



# The ITER project

*new baseline, business opportunities*

**Alain BECOULET**

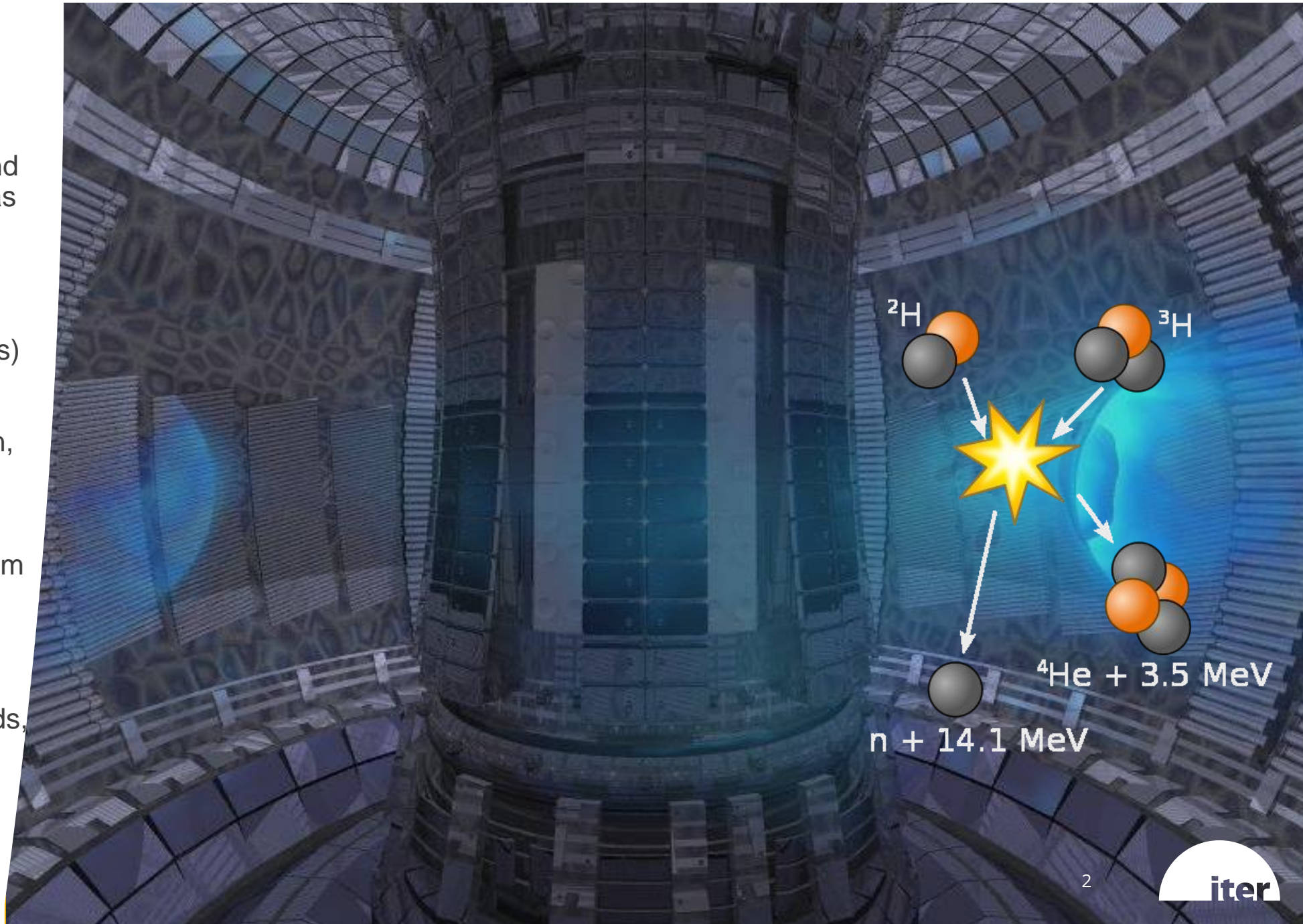
DDG, Chief Scientist, Member of the Academy of Technologies of France  
*6th Forum FUSION Germany; Greifswald; 14-15 January 2025*



## WHY ITER?

"Demonstrate the scientific and technical feasibility of fusion as a source of energy":

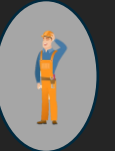
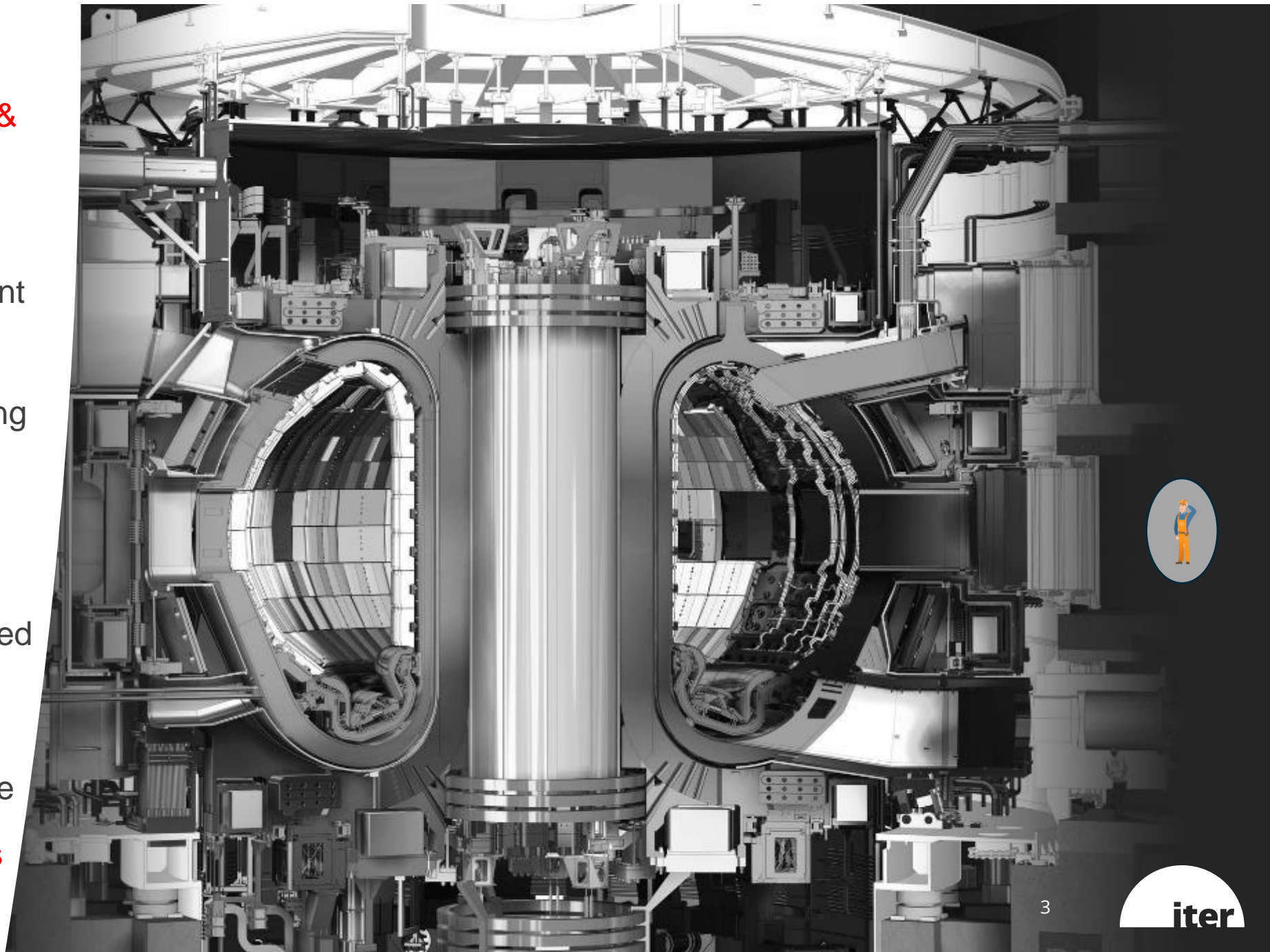
- " **Q=10** " in **D-T** plasmas
- "**Stationarity**" (400s->3600s)
- "**Nuclear**": licensing, maintenance, de-activation, dismantling and waste management.
- Proof(s) of concept of tritium **breeding**
- **Knowledge management** and transfer to future reactors: codes & standards, etc.



