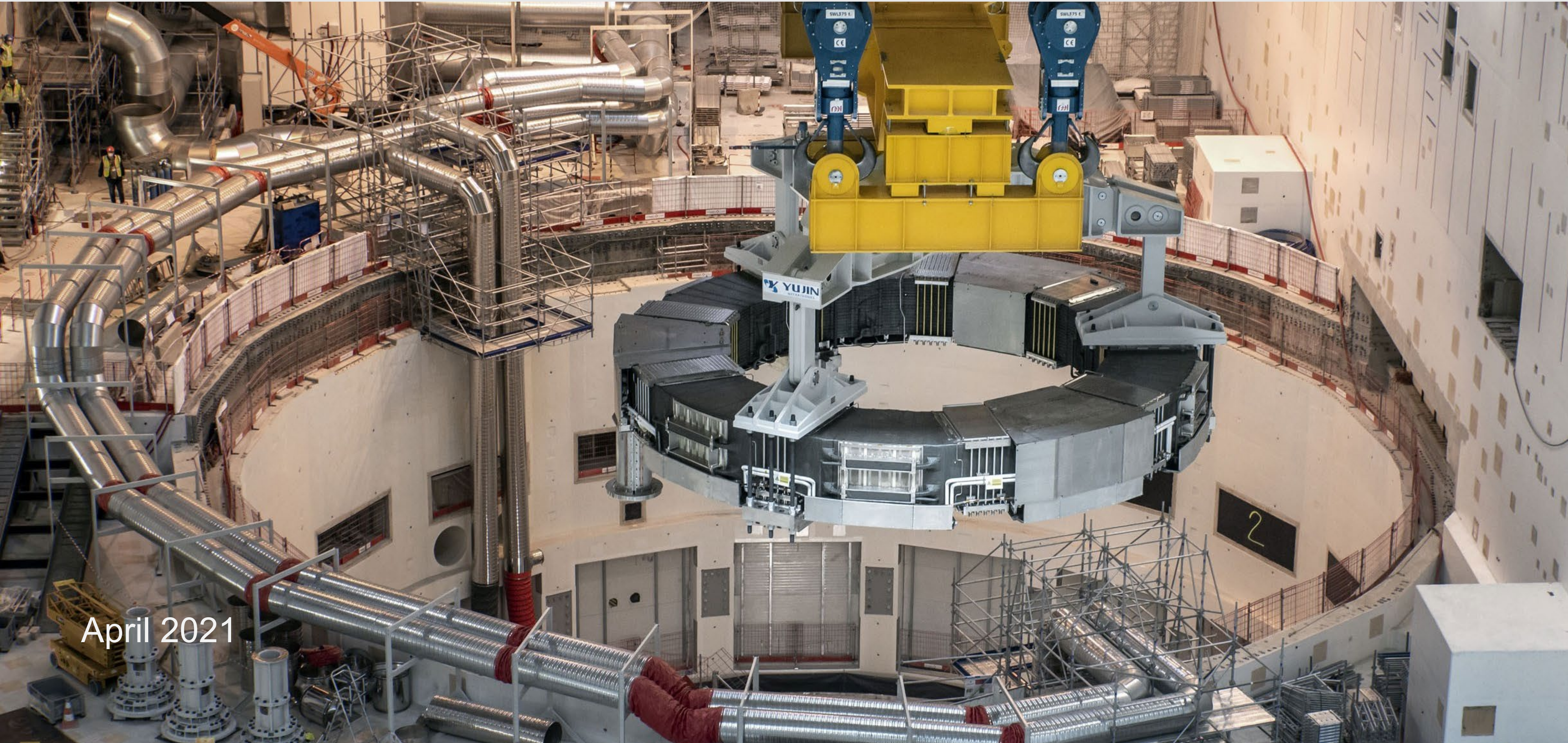
# Cryostat base installation

# Cryostat base installation

# Cryostat lower cylinder installed

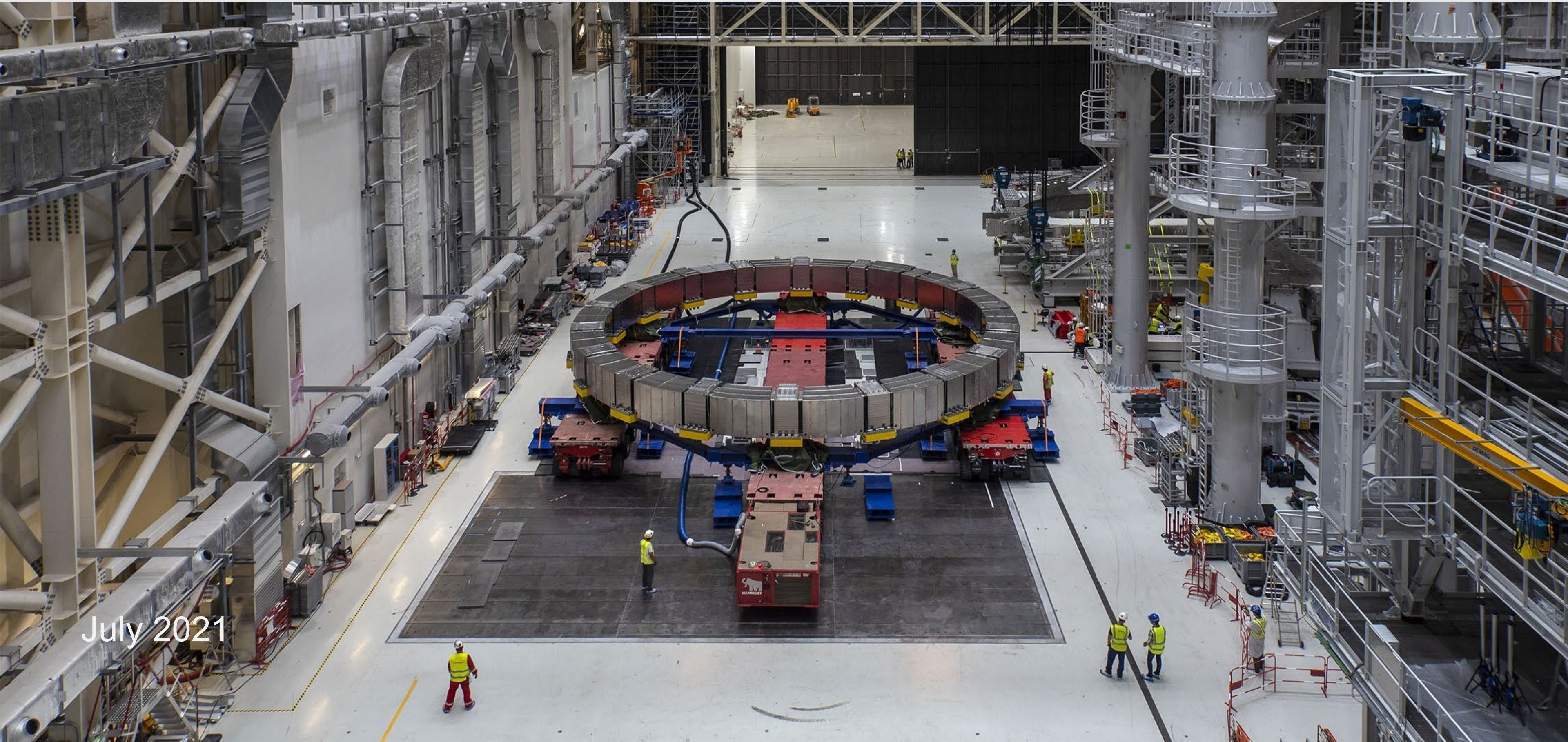


# First magnet was installed in tokamak pit

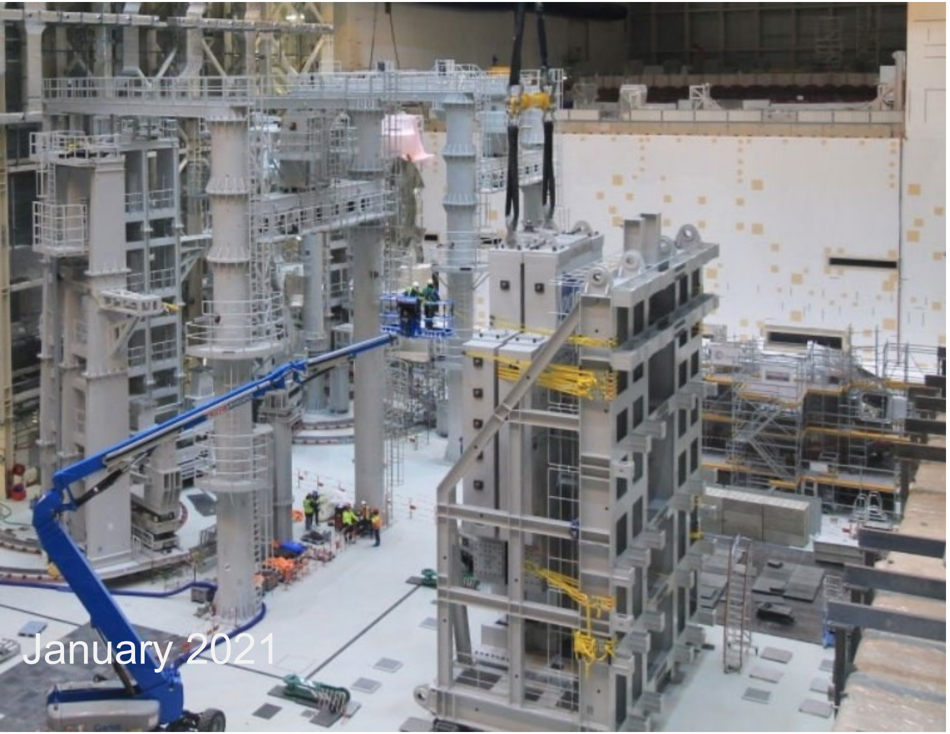


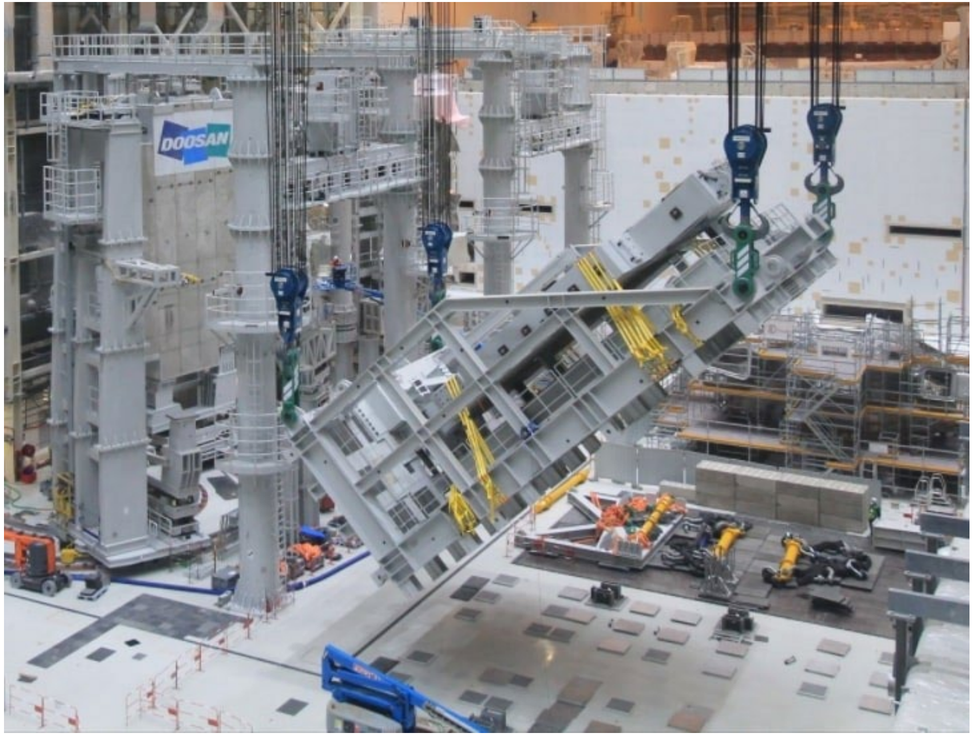

April 2021

