IBF/25
INTERNATIONAL
ITER BUSINESS FORUM

TOKAMAK Program: status, lessons learned and future business opportunities

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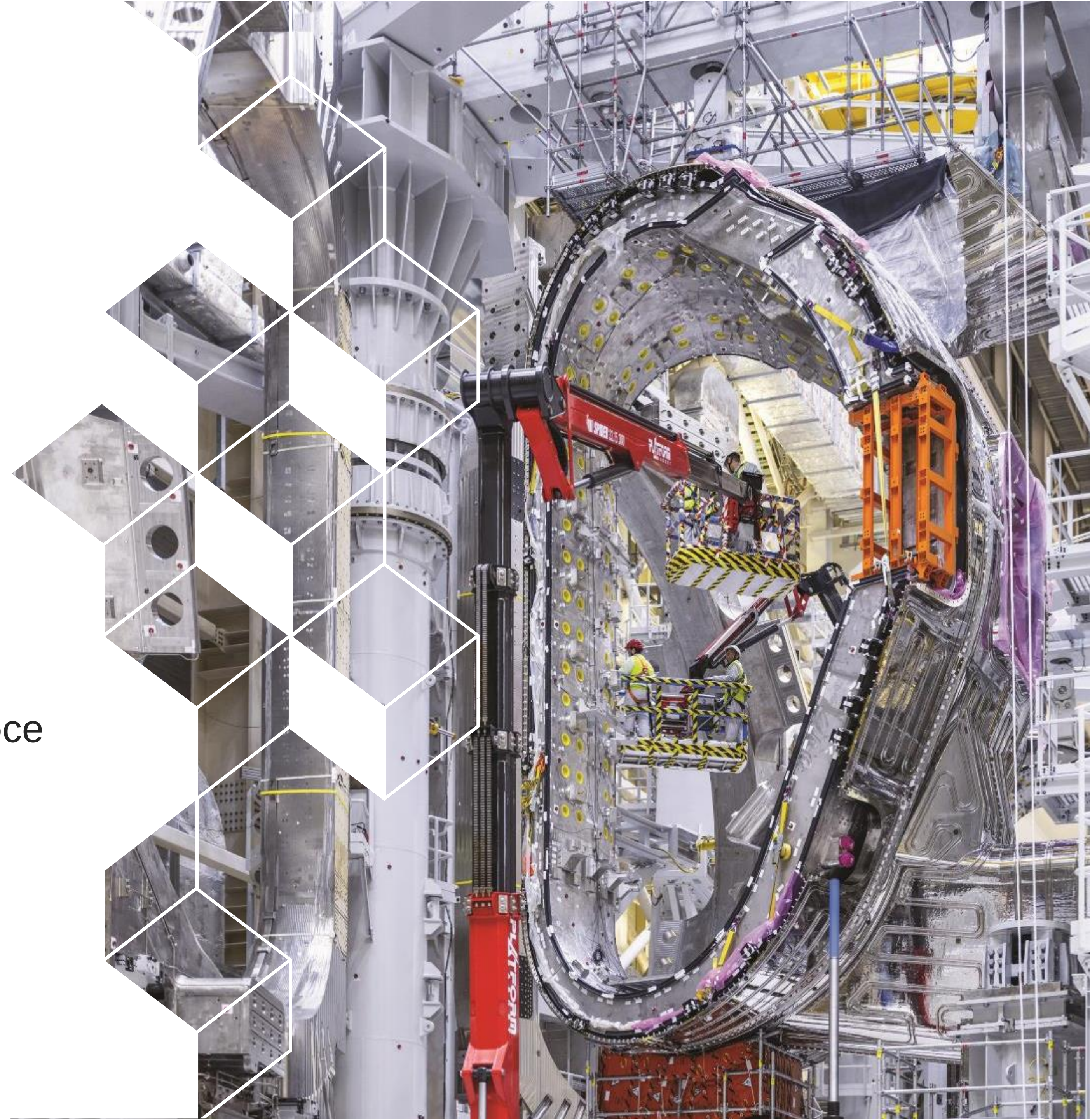