# WHAT is ITER?

A tokamak designed for **power & duration** performance

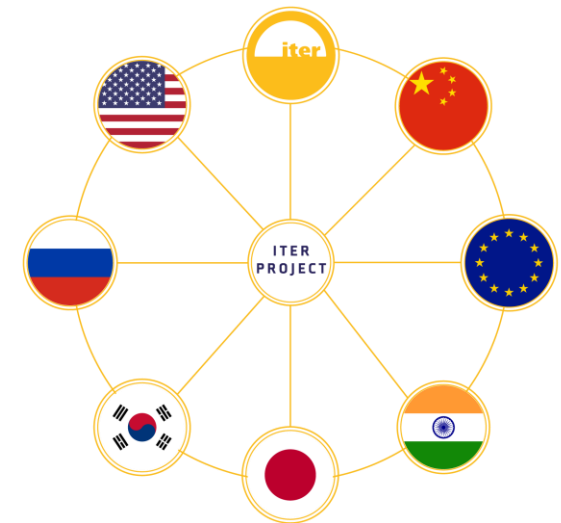
- A **830m<sup>3</sup>** toroidal vacuum chamber, the first confinement barrier.
- A "magnetic bottle" with a **10,000 tonne** superconducting magnet, cooled to **-269°C**, enclosed in a **30mx30m** cryostat, the second confinement barrier.
- A plasma of **deuterium and tritium**, confined and controlled by the magnetic field, and heated to **100-150 million degrees**.
- Auxiliaries providing real-time heating, fuel, diagnostics, controls, etc, and **continuous heat removal** (**10-20 MW/m<sup>2</sup>** on the divertor).





## WHO is ITER?

- An international cooperation without equal in history.
- An international treaty between 7 partners
- France as host country





## ITER WORKSITE OVERVIEW

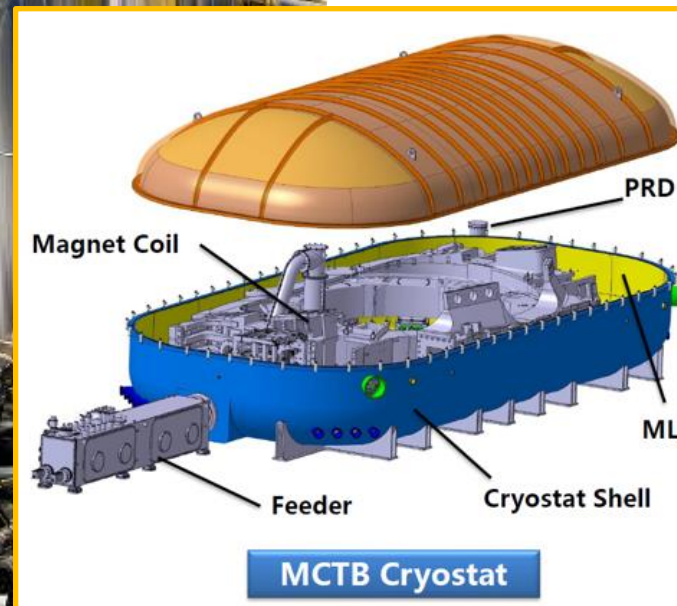
- Most plant support systems are operational or in commissioning.

# CRYOGENICS PLANT COMMISSIONING

Helium gas compressor and gas distribution network has completed functional testing in July 2024.

This completes the performance test of the first compressor train.

The commissioning plan targets making the first liquid helium this year, with the near-term goal to support operation of a Magnet Cold Test Bench (MCTB) under construction.



# SUPPORT SYSTEM COMMISSIONING

**Heat rejection and cooling water system**



**Reactive Power Compensation Commissioning**

**Chilled water system (condensers and evaporators)**



**EC Heating energization of the 22kV main switchgear**

# PF/TF/CC MAGNET MANUFACTURING AND DELIVERY

All Poloidal Field coils have been completed and delivered (PF2 pictured at right)

All 19 Toroidal Field coils (18 + 1 spare) have been completed and delivered.

12 of 18 correction coils have been completed and delivered.

*Last TF coil en route,  
December 2023*





# CENTRAL SOLENOID DELIVERY AND SUB-ASSEMBLY

Four CS modules have been delivered.

Two modules are stacked and aligned, and a third is in progress.

All six modules plus a spare are scheduled to be delivered by mid-2025.



*Stacking third module, August 2024*

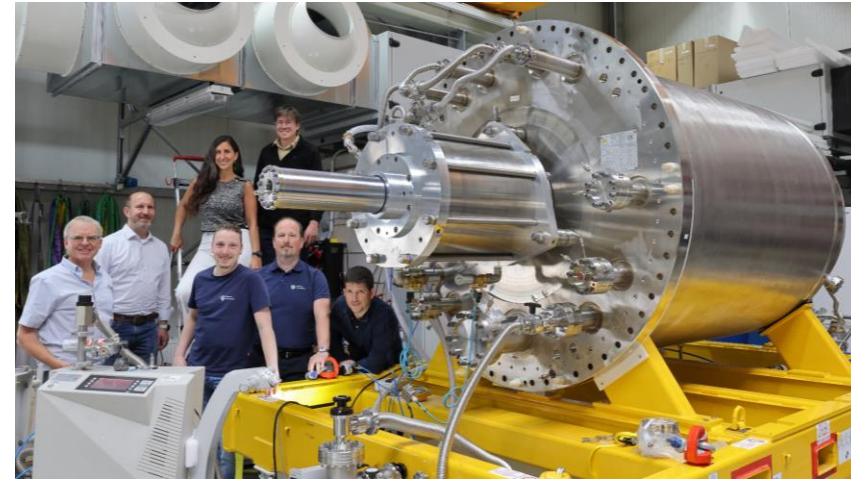
# ADDITIONAL MANUFACTURING AND DELIVERIES