# Next magnet awaiting installation

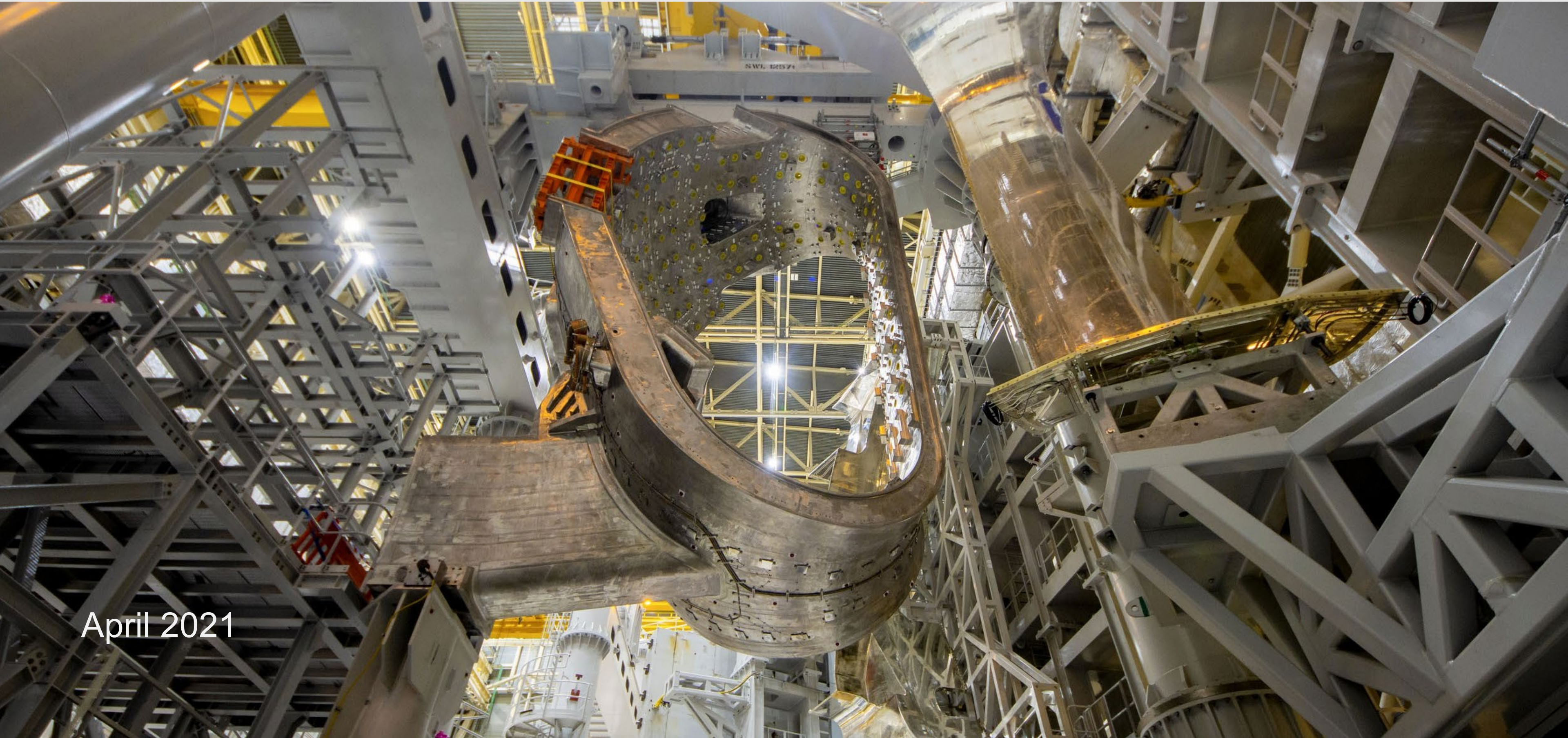


# Testing of vacuum vessel sector assembly tooling

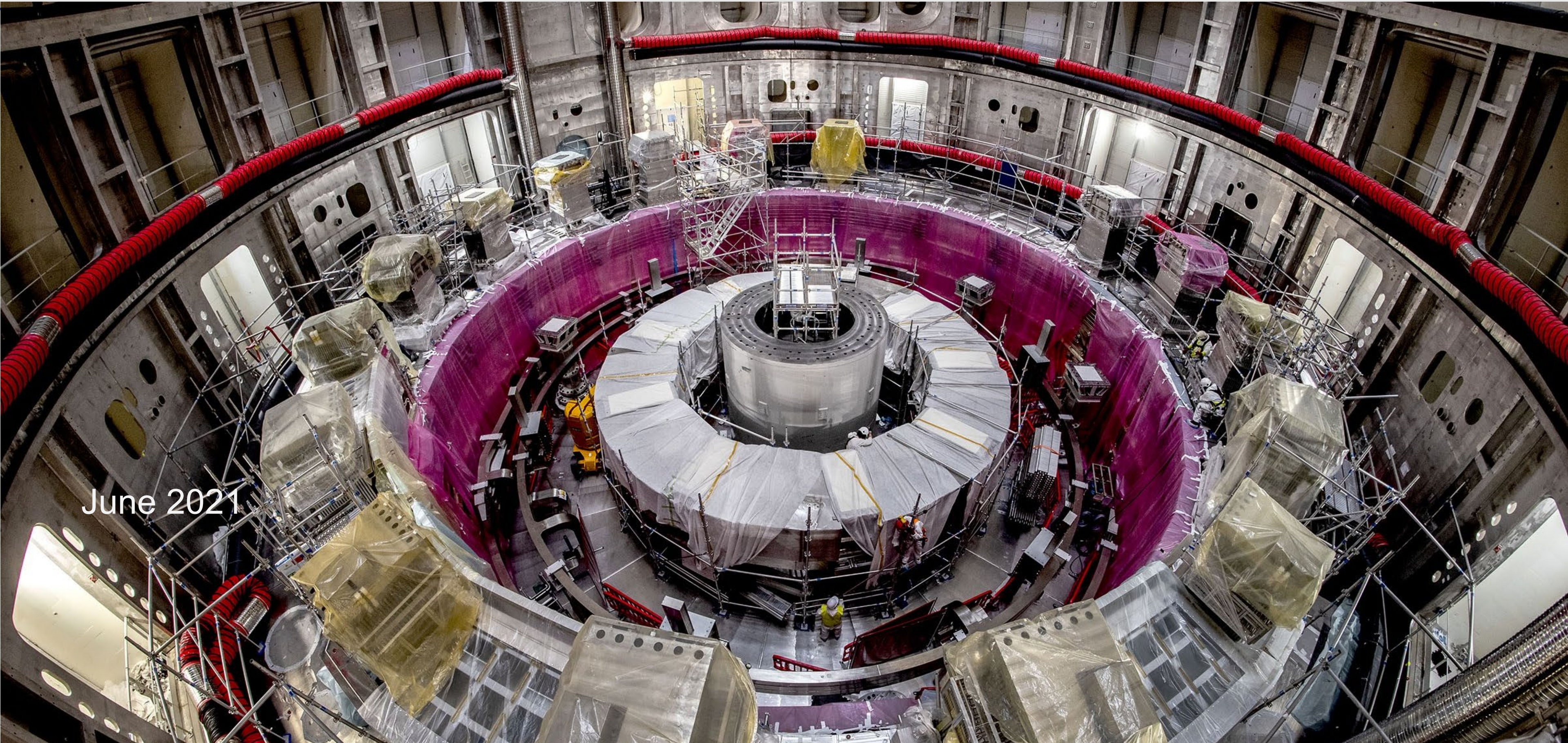


# First vacuum vessel sector successfully docked



# Tokamak pit is filling up

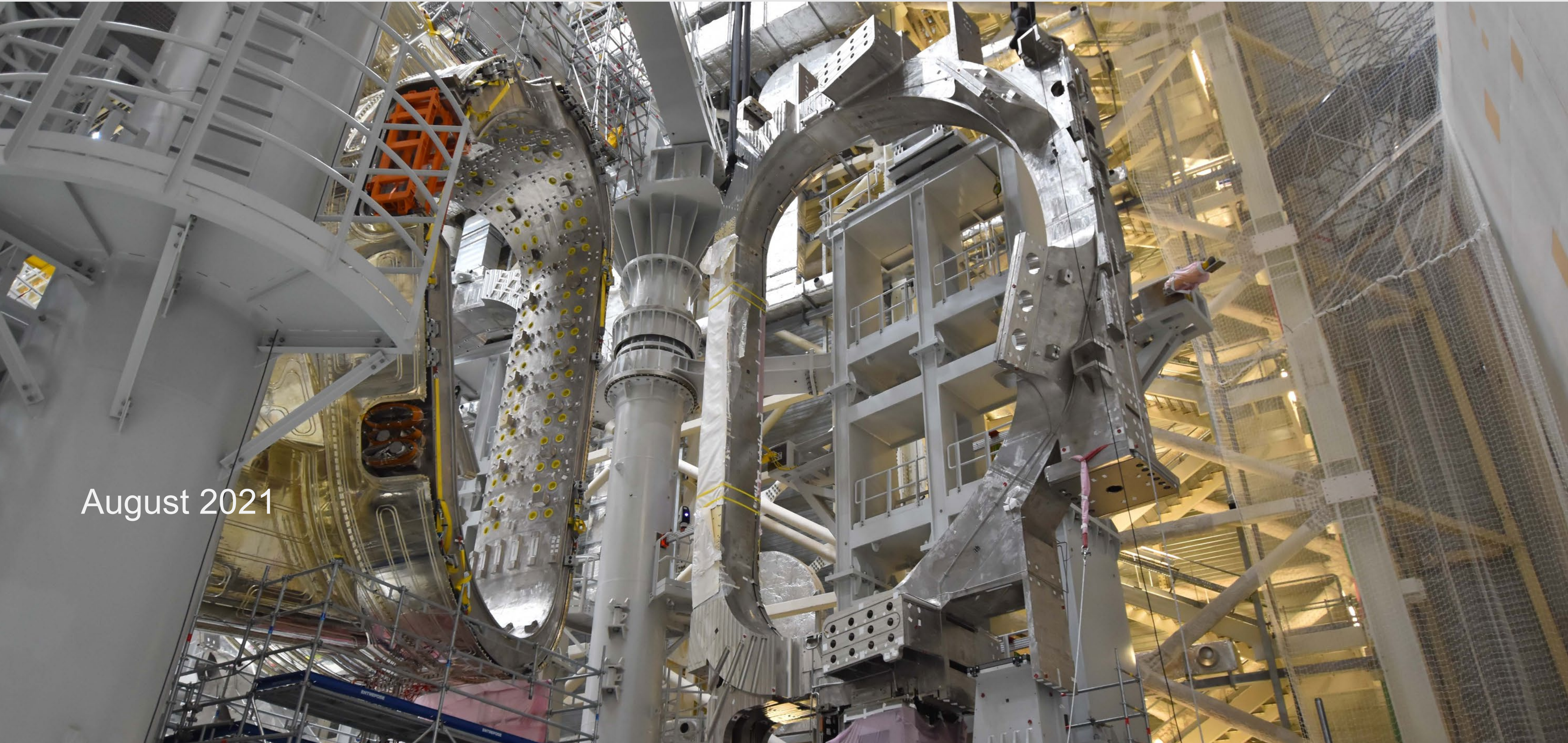


June 2021

# Sub-assembly of sectors is progressing

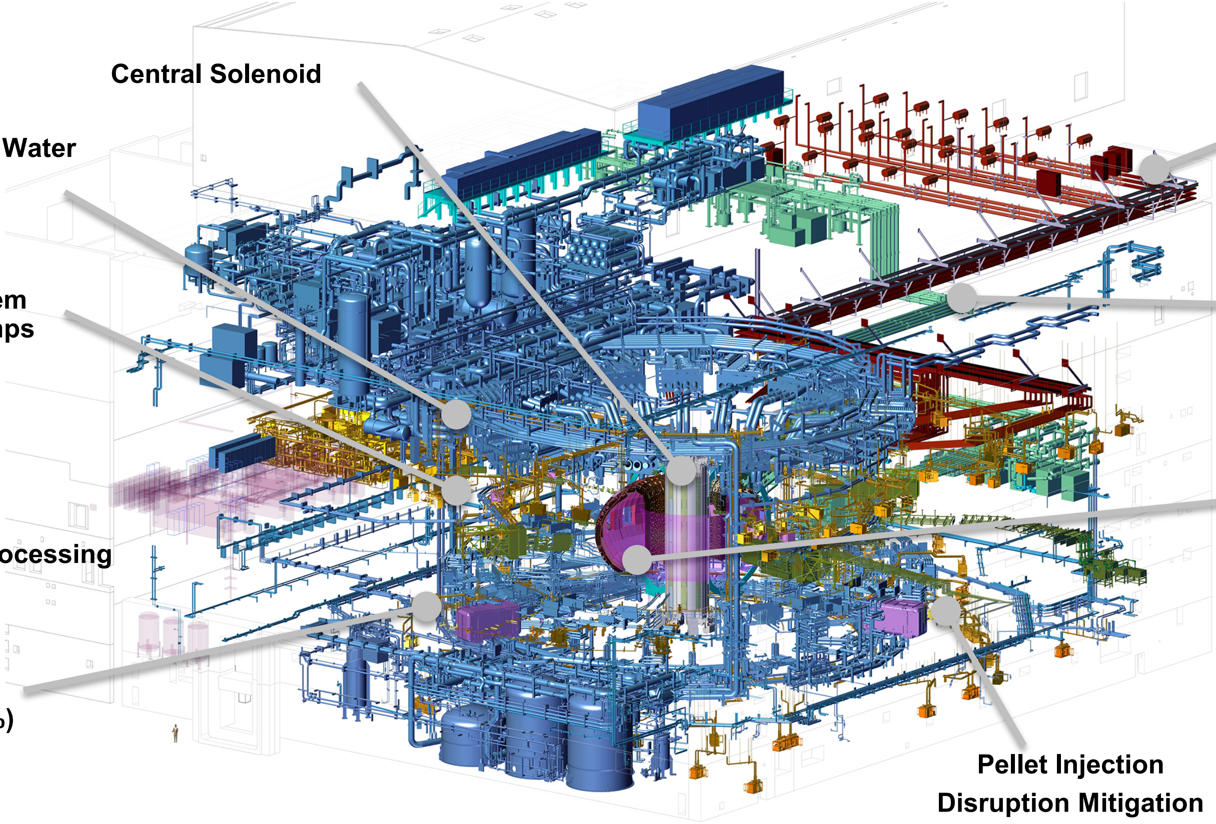

July 2021