FRIDAY APRIL 25th

Content

1. **ITER Tokamak Program scope and status**

2. **Lessons Learned**

3. **Focus on in-vessel components for future business opportunities**

ITER TOKAMAK PROGRAM SCOPE AND STATUS

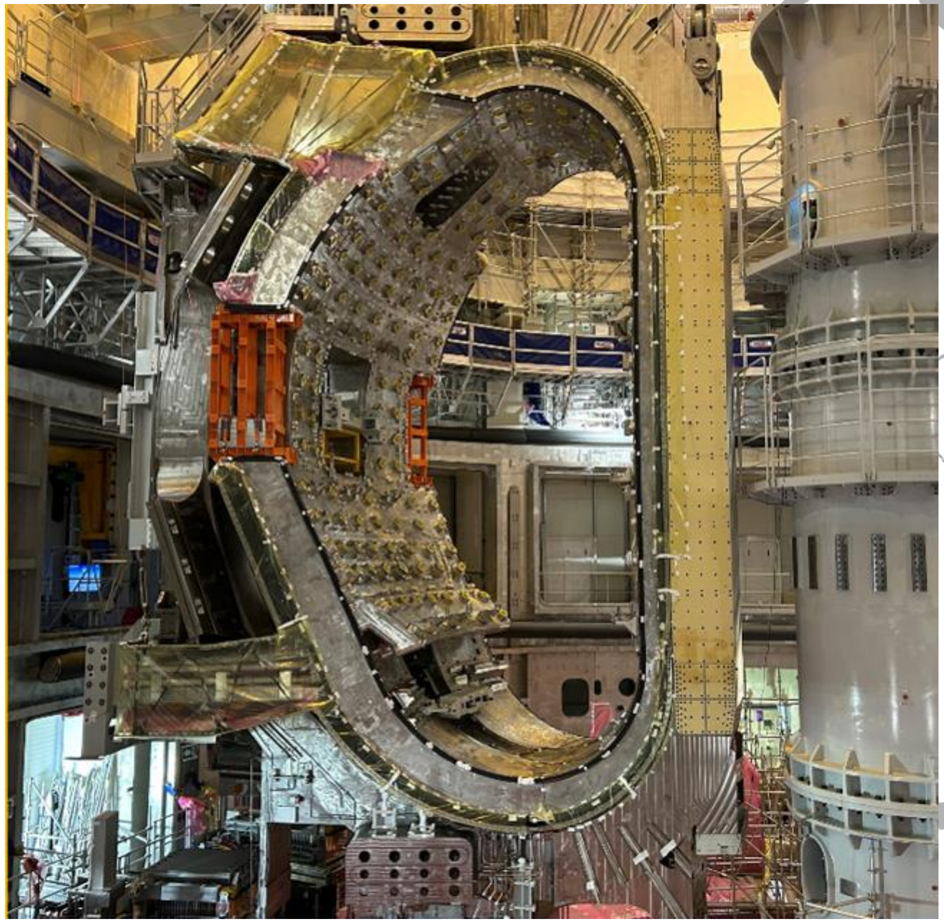
1. **Superconducting Magnets**: 19 TF coils (10EU+9JA) and 6 PF (5EU+1RF) coils completed. CS coil (US) in progress

2. **Vacuum vessel**: 6 sectors delivered (4KO+2EU), 3 (EU) in progress to be delivered. Sectors to be welded in-pit.

3. **Cryostat (IN)&thermal shields (KO,IN)**: delivered

4. **In-vessel coils and feeders (EU.CN,KO)**: production ongoing

5. **Divertor and blanket (EU,CN,JA,RF)**: series production ongoing by DAs. Temporary 1st wall to be procured



Huge experience accumulated over 18 years in development / production of complex/large components in the different DAs and in IO

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Lessons learned

Main aspects of an ITER procurement/contract

Procurement/production strategies

- *Technical and contractual risks*
  - How to minimize level of technical and financial risks for the project and for the supplier
- *Interfaces among suppliers*
  - With productions involving multiple suppliers, how to select the best sharing strategy

Technical specifications and requirements

- *Technical specification is THE tender/contract*
  - Clarity and completeness of the documentation
- *Technical and contractual requirements*
  - Clarity and feasibility of the requirements

Relationship customer/suppliers

- *Relationship customer (IO)/supplier*
  - Reciprocal trust, collaborative vs confrontational

Lessons learned

Technical and contractual risks

- Level of technical and financial risks for the supplier
- Often ITER contracts relate to “first-of-a-kind” components with high level of technical uncertainty and large financial value …

- Impossible for the supplier to quantify & cope with level of technical/financial risks in the contract
- For EU & JA TF coils with VERY HIGH risks, we have:
  - Before production used R&D & Prototype contracts to reduce/minimize technical uncertainty
  - Split full TF coil production in smaller contract with lower financial value

Tender for production with already proven technologies & smaller contracts value

lower risks ↔ more competition ↔ lower price

Successfully completed all 19TF coils

(within budget for the 10 EU TF coils)

Lessons learned

Interfaces among suppliers

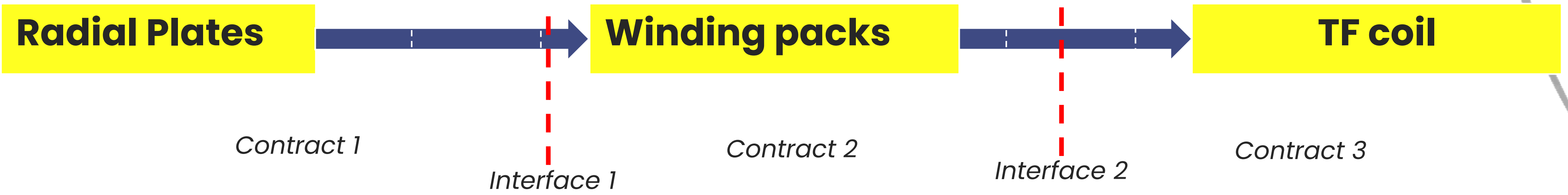
- Splitting the procurements in smaller packages helps in reducing risks BUT