**Divertor cassette body: 100% of manufacturing has been launched**



**Magnet feeder components 81% complete**

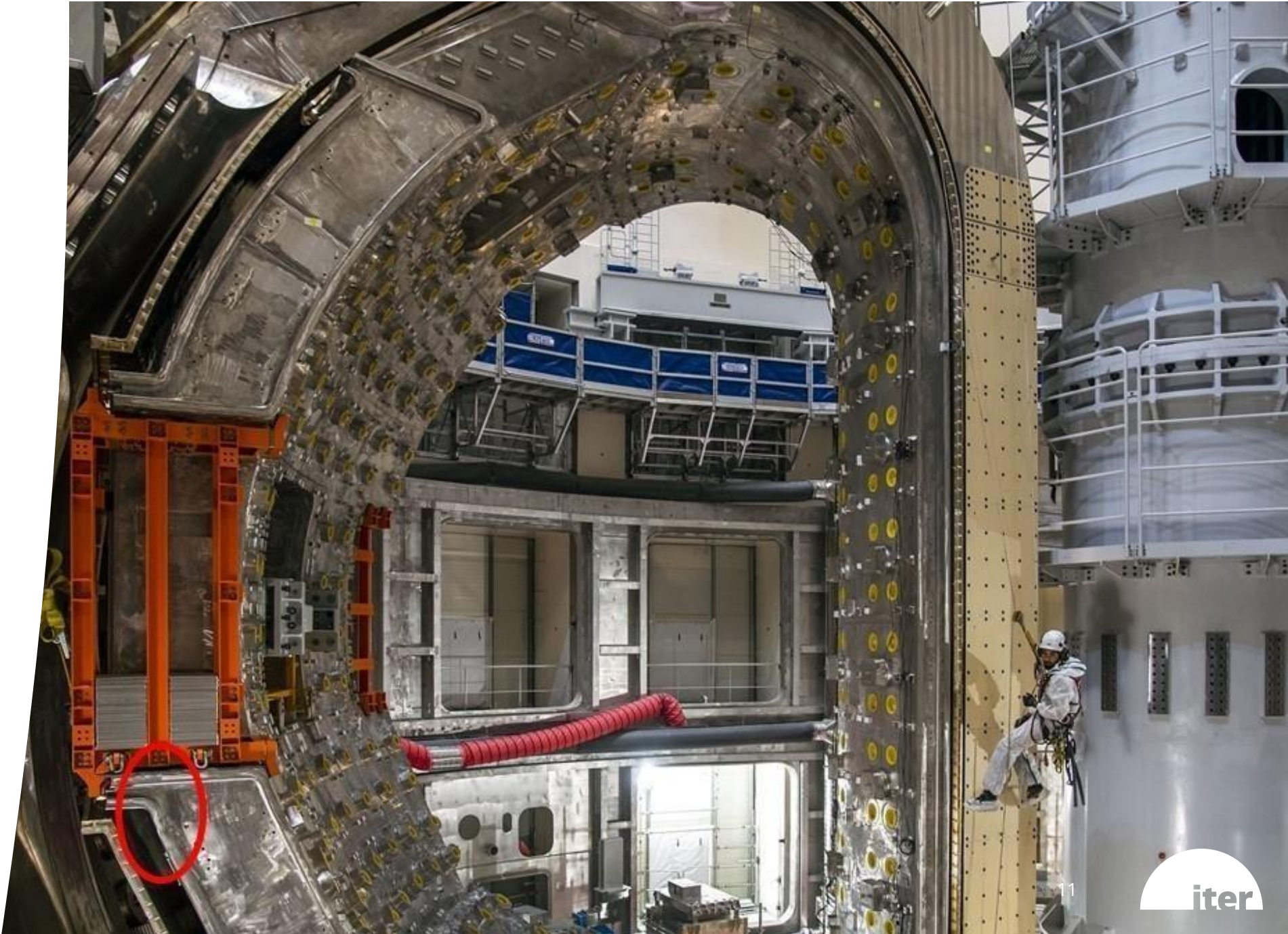
**Divertor cassette dome: series manufacturing ongoing for 58 domes**



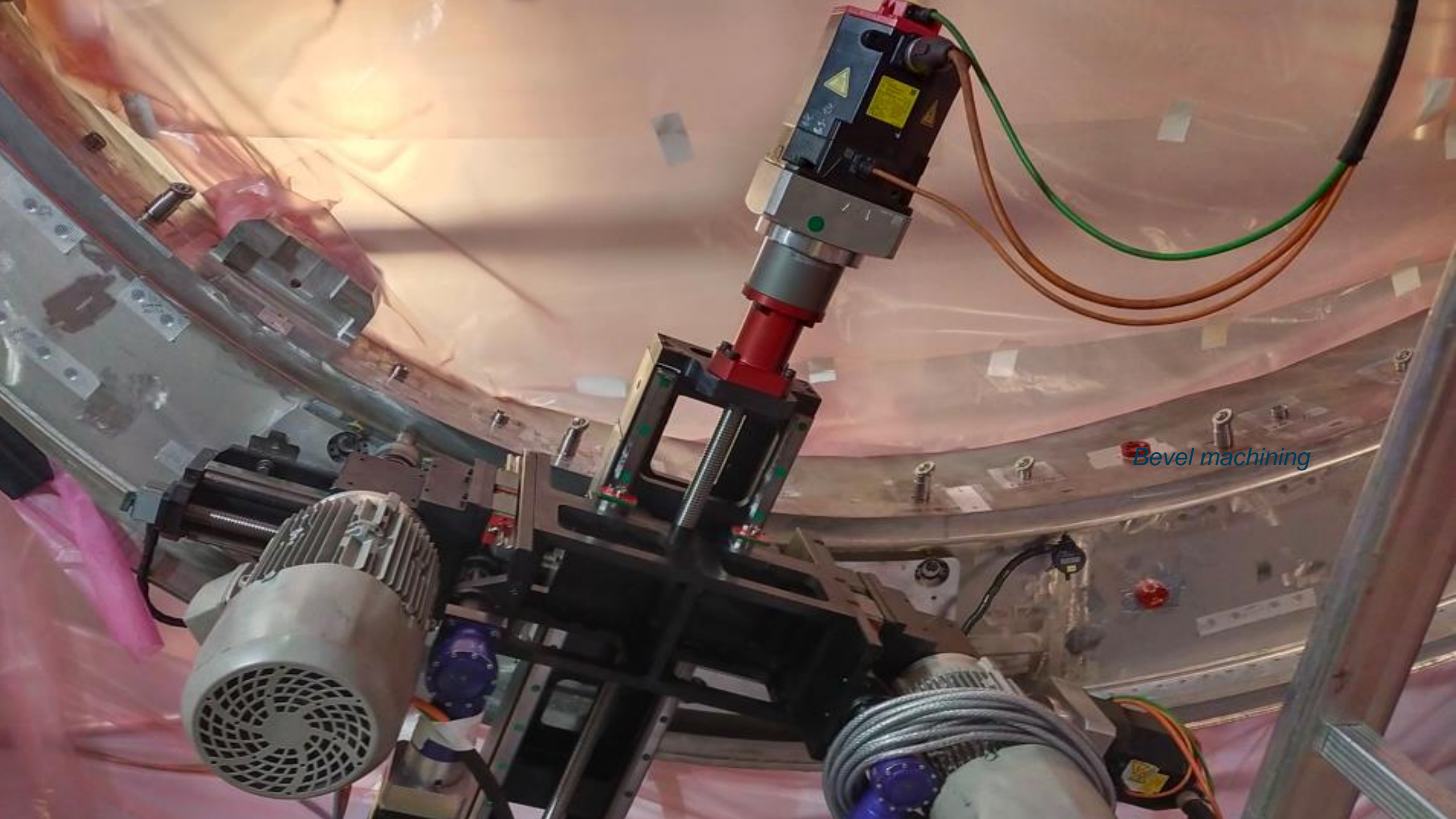
**First of 8 Torus and Cryostat Cryopumps passed FAT in May 2024**