# Toroidal field coils installed for sector assembly



# US ITER Hardware Scope

## US contributes 9% to construction



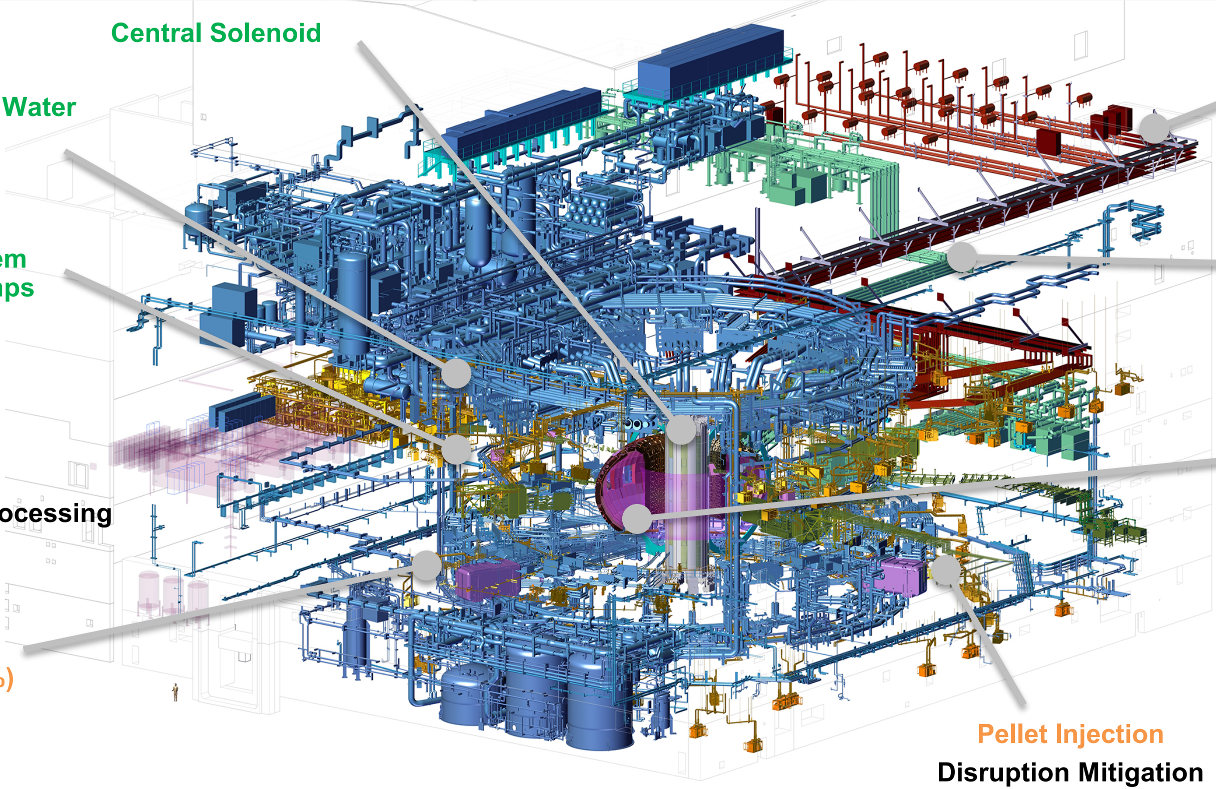
# ITER Project Funding History

- Hardware delivery in the US ITER Project is divided into two sub projects:
  - SP-1: design of all hardware and delivery of hardware for first plasma
  - SP-2: delivery of remaining hardware
- SP-1 was baselined in 2017
- Appropriations for hardware were lower than the baseline early on, but higher in recent years; total to date is a cumulative $97M deficient relative to baseline
- Priority given to hardware needed for first plasma
- With larger appropriations, we've been to restart activities that had to be put on hold