- Productions involving multiple suppliers can be source of complexity…
- We have used so far two alternative models :
  - Vertical sharing of the production activities
  - Horizontal sharing of the production activities

- For the EU TF coils we have used the vertical model
- For the EU PF (production in Cadarache, we have used the horizontal model

Vertical vs **horizontal splitting of procurement**

For TF coils vertical splitting: each contract covers a different production phase



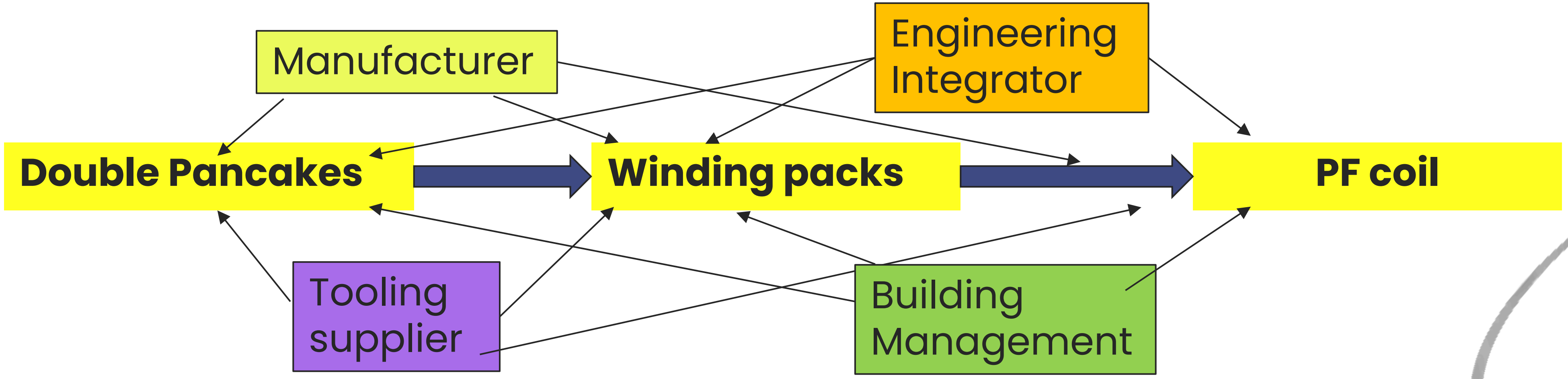
- Each supplier solely responsible for scope of its own contract
- 2 clear interfaces, no co-activity
- Each interface involving only 2 suppliers

  To avoid gaps of responsibilities, acceptance by F4E of a component only after acceptance by the receiving supplier

This scheme has been quite effective over the years !

Vertical vs **horizontal splitting of procurement**

For PF coils horizontal splitting: all contracts cover each production phase



- On each task involved at least 4 suppliers.: co-activity
- Multiple and complex interfaces for F4E to manage

This scheme has been very complex and difficult to manage

Lessons learned

Technical specification is THE key document

- ‘Too generic’ / ‘subject to interpretation’ technical specs can result in time consuming discussions/schedule/cost impact/deterioration of the relationship with the supplier

- Technical specification must be as detailed as possible, specifying as clearly as possible the scope of work to be performed

Technical and contractual requirements

- Clarity and feasibility of the requirements
  - Technical alignment prior to contract signature
  - Investigate relaxation when requirements are not attainable

- Requirements can go beyond those of fission nuclear power plants

- Focus of the IO is on the management of the interfaces, still keeping its role of surveillance as nuclear operator