# CHALLENGES OF FIRST-OF-A-KIND COMPONENTS

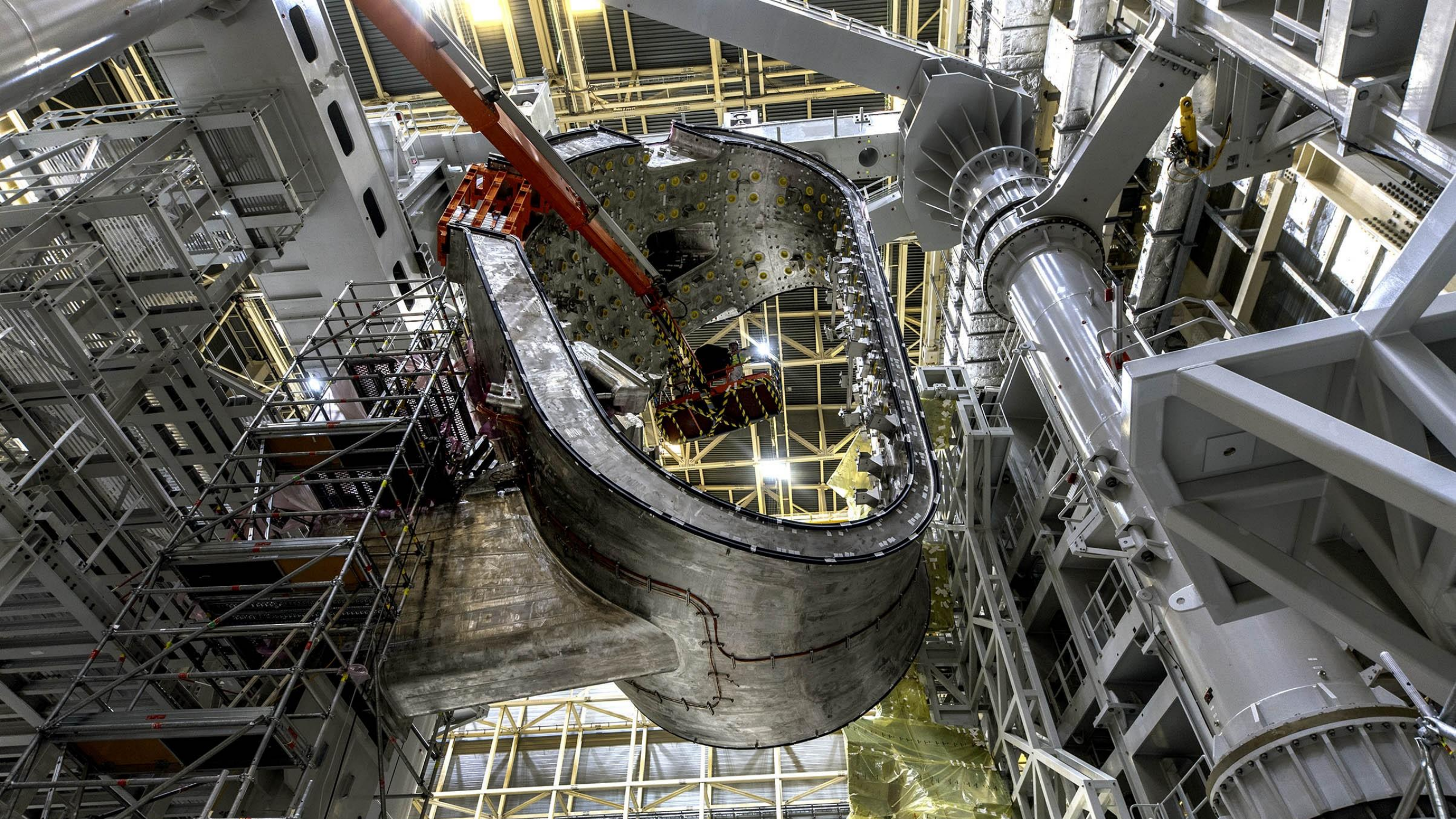
Vacuum Vessel sectors have geometric non-conformities in the field bevel joints.

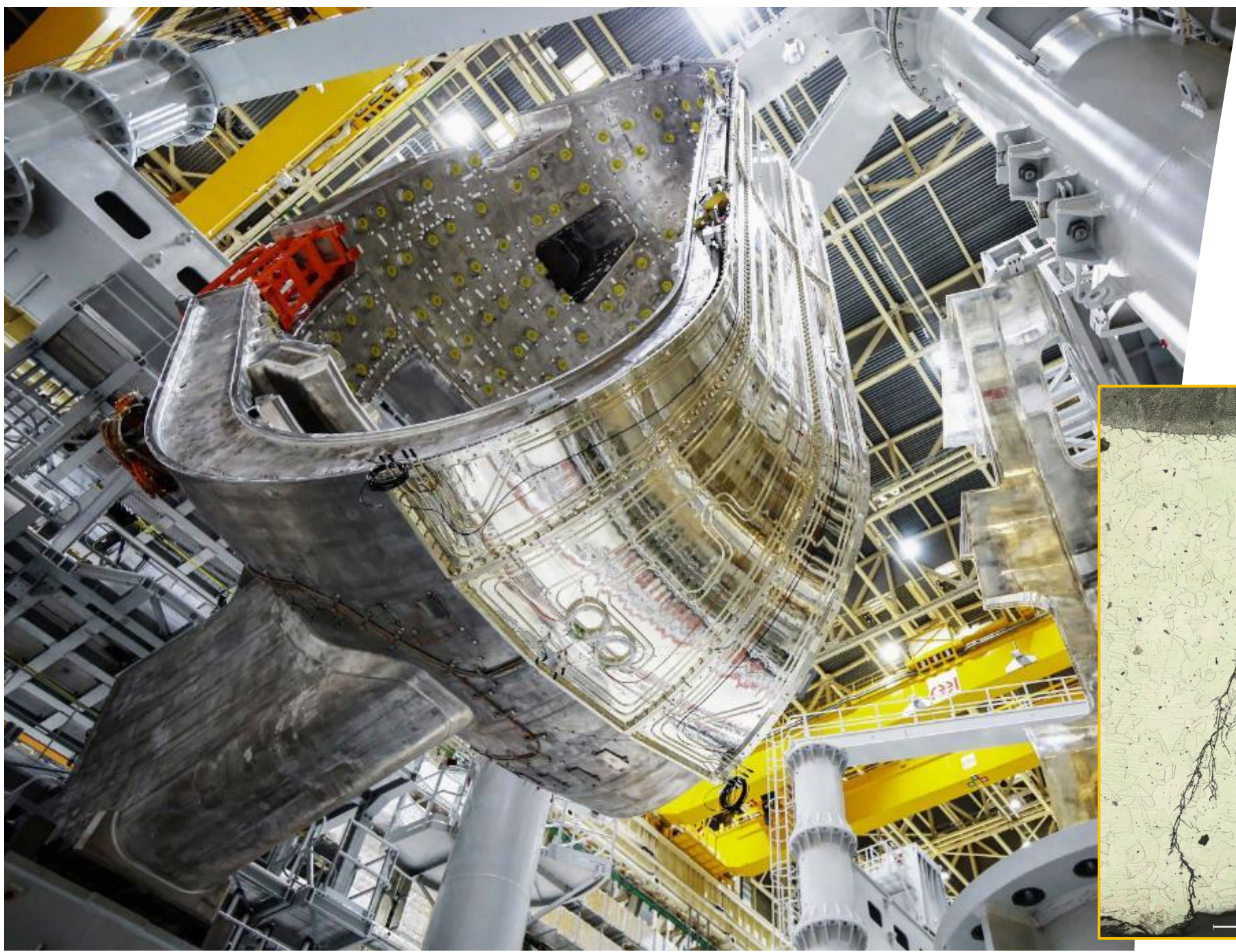






*Bevel machining*





## CHALLENGES OF FIRST-OF-A-KIND COMPONENTS

Leakage identified in thermal shield cooling piping due to chloride stress corrosion.



## VVTS REPAIR PROCESS

- Replacement of corroded pipes with new 316L pipes
- 2 mm panel machining to eliminate potential panel corrosion risk
- Surface polishing replacing Ag coating for good emissivity: surface roughness less than  $0.1 \mu\text{m}$  – lower emissivity at 80K