# US ITER Hardware Scope

## US contributes 9% to construction

Key: Finished • Hardware in fabrication • Prototypes in fabrication • In design



# Most US ITER funding remains in the US

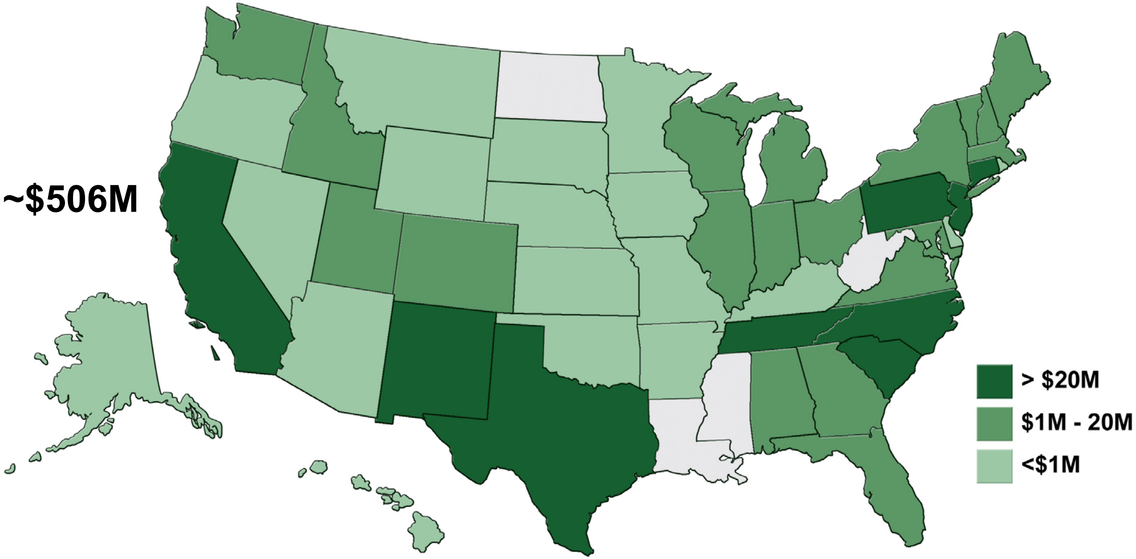
As of June 2021, ~$1.3 billion has been awarded to US industry and universities, and obligated to DOE national laboratories in 46 states plus the District of Columbia.

**Awards to industry: ~$729M**

**Awards to universities: ~$26M**

**Obligations to National Laboratories: ~$506M**

# Total: ~$1.3B



# Design, fabrication and deliveries continue across US scope

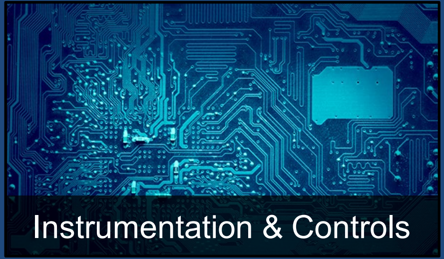

Central Solenoid


Tokamak Cooling Water System

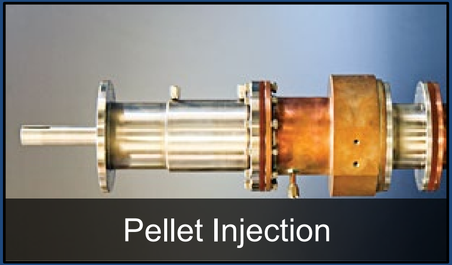

Electron Cyclotron


Diagnostics


Vacuum & Roughing Pumps


Instrumentation & Controls


Ion Cyclotron


Pellet Injection


Exhaust Processing

# Central Solenoid Modules

Deliveries are underway!

# Central Solenoid Modules

# Central Solenoid Modules

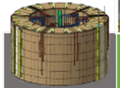
Module 1 is in France;
will arrive at ITER site ~September 9

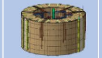
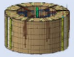
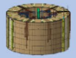
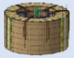
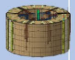

Transfer of Module 1 by barge from Fos (Port of Marseille)

Module 2 is now
at the Port of Houston


Protection around Module 2 in Houston

# Remaining modules are in fabrication

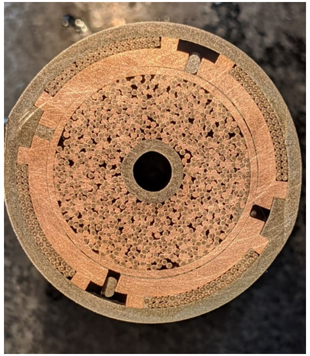
| Modules | Stations 1–2<br>Receiving & Winding | Station 3<br>Joint & Terminals | Station 4<br>Stack & Join | Station 5<br>Heat Treatment | Station 6<br>Turn Insulation | Station 7<br>Ground Insulation | Station 8<br>Vacuum Pressure Impregnation | Station 9<br>Helium Piping | Station 10<br>Final Test<br>Pre-Test | Testing | Post Test | Shipping<br>Shipping<br>Packaging | Ready to Ship |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | | | | In-transit to IO |
| 2 | | | | | | | | | | | | | In-transit to IO |
| 3 | | | | | | | | | |  | | | |
| 4 | | | | | | | |  | | | | | |
| 5 | | | | | | |  | | | | | | |
| 6 | | | | |  | | | | | | | | |
| 7 | | |  | | | | | | | | | | |

As of mid-August 2021

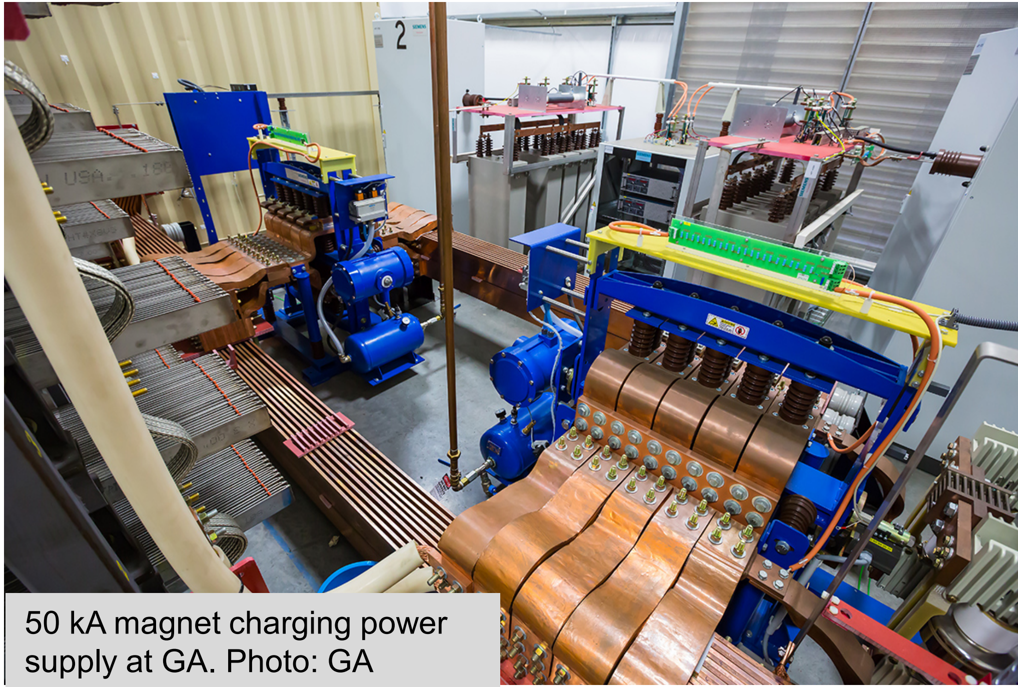
# Multiple challenges had to be overcome

- Fabrication and qualification of 10 workstations
- Coax joint design and fabrication
- Test station power supply component failure
- Quench detection