Lessons learned

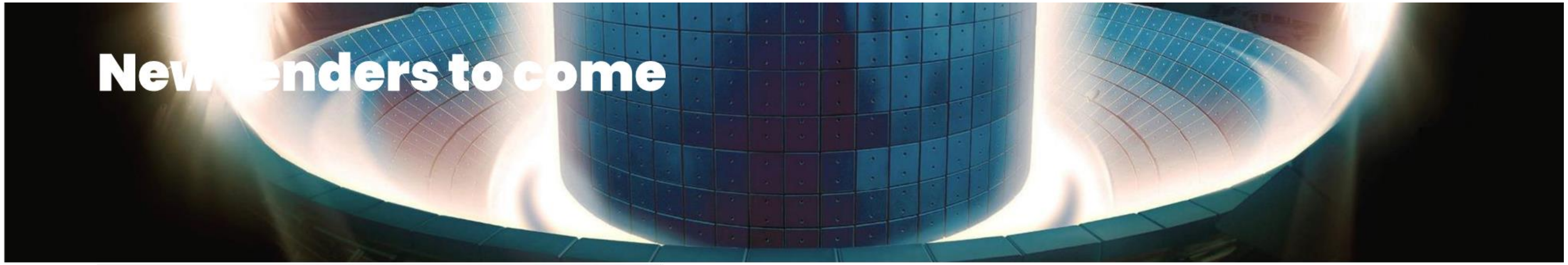
ESPN impact

- French Nuclear Pressure Equipment Directive (ESPN) provides additional difficulties
  - Directive (law) applicable only in France
  - Can impact cost and schedule if not properly managed and planned
  - Planning / Transparency with the Agreed Notified Body is key: ANB must know the engineering and manufacturing schedule in detail to plan resources in advance and not to become the bottle neck
  - Support from the IO to manage the ANB has proven of a great help
    - IO can act as 'manufacturer' of the nuclear pressure equipment, having in its responsibility the management of the ANB

Relation client/supplier

- IO+supplier is a partnership, as the objective is the same
- Full transparency is a must, on both sides
- A healthy contractual relation is firstly based on mutual trust
- Together we work better

FUTURE BUSINESS OPPORUNITIES

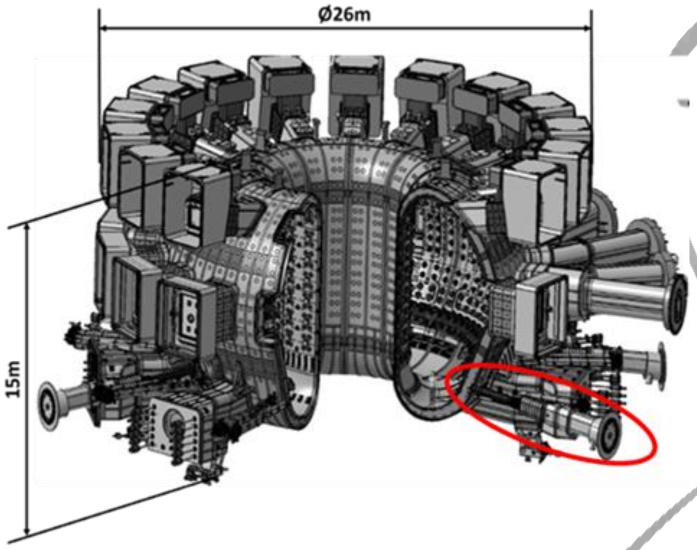


- A — Item Range: 300 000 - 2 000 000 EUR
- B — Item Range: 1 500 000 - 5 000 000 EUR
- C — Item Range: 4 000 000 - 12 000 000 EUR
- D — Item Range: above 10 000 000 EUR

Tender Process	Cost Range	2025	2026		2027		2028	
		S2	S1	S2	S3	S4	S5	S6
Lower penetration: In vessel Viewing Port Extension (IVVPE) Manufacturing	C							
Temporary First Wall manufacturing	D							
Temporary First Wall raw materials	C							
Qualification of the Low Friction Coating (LFC) Suppliers	B							
Procurement of Ultrasonic Flow Meters	C							
Procurement of the Remote Handling Connectors (RHC) for Divertor Operational Instrumentation	B							

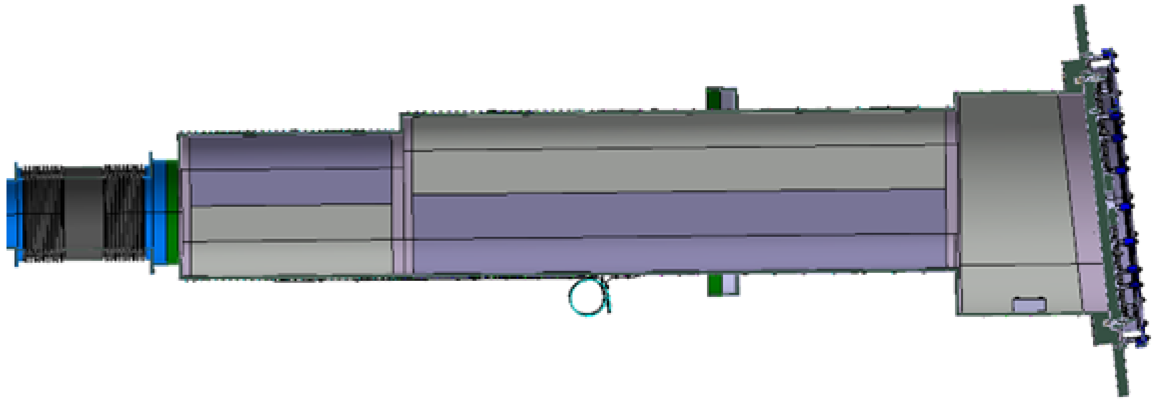
VV Lower Penetration: In-Vessel Viewing port Extension