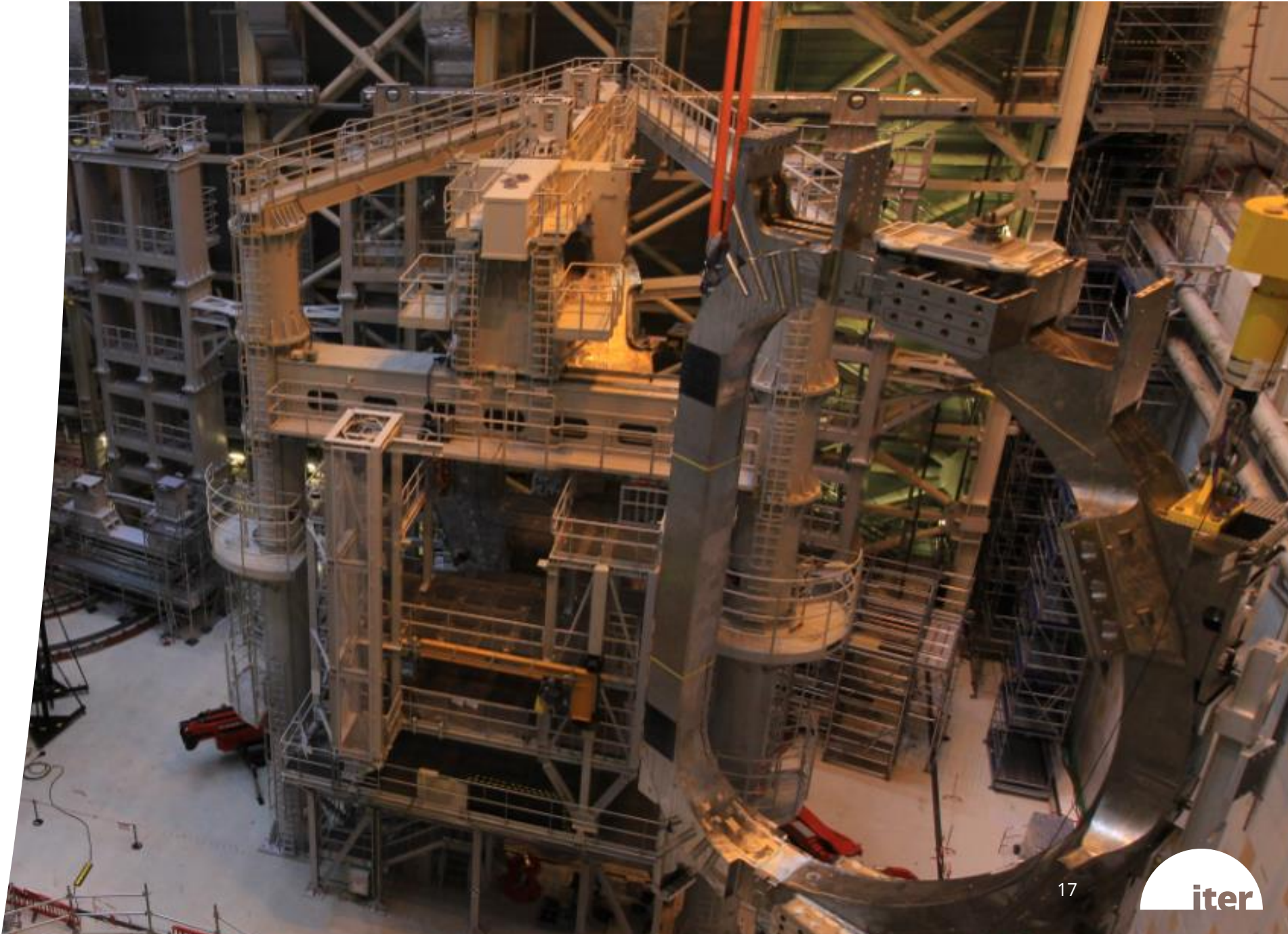
## VVTS MANUFACTURING

A risk mitigation measure: a contract to manufacture 3 (or more) new VVTS sectors progressing as planned.



# CHALLENGES OF FIRST-OF-A-KIND COMPONENTS

The ITER tokamak assembly  
has now restarted.



The Thermal Shields are back in.



# The PREVIOUS (2016) BASELINE:

- Designed to reach **First Plasma** – any symbolic plasma experiment – as rapidly as possible
- Constrained by the fact that some key components would not be available
- First Plasma scheduled for end-2025: a brief, low-energy machine test (100 kA)
- To be followed immediately by further in-vessel components assembly
- Reaching **full plasma current in 2033, and starting DT operations in 2035**

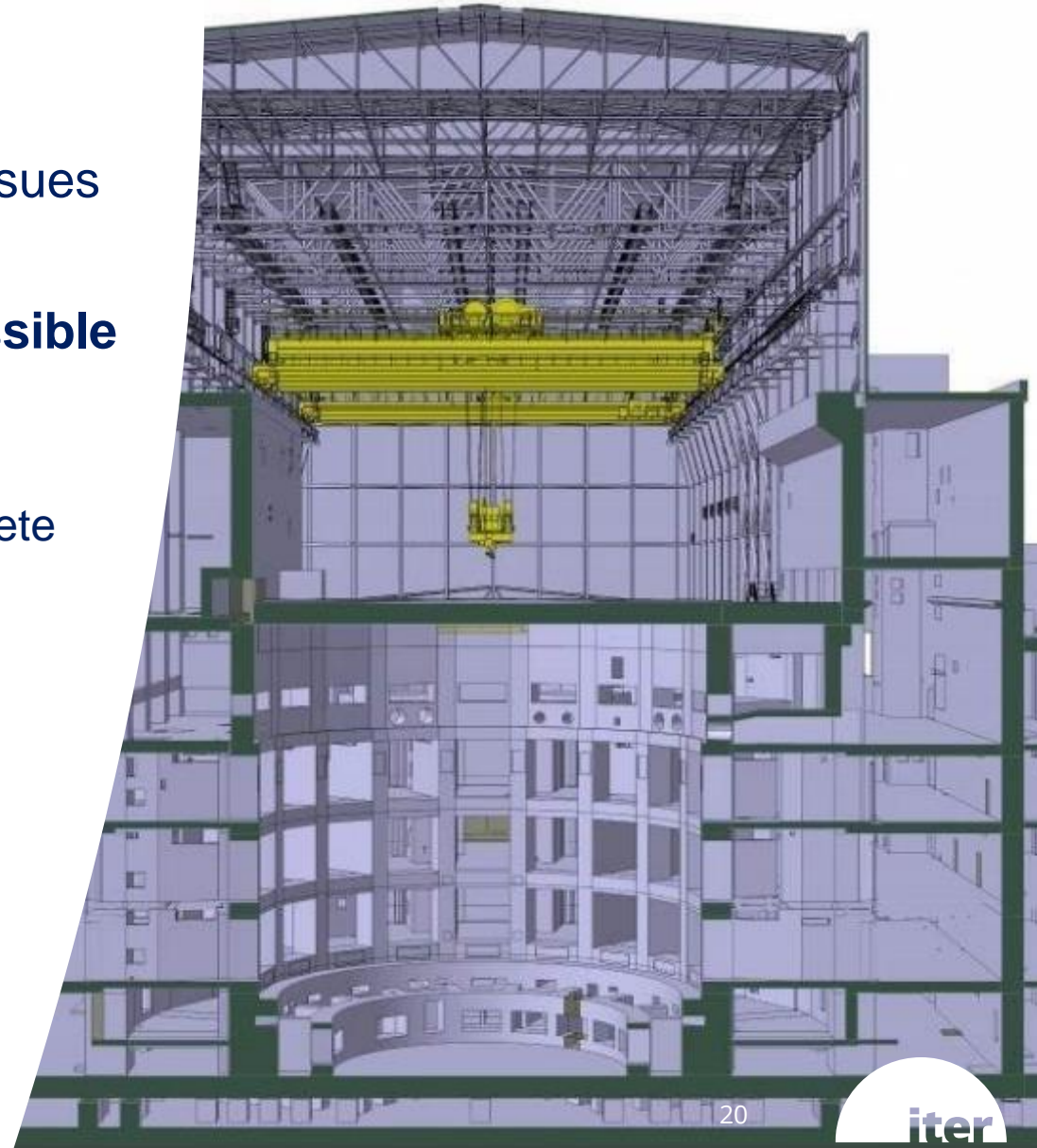
# OVERVIEW OF NEW PROJECT BASELINE PROPOSAL

WHY? Delays in deliveries (e.g. VV), issues of quality, issues with regulator, Covid impacts, unrealistic plans

GOAL: **Deliver substantive research as rapidly as possible**

## KEY CHANGES:

- More components are now available to build a more complete machine
- Start of Research Operations targeted in **2034**
  - To include 27 months of research
  - Full Magnetic Energy: delayed from 2033 to **2036**
- Start of DT Operations Phase: delayed from 2035 to **2039**



# The NEW (2024) BASELINE

👉 Designed to reach **First Plasma** – and immediately after to move to full magnetic energy to commission machine as much as possible before final FW installation

- Less risky commissioning, research, safety demonstration plan
  - Start of Research Operation (SRO) 15 MA/5.3T, to include successful demonstration of magnet reliability, control system, disruption mitigation, using H and DD plasmas
  - DT-1: DT operation focused on achievement of specific project goals ->  $Q \geq 10$ , 300-500s with limited fluence (1/100 of end-of-life)
  - DT-2: Full achievement of Project goal (safety demonstration based on DT-1)
- Stepwise licensing and safety demonstration
- TF Test facility under fabrication, a few TF coils will be tested at 4k
- Replacement of Beryllium with Tungsten for First Wall
- Increase of heating power
- VV welding re-sequenced, from triplets to 9 sectors simultaneously
- Assembly contracts reformulated, refocus on key assembly tooling