  wire arc



Final coax joint configuration

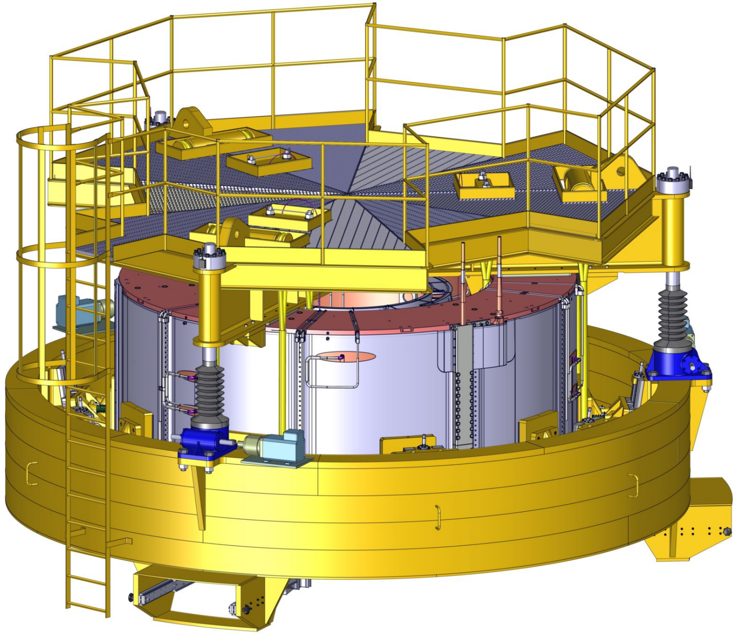


50 kA magnet charging power supply at GA. Photo: GA

*Many lessons were learned and applied to next steps in fabrication*

# Central Solenoid Assembly Tooling final delivery planned for September

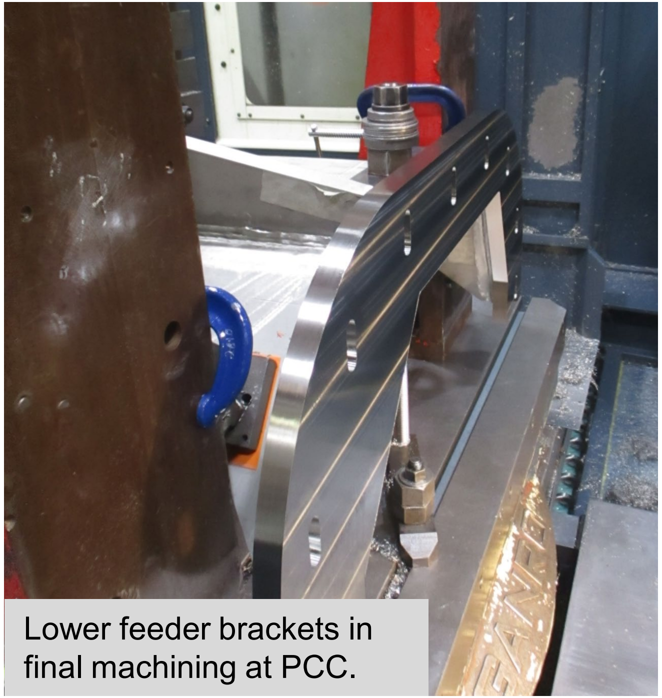
Lifting fixture passed factory acceptance testing in August 2021



# Central solenoid structures fabrication and deliveries continue

Inner tie plate during cryogenic shock testing at PCC.

Upper feeder brackets during forming at PCC.



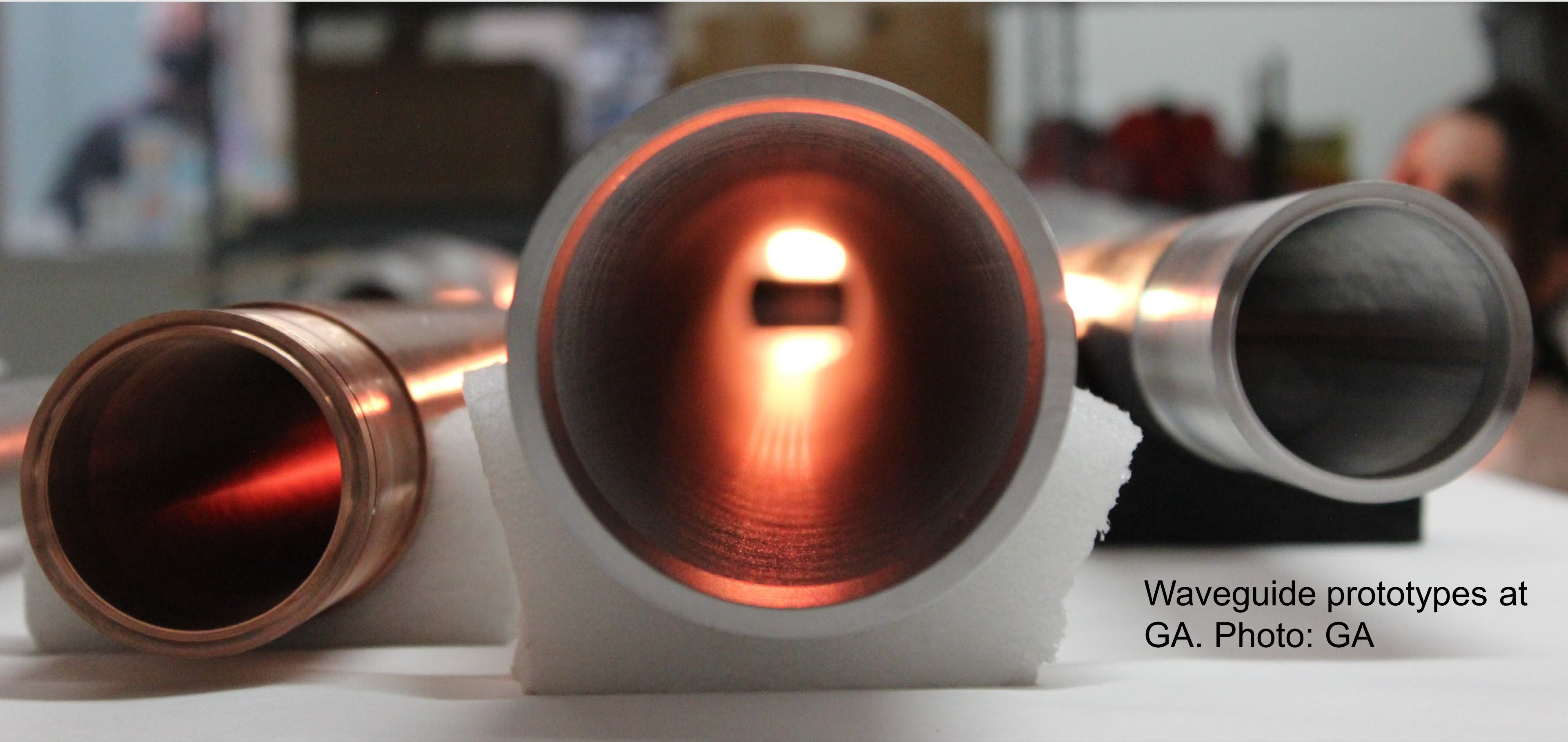
Lower feeder brackets in final machining at PCC.

# Tokamak Cooling Water System Fabrication and deliveries continue

Volume control tank delivered to the ITER site

Pump casing for the vacuum vessel primary heat transfer system primary pump

# Fabrication underway for electron cyclotron heating transmission lines first articles



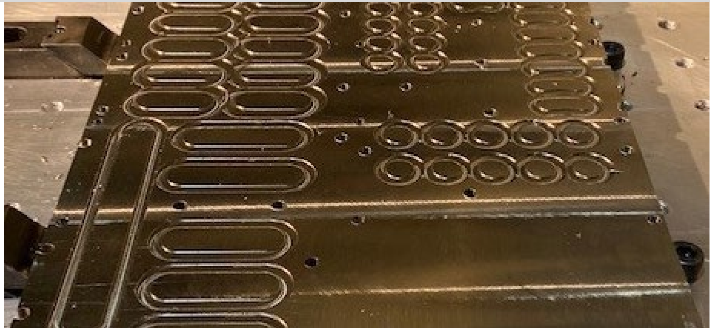
Waveguide prototypes at GA. Photo: GA

# Diagnostics work is progressing

Low Field Side Reflectometer Test Antenna Block Assembly manufacturing development at General Atomics. Photos: GA