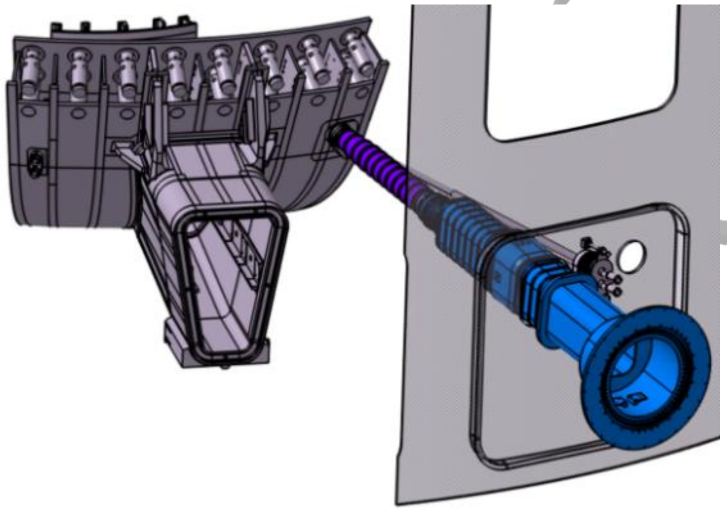
The Lower Penetrations (LP) are Vacuum Vessel (VV) sub-components connecting the VV to the Cryostat (CR) and propagate the primary vacuum from the VV to the outside of the CR into the Port Cells (PC).



The IVV Port is divided in two main parts IVV Port Stub Extension (IVV PSE), connected with the VV stub, and IVV Port Extension (IVV PE) connected with the CR wall.

These two structures are connected by a metallic bellow (not in the scope of this supply) able to absorb relative motions between both structures.

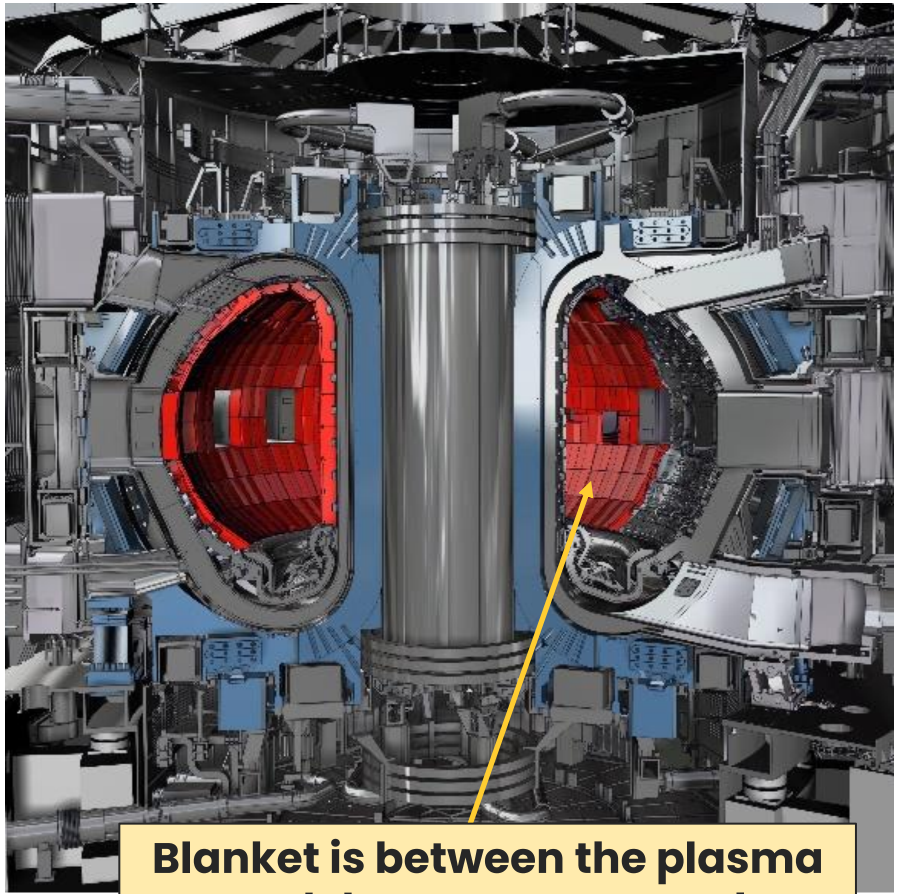




The Blanket System

Main Functions of the ITER Blanket

1. Provide shielding to reduce heat & neutron loads in the VV & ex-vessel components.
2. Absorb a portion of radiative and particle heat fluxes from the plasma.
3. Provide a plasma-facing surface that produces a low influx of plasma impurities.
4. Provide limiting surfaces that define the plasma boundary during startup & shutdown.
5. Provide passage accommodations for interfaces of the plasma diagnostics.