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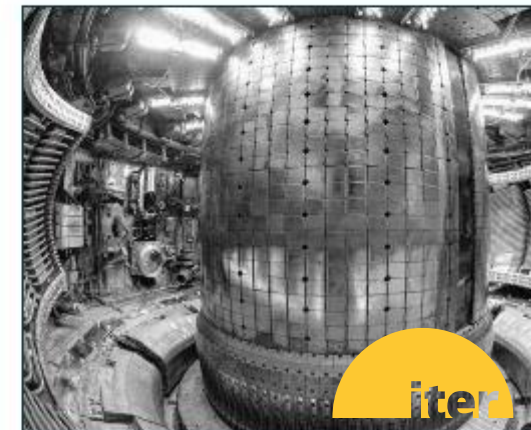
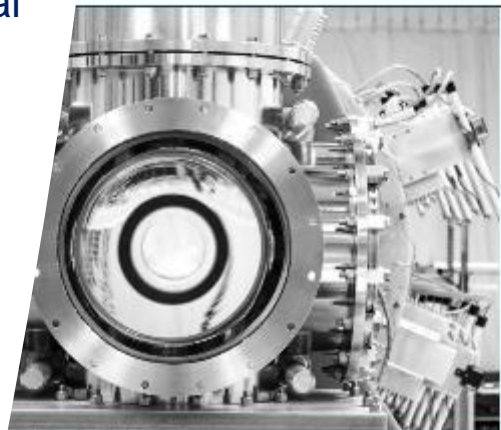
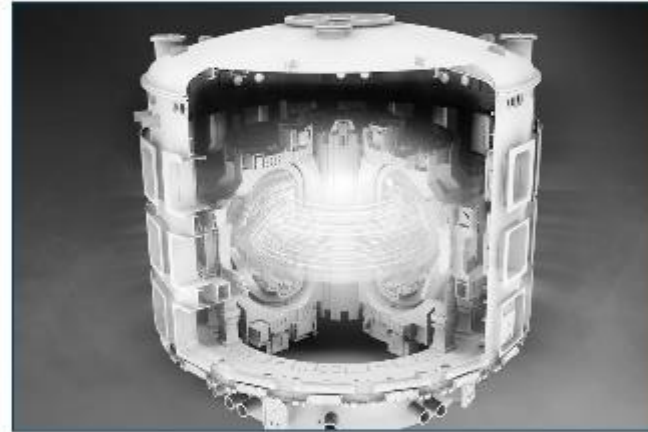
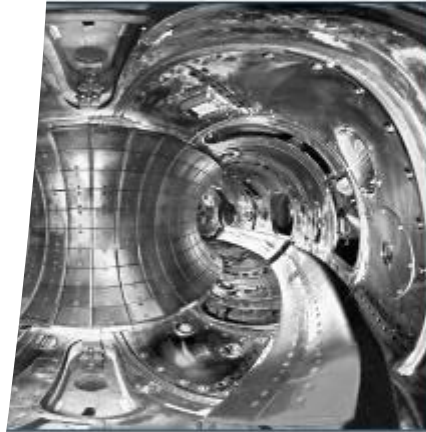
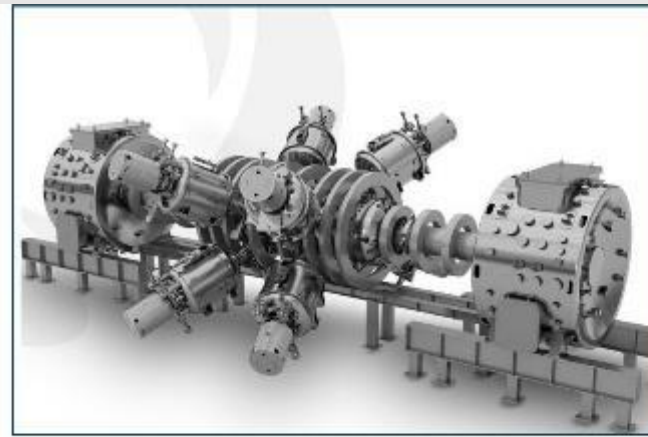
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# ENGAGEMENT WITH PRIVATE SECTOR FUSION INITIATIVES

- Requested by ITER Council, November 2023
- Initial workshop held at ITER, May 2024
  - **350** participants
  - Strong private sector endorsement
- Establishing channels for further engagement and knowledge sharing
  - ITER Design Handbook
  - Systematic approach for access to ITER documents
  - Incorporation of appropriate resource and legal constraints
  - Discussions with ITER technical experts
  - Open-sourcing of some ITER science software
  - Etc.



# READY FOR MACHINE ASSEMBLY!

The next ITER Business Forum will take place in Marseille, France, from 23 to 25 April 2025.

## ITER is moving forward!

Join the next International ITER Business Forum in Marseille from 23 to 25 April 2025!

The character of the city, its identity and its location at the heart of the Calanques are what make Marseille a unique and pleasant city to visit. Marseille is considered one of the 50 greatest places in the world (Times Magazine).



# ITER at COP28



*IAEA Director-General Rafael Mariano Grossi attends High-Level Panel discussion at COP28 on 1 Dec 2023*



For the second time on stage at a COP conference

Creation of the World Fusion Energy Group, precluding a worldwide technology transfer to industry

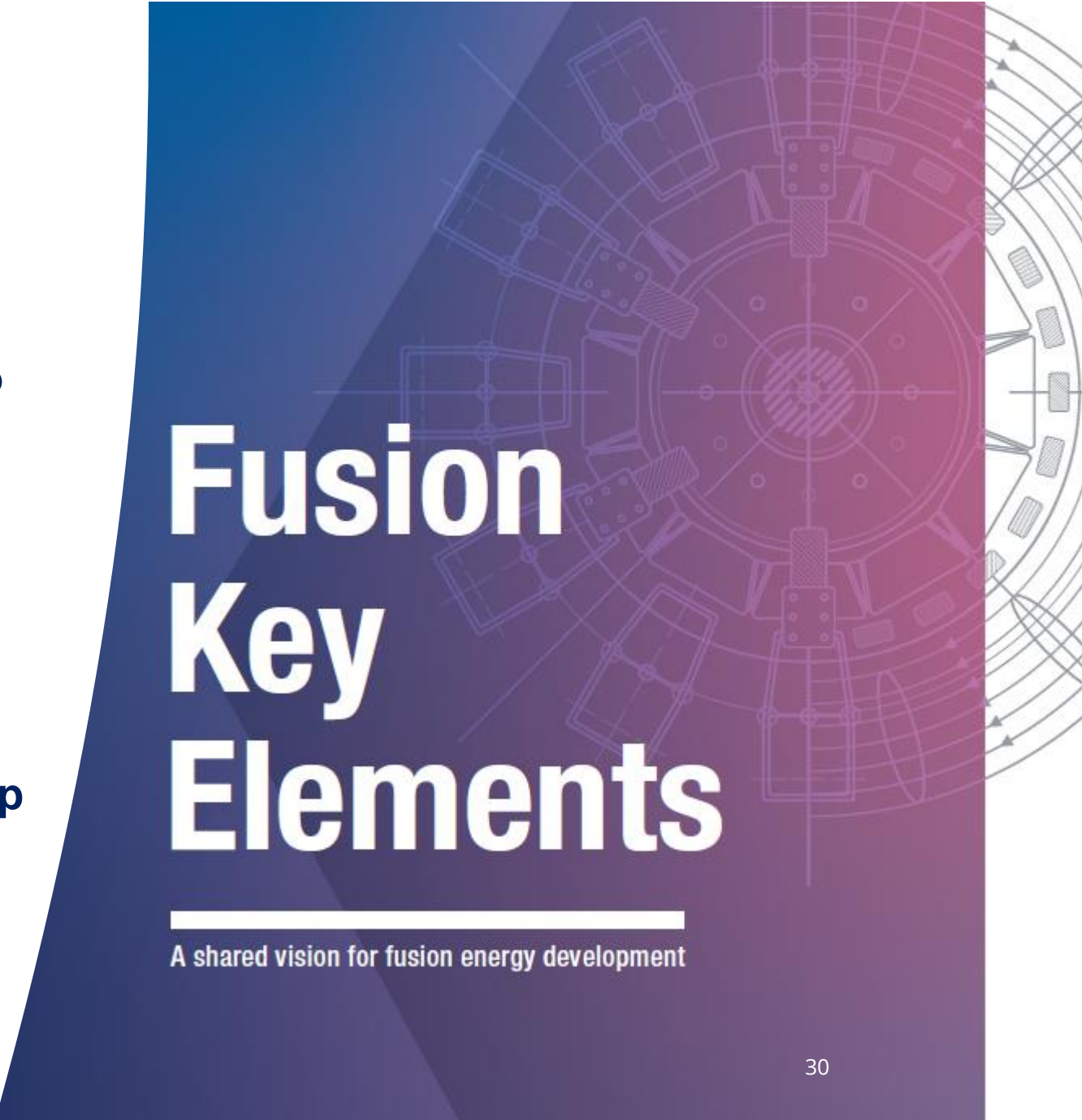
# A SHARED VISION FOR FUSION ENERGY DEVELOPMENT