Test antenna block weldment

Test antenna weldment



Weld plugs antenna cap

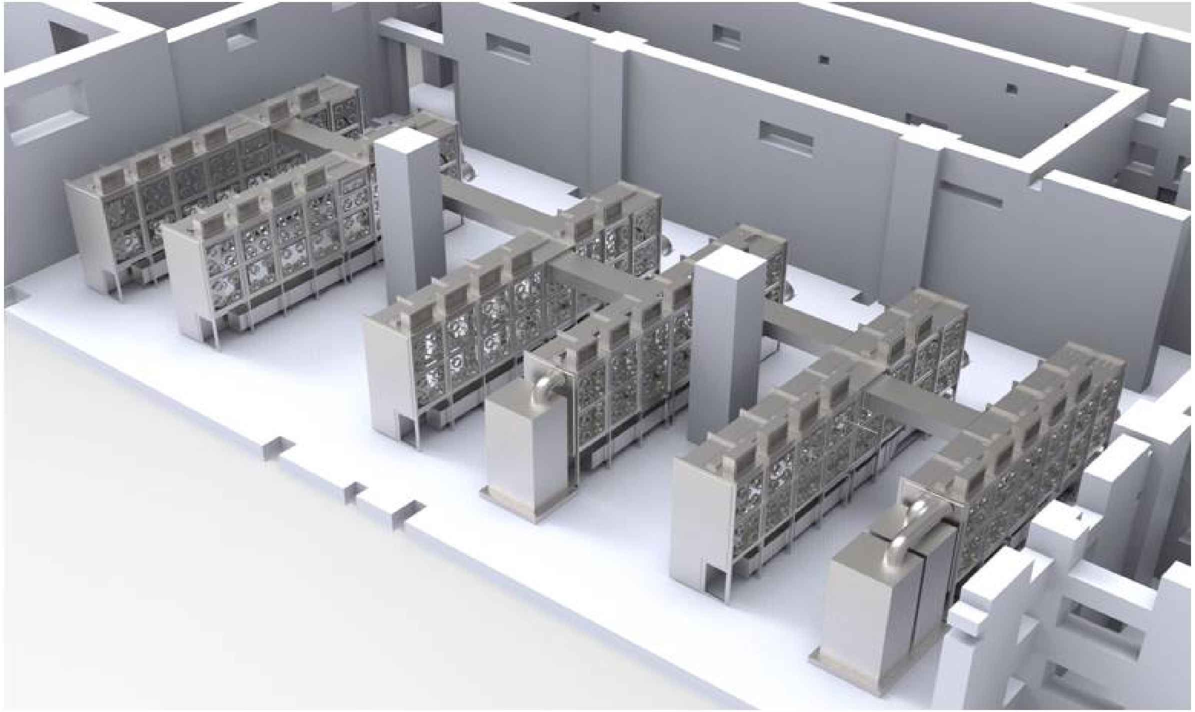
# Disruption mitigation R&D efforts progress for DT operation

Pellet expertise yields valuable R&D for disruption mitigation design

Recent experiments addressed

- Pellet formation (28.5 mm hydrogen and deuterium pellets)
- Pellet dispersion (28.5 mm deuterium pellets)
- Pellet fragmentation (28.5 mm deuterium pellets)

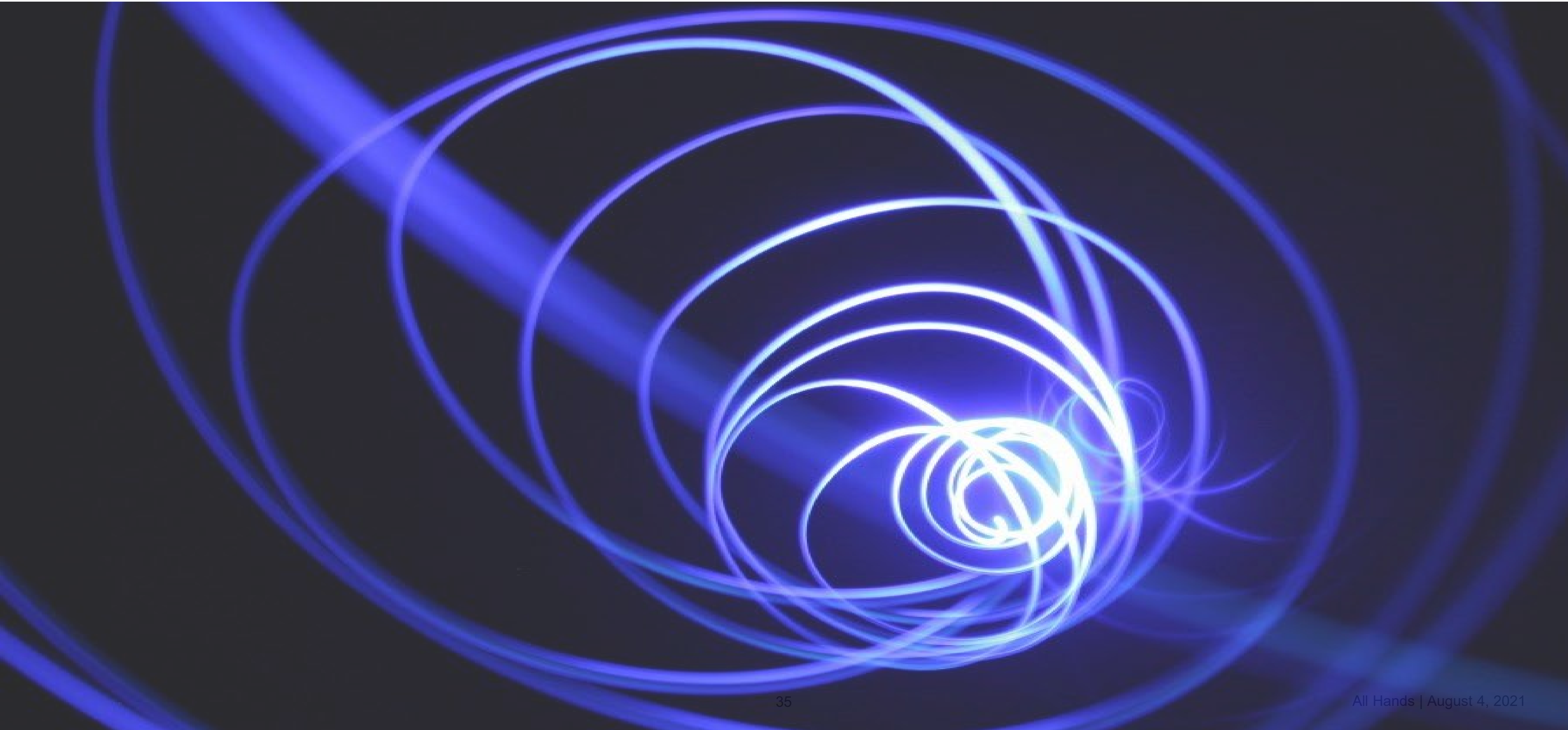
# Tokamak exhaust processing is moving forward