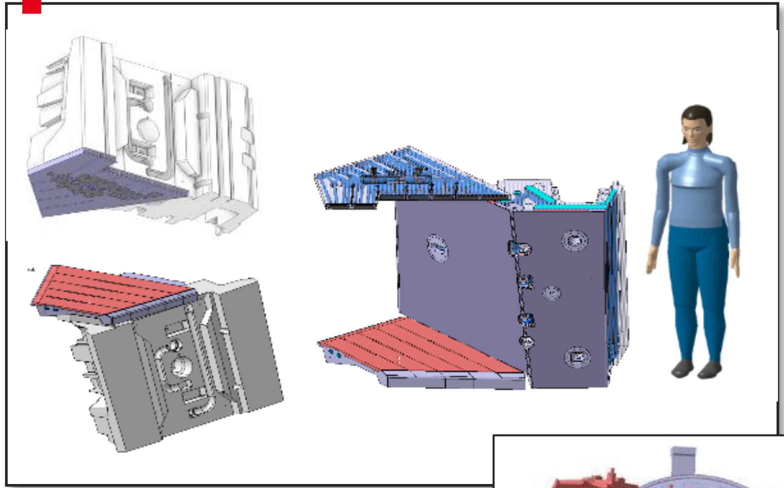


Blanket is between the plasma and the Vacuum Vessel

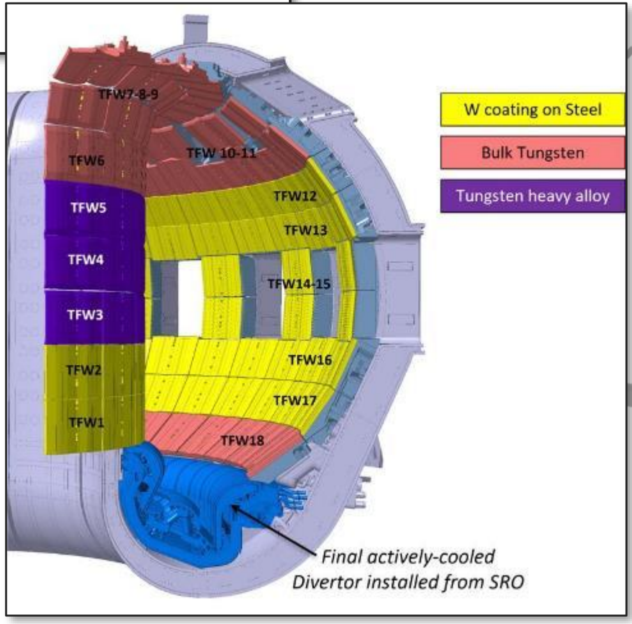
Some numbers:

• Number of Blanket Modules:	440
• Max allowable mass per module:	4.5 tons
• First Wall Coverage:	~610 m^2
• Steel / heat sink / armor materials:	316L(N)-IG / CuCrZr / W
• Heat flux on FW Panels:	up to 4.7 MW/m^2
• Cooling water conditions:	4 MPa and 70°C