The **Fusion Key Elements**, edited by the IAEA, was endorsed by the World Fusion Energy Group inaugural ministerial meeting in Rome

<https://www.iaea.org/events/ministerial-meeting-of-the-iaea-world-fusion-energy-group>



The banner features the World Fusion Energy Group logo on the left, which includes a stylized globe icon and the text 'WORLD FUSION ENERGY GROUP'. To the right of the logo is a vertical line, followed by the text 'For the Clean Energy Future'. On the far right, there are logos for the IAEA and the Italian Ministry of Foreign Affairs and International Cooperation, with the text 'Ministero degli Affari Esteri e della Cooperazione Internazionale'.



The cover features a large, stylized technical drawing of a fusion reactor in the background, overlaid with a blue-to-purple gradient. The title 'Fusion Key Elements' is written in large, bold, white sans-serif font. Below the title is a thick white horizontal line, followed by the subtitle 'A shared vision for fusion energy development' in a smaller white font. The page number '30' is located in the bottom right corner.



# IO Procurement Forecast

William De Cat, Operations Manager PRD – 8 January 2025

For the detailed descriptions, please refer to the ITER Organization's website;

<https://www.iter.org/industry/procurement/tenders/forthcoming-tenders>



# Central Integration; Safety&Quality; Communication

Program /Division	Issue Date	Solicitation Type	Title of Procurement	Cost Range
CID	Q1 2025	Call for Tender	PDM/PLM System Global Engineering Support (KJT)	C
CID	Q1 2025	Call for Tender	Supply of Microsoft Licences from a Reseller (KJT)	A
CID	Q2 2025	Call for Tender	Framework Contract for SAP Success Factor support Services (KJT)	A
CID	Q2 2025	Call for Tender	Framework Contract for SAP Application Maintenance Services (KJT)	C
SQD	Q1 2025	Open Tender	Quality control services inspectors for QMD (EBT)	B
COM	Q4 2024	Open Tender	Visit Guides (KRH)	A

**Cost Range**

- A: Item Range: 300 k - 2 MEUR
- B: Item Range: 1.5 – 5 MEUR
- C: Item Range: 4 - 12 MEUR
- D: Item Range: above 10 MEUR



# Control & Integrated Commissioning Program

Program /Division	Issue Date	Solicitation Type	Title of Procurement	Cost Range
CIC	Q4 2026	Call for Tender	Large display screen in main control room supply and installation Contract (LLU)	-
CIC	Q1 2025	Call for Tender	Supply of electricity and Balance Responsible Entity	D

# Machine Assembly Program

MAP/VPA	31/12/2024	Supply	CFT /OT	VV Stability clamp - Design + Manufacturing New tooling for handling VV	C
MAP/VPA	30/12/2024	Supply	CFT /OT	Tooling for ports installation	D
MAP/VPA	01/12/2024	Works (FIDIC)	MS +RT	Remaining TAC 2 - SMPA Sector Module in Pit Assembly	D
MAP/VPA	30/06/2025	Works	CFT: Call for Tender	Remaining TAC 2 - VVPA	D

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# Nuclear Technologies Program

Program /Division	Issue Date	Solicitation Type	Title of Procurement	Cost Range
NTP	Q1 2025	Call for Tender	Design, mock-up prototype manufacturing and testing for TBM frame and TBM refurbishment Service Contract (ERA)	B
NTP	Q1 2025	Open Tender	Final Design and Procurement of Divertor Operational Instrumentation Remote Handling Connectors Supply Contract (ERA)	A
NTP	Q2 2025	Call for Tender	ITER Hot Cell Facility (JLE)	D
NTP	Q2 2025	Call for Tender	Blanket Supply Contract (ERA)	B
NTP	Q2 2025	Call for Tender	Remote Handling in-vessel mock-ups structure detailed design, manufacturing and Installation Supply Contract (JLE)	B
NTP	Q2 2025	Call for Tender	Neutral Beam Port Liners Supply Contract (ERA)	B
NTP	Q3 2025	Call for Tender	Procurement of Ultrasonic Flow Meters (ERA)	C

## Cost Range

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# Diagnostics Program

Program /Division	Issue Date	Solicitation Type	Title of Procurement	Cost Range
DIAG	Q1 2025	Open Tender	Procurement of rails, dogleg plates, skids, pads for Port plugs (AJI)	B
DIAG	Q1 2025	Open Tender	Manufacturing of non-FP LEVI MI Cables Supply Contract (AJI)	B
DIAG	Q1 2025	Call for Tender	Development of Preliminary Design of 55.GL In-Vessel Lighting (AJI)	C
DIAG	Q1 2028	Call for Tender	Manufacturing for ex-vessel and back-end components for dust monitoring (AJI)	-
DIAG	Q4 2024	TBC	Supply of B4C (Boron Carbide) shielding blocks for IO Port (AJI)	C
DIAG	Q4 2025	Call for Tender	Analysis and Specialized Engineering for Diagnostic Port Structures, integrated Diagnostic and Distributed Diagnostic Systems reviews Framework Contract (AJI)	C
DIAG	Q4 2025	Call for Tender	Supply of Port Handling Tools Framework Contract (AJI)	B

## Cost Range

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# Plant Installation Program

Program /Division	Need Date	Contract Type	Solicitation Type	Title of Procurement	Description of Scope	Cost Range
PIP/MIP	30/08/2024	Works (FIDIC)	OT: Open Tender	STOS	New Contract	B
PIP/ASP	30/04/2026	Works (FIDIC)	CFT: Call for Tender	TSI-3 Contract	Tokamak Service Installation No. 3 Contract. Installation of: Building Services and Liquid & Gas systems (PBS 62/65) in Building 14 (FP phase scope); Electrical systems (PBS 43/62) for Tokamak Complex (FP phase scope).	D
PIP/ASP	31/12/2025	Works (FIDIC)	OT: Open Tender	Common Support Batch 4	Procurement/Installation CS	A
PIP/ASP		Works (FIDIC)	CFT: Call for Tender	TB21-TO101 Installation Works	instllation of F4E free-issued materials and equipment for Electrical Systems	B

# Tokamak Program

TKP/DRW	01/03/2025	CFT: Call for Tender	Lower penetration: In vessel Viewing Port Extension (IVVPE) (tube) Manufacturing for the ITER Vacuum Vessel	Lower penetration: In vessel Viewing Port Extension (IVVPE) Manufacturing for the ITER VV, that should include PCR 1399: -MI Cables as Heaters for IVVS PE ( 12 ) -Junction Box Procurement - In Cryostat Cabling from JB to Feedthrough ( Kapton cables ) - Heater Cubicle Integration	B
TKP/DRW	30/06/2025	Restricted Tender	VV ISI Training and labs centre	Laboratory to be installed in Corbiere	A