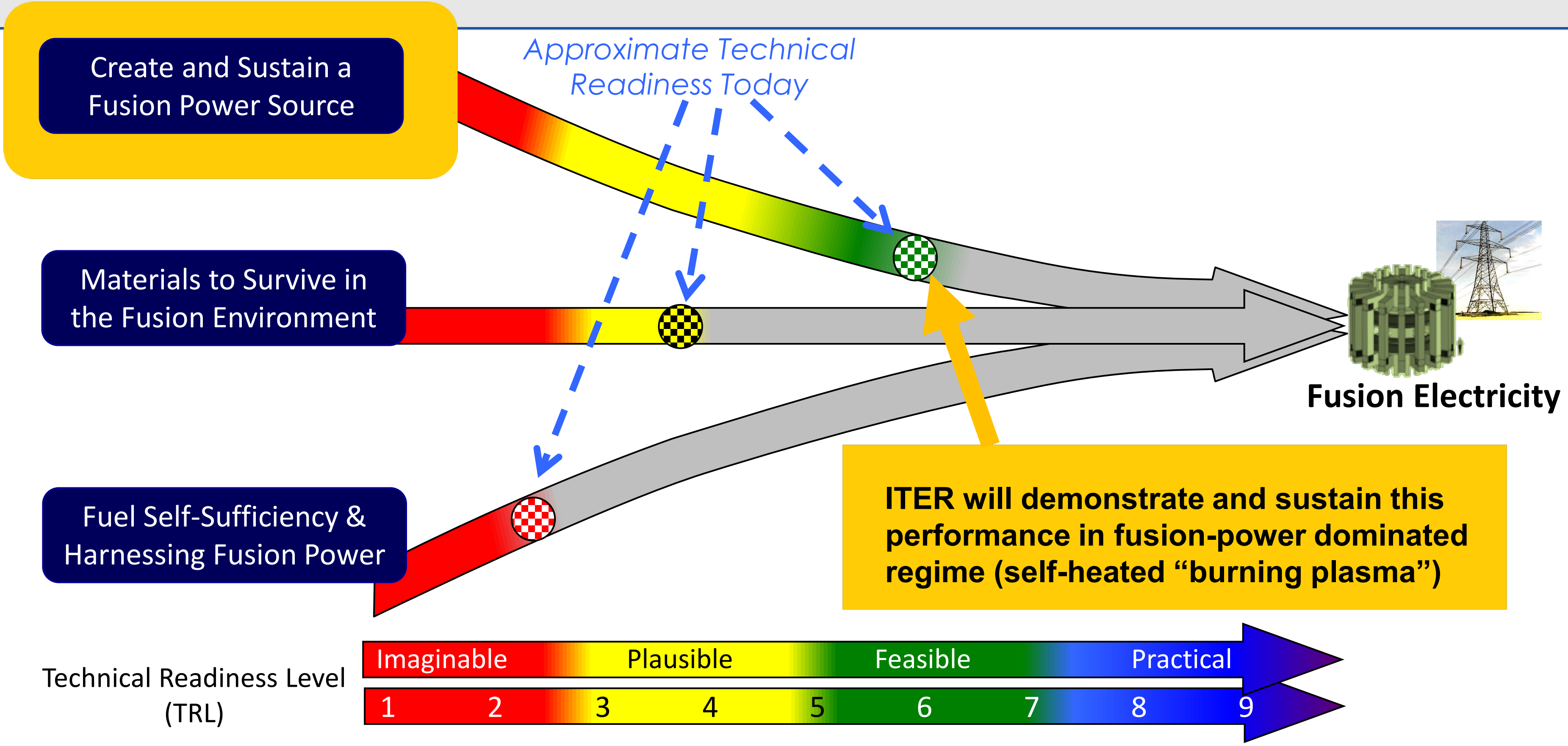
System will require throughput of 240 Pa*m$^3$ /sec (unprecedented by about 2 orders of magnitude)

Prototype contracts will be awarded soon (to manage risk).

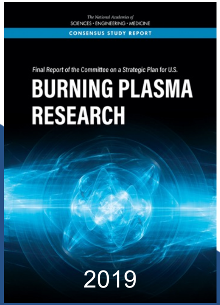
# ITER’s role in US fusion



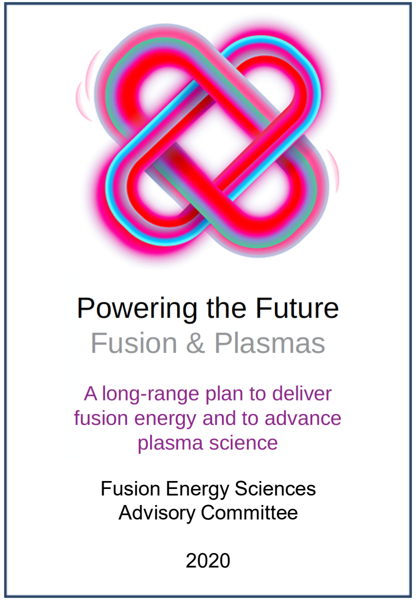
# Generating electricity from fusion energy requires resolution of three scientific/technological challenges



# What does ITER mean for US fusion?



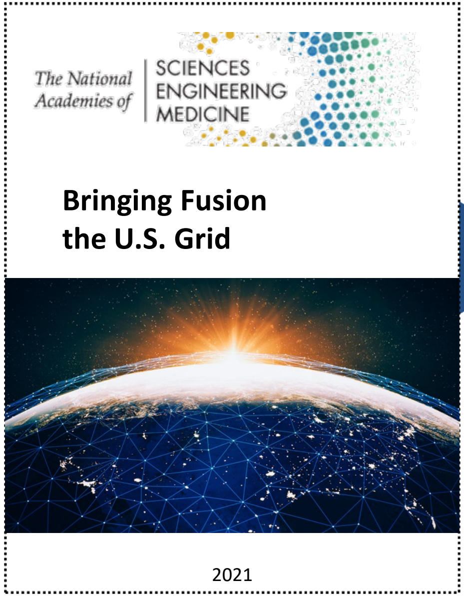





"Partnership in the international ITER fusion project is **essential for US fusion energy development**, as is supporting the continued growth of the private sector fusion energy industry…

**US partnership in ITER provides access to a high-gain reactor-scale burning fusion plasma** and an accompanying US ITER research team and program to exploit this facility must be developed."

"The Department of Energy should **assure maximum possible access to ITER information** for the members of the fusion pilot plant design teams."



# US ITER benefits US fusion activities…yielding new IP and experience

- Tools and strategies for plasma control and performance
- Superconducting magnet technologies
- Radiation transport analysis
- High-powered plasma heating
- D-T fuel cycle technologies
- Continuous plasma fueling
- Fusion materials
- Fusion power and particle handling
- Burning plasma science and diagnostics

# Looking Ahead

ESCS-006260
EXEC-2021-001322

**Department of Energy**
Office of Science
Washington, DC 20585

**Office of the Director**

June 14, 2021

MEMORANDUM FOR THE SECRETARY

THROUGH: KATHLEEN HOGAN
ACTING UNDER SECRETARY FOR SCIENCE
AND ENERGY

FROM: J. STEPHEN BINKLEY
ACTING DIRECTOR
OFFICE OF SCIENCE

SUBJECT: **ACTION**: Requesting Approval of and Signature on the U.S. Contributions to ITER Project Baselining Strategy Report to Congress

**ISSUE:** Whether to approve and sign the U.S. Contributions to ITER Project Baselining Strategy Report to Congress.

**BACKGROUND:** The Report to Congress responds to legislative language set forth in the Joint Explanatory Statement accompanying the Consolidated Appropriations Act of 2021 (Public Law No. 116-260):

Baselining Report to Congress signed and approved by DOE

July 21, 2021

# Thank You!

# U.S. In-kind Hardware Scope

First Plasma SP-1

Post-First Plasma SP-2

| 100% R&D and System Design | Full Fabrication | Partial Fabrication / Completion of Fabrication | | Full Fabrication |
|---|---|---|---|---|
| • All Hardware R&D **(Complete)**<br>• All System Designs | • Central Solenoid **(In fabrication; some items delivered)**<br>• Toroidal Field Conductor **(Complete)**<br>• Steady State Electrical Network **(Complete)** | | **[SP-1% / SP-2%]*** | • Tokamak Exhaust Processing<br>• Diagnostics (five of seven) |
| | | • Tokamak Cooling Water | [58% / 42%] | |
| | | • Roughing Pumps | [56% / 44%] | |
| | | • Vacuum Auxiliary | [85% / 15%] | |
| | | • Pellet Injection | [ 9% / 91%] | |
| | | • Ion Cyclotron Heating | [15% / 85%] | |
| | | • Electron Cyclotron Heating | [55% / 45%] | |
| | | • Diagnostics (2 of 7) | [15% / 85%] | |
| | | • Diagnostic Ports | [10% / 90%] | |
| | | • Instrumentation & Controls | [44% / 55%] | |

** Percentage of work done in SP-1 and SP-2, respectively; does not represent work completed to date.*

# Key Definitions

**First Plasma**
An ITER operational phase that includes: 1) integrated systems testing at low power, and 2) achievement of the specified first plasma and integrated systems testing of magnets at full field.

**Post-First Plasma**
A series of stages including fabrication, installation, and operations/research following the First Plasma phase, leading to achievement of full performance of engineering systems and operation with deuterium and tritium aimed at demonstrating a high-gain fusion “burning plasma.”