BLK future business opportunities

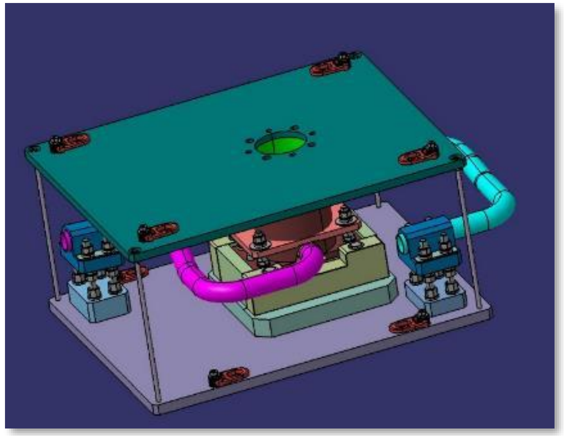


1. **Neutral Beam Port Liners**
   Tendering in 2025



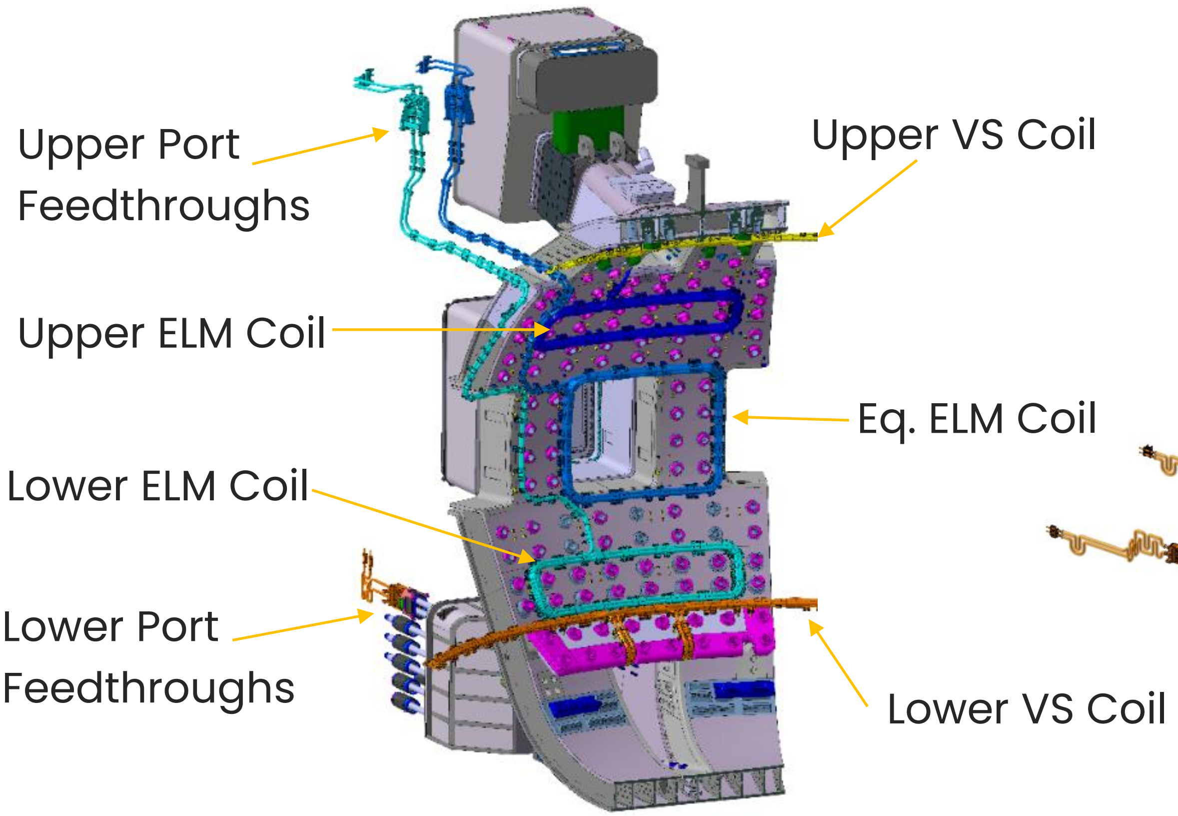
2. **Temporary First Wall**
   Tendering in 2026

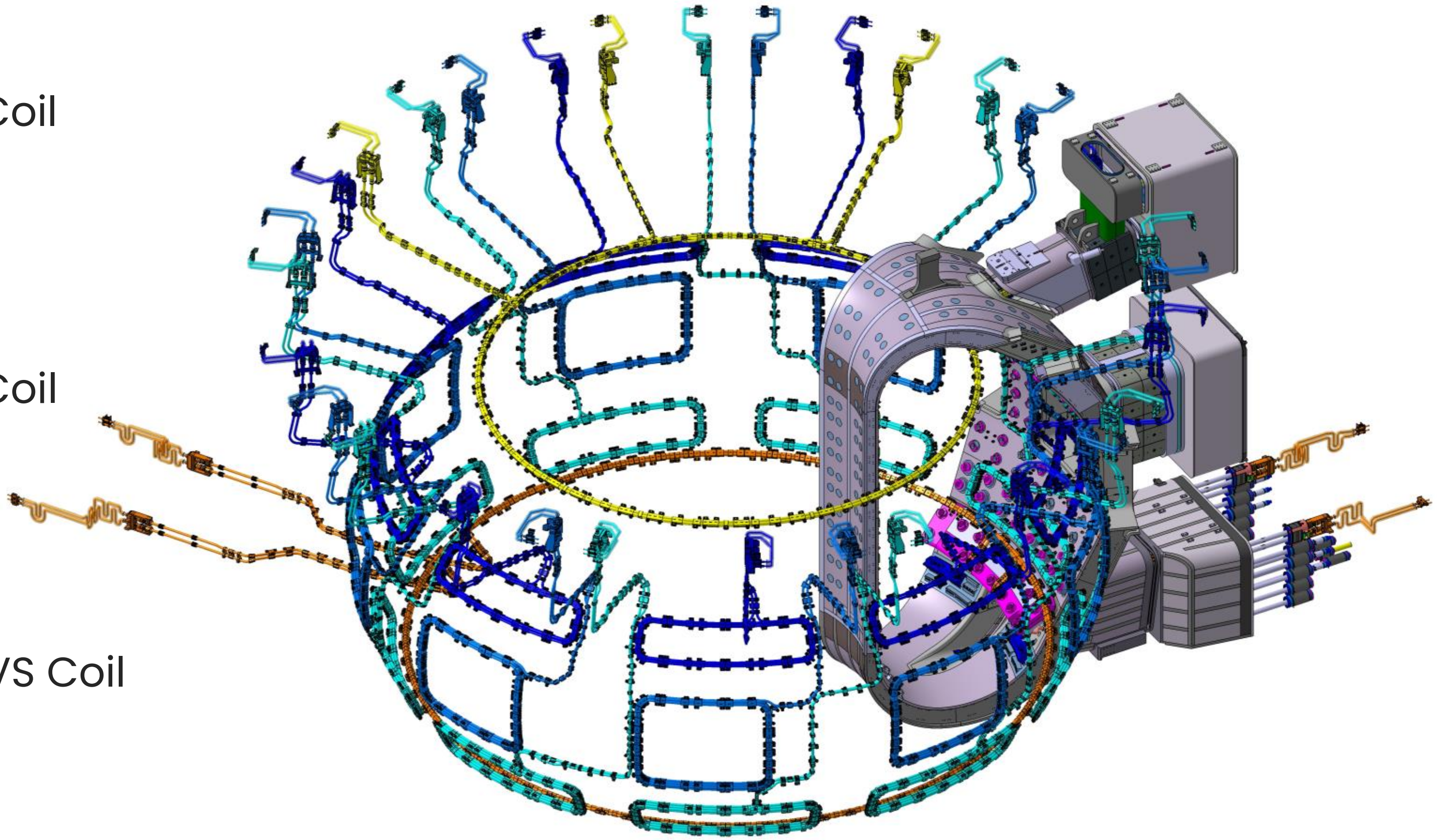
3. **Assembly Validation and Trials**
   Various small scope tendering 2025-2030



The IVC System

- Conventional water cooled coils attached to the inner wall of the vacuum vessel



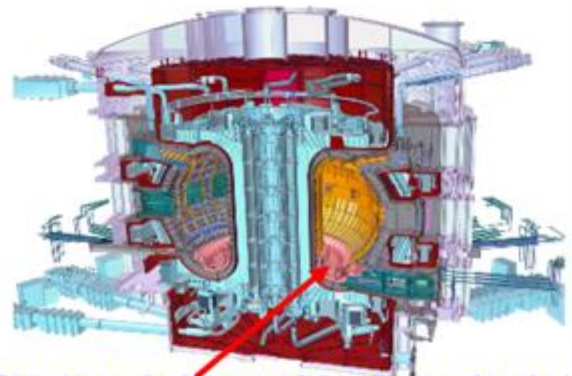


- **2 coil systems**
  - ELM coils: 3 x 9 picture framed coils (for controlling Edge Localized Modes)
  - VS coils: 2 rings (controlling Vertical Stability)

IVCs procurement status

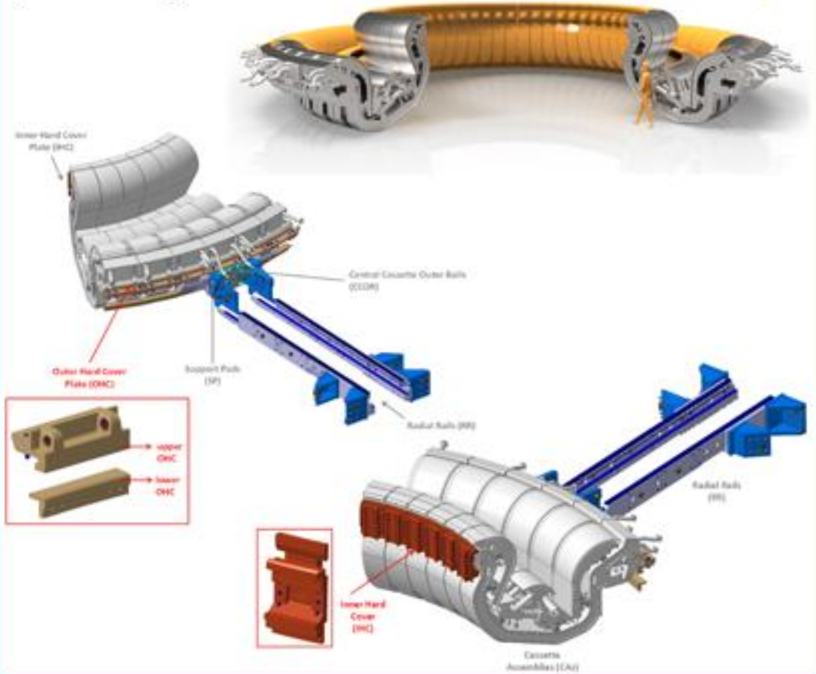
- Procurements are divided into IVC System key components/expertise (all in-cash):
  - Conductors (ICAS, EU) – 70 % delivered (completion in 2026)
  - VS coil tooling and winding (Vitzrotech/Yujin, KO) – Phase 2 (prototying) ongoing
  - ELM coils and feeders (ASIPP, CN and ASG, EU) – Phase 2 (coil prototyping) ongoing
  - Feedthroughs (ASIPP, CN) – Phase 2 (prototyping) ongoing, start of series production in 2025
  - Electrical Insulating