# Plant Systems Program

Program /Division	Need Date	Contract Type	Solicitation Type	Title of Procurement	Description of Scope	Cost Range
PSP/CWS		Supply	CFT: =Call for Tender	IBED PHTS and NBI PHTS Pressurizers	Procurement of IBED PHTS and NBI PHTS Pressurizer (26PHBD-PZ-1001 & 26PHNB-PZ-5000)	C
PSP/DMS	01/06/2025	Service / Supply	CFT: Call for Tender	DMS Manufacturing and Assembly (PHASE 2)		D

# Electrical Systems Program

ESP/ECPS	Q1-2025	Services	OT (Open Tender)	Commissioning of Switches and busbars from RFDA	Component commissioning and circuit commissioning with dummy loads for the equipment in PA4.1.P3.RF.01.	B
ESP/ECPS	Q4-2025	Services	CFT	Design, Manufacturing, Testing, Installation and Commissioning of the Stage 2 Main Coil Power Converters	The purpose of this contract is for the procurement of a Stage 2 Main Coil Power Converters (MCPC)	D
ESP/ICPS	Q4-2025	Services	CFT	Preliminary design ELM coil power supply	This tender is to procure an Edge-Localized-Mode Power Supplies (ELM-PS) system. This system consists in 27 power supplies that are required to generate currents up to 15 kA or voltages up to 300 V, in DC and/or AC (0-50 Hz)	D

**Cost Range**

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# Buildings & Site Management Program (1/2)

Program /Division	Need Date	Contract Type	Solicitation Type	Title of Procurement	Description of Scope	Cost Range
BSM_CEI	Q1-2028	Works (FIDIC)	CFT: Call for Tender	RF HEATING NEW BUILDINGS	Construction of the New RF Heating Buildings	D
BSM_CSM	2024	Works	CFT: Call for Tender	New Warehouse in CA2 (for TS11/TB22)		B
BSM/BFO	Q1-2026	Services	CFT: Call for Tender	Statutory Inspection	renewal	A
BSM_CEI	Q3-2025	Supply	OT: Open Tender	Cryostat Bellows Embedded Plates Insulation	"Phase 1 (design): Complete Design (FDR) for Insulation System and prepare MRR + System Certification Phase 2 (installation): Procure and install the thermal insulation at the interfaces between the Cryostat Bellows and the Tokamak Building A total of 54 interfaces have to be thermally insulated. Those interfaces correspond to the anchorage in the Bioshield of : <ul style="list-style-type: none"> <li>• 18 rectangular bellows linked to Port Cells at B1 (Lower level)</li> <li>• 14 rectangular bellows linked to Port Cells and 4 circular bellows linked to Neutral Beam Cell at L1 (Equatorial level)</li> <li>• 14 rectangular bellows linked to Port Cells and 4 rectangular bellows linked to Neutral Beam Cell at L2 (Upper level)</li> </ul> The installation will proceed level by level, starting at B1 and finishing at L2. The thermal insulation installation is scheduled after the installation of the cryostat Frames and Bellows."	B

## Cost Range

A: Item Range: 300 k - 2 MEUR

B: Item Range: 1.5 – 5 MEUR

C: Item Range: 4 - 12 MEUR

D: Item Range: above 10 MEUR

# Buildings & Site Management Program (2/2)

Program /DivisionBSM	Need Date	Contract Type	Solicitation Type	Title of Procurement	Description of Scope	Cost Range
BSM_CEI	31-Mar-26	Services	CFT: Call for Tender	Renewal of Engineering support and oversight of construction and testing activities for buildings civil works and services	Engineering support and oversight of construction and testing activities for buildings civil works and services	C
BSM_CEI	Q3 2025	Works (FIDIC)	CFT: Call for Tender	Preparatory Works for the New RF Heating Buildings for the New RF Heating Buildings	Preparatory Works for the New RF Heating Buildings for the New RF Heating Buildings (foundation, network rerouting)	B
BSM_CSM	30-Jun-25	Services	OT: Open Tender	Scaffolding inspection	renewal of existing contract FMW	A
BSM_CSM	07-Sep-25	Services	CFT: Call for Tender	Lifting equipment new contract	Lifting equipment rental new contract for 2026-2029	C
BSM/BFO	01-Jun-25	Services	OT: Open Tender	Bus services	renewal of Buse service Contract	A
BSM/BFO	30 – Jun - 25	Works (FIDIC)	OT: Open Tender	ESP building	design and built contract to install a new workshop of approximately 2,000m2 on the IO platform. This building shall be delivered fully equipped ready for use with HVAC system, electrical system and all the usual equipment for such building.	B

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# Heating & Current Drive Program

Program /Division	Need Date	Contract Type	Solicitation Type	Title of Procurement	Description of Scope	Cost Range
HCD/NB	Q2 2025	Supply	CFT; Call for Tender	Metallic seals for Neutral Beam	This contract covers the procurement of metallic seals for NBI vessels and HNB Front end components (FECs). Those for the vessels are large shaped metallic seals and those for FECs are circular seals. This type of seals is required to accommodate high levels of requirements for ITER leak tightness and confinement of Neutral Beam Injectors.	B
HCD/NB	Q2 2025	Supply	CFT; Call for Tender	VVPSS Box for HNB	Electronic motors and inverters for SMF Compatibility test	B
HCD/ICNS	Q2 2025	Supply	Open Tender	Final design of Arc Detection (feedthroughs & voltage probes & cavity probes)	The scope is the design, manufacturing, testing and series production of the in-vessel probes and feedthroughs components of the Ion Cyclotron Heating and Current Drive system (IC H&CD, PBS-51)	A
HCD/ICNS	Q2 2025	Supply	Open Tender	PBS 51 - Bioshield Design & procurement	Design of the Port cell Bioshield plug, (permanent and non permanent part). Manufacturing of the Bio shield elements and delivery to ITER site	A
HCD/ICNS	Q2 2025	Supply	Open Tender	HVPS for Antenna & Antenna prototype test	procurement of 480V/12kV/20A HVPS for powering the second amplification stage of the RF source to be used for the Antenna SAT and Prototype FDR test	A
HCD/ICNS	Q3 2025	Supply	Open Tender	Faraday screen prototype manufacturing & series production	manufacturing design of the ICH Faraday screen, followed by prototype manufacturing and high flux testing,	A



Thank You

# Updated ITER Research Plan (proposal to ITER Council)

Now		~18 months	~27 months (start autumn 2034)		~10 months
Engineering fabrication of system	Pre-SRO assembly	Integrated Commissioning I	Start of Research Operation (SRO)	Post SRO Assembly	Integrated Commissioning II

- Install:
- Actively cooled W divertor
  - Blanket shield blocks
  - Inertial W First Wall panels
  - 40 MW ECH
  - 10 MW ICH

- Commission PCS and Protection Systems to reduce risks in DT-1
- **Hydrogen L-mode to 15 MA/5.3T**
- **Demonstrate H-mode DD plasmas**
- First assessment of boronization, fuel retention/recovery, ICWC

- Final, actively cooled W First Wall
- NBI: 33 MW
- ECH: 40 → 60-67 MW
- ICH: 10 → 20 MW
- Final diagnostics set

**DT-2,  $\sim 3 \times 10^{27}$  neutrons**

FPO-y	FPO-(...)	FPO-x
DT (Q=10), high duty $\geq 500$ s Q $\geq 5, 1000, 3000$ s		

**DT-1 ~ 10 years,  $\sim 3 \times 10^{25}$  neutrons**

FPO-5	FPO-4	FPO-3	FPO-2	FPO-1
D, DT (Q=10) $\geq 500$ s High duty, 250 MW, $\geq 300$ s	D, DT (Q=10) 500 MW, $\geq 300$ s	D, DT (Q=10) 500 MW, $\sim 50$ s	D, DT, 100 MW, $\sim 50$ s	H, H+T, D

**Q = 10 burn extension**

(start autumn 2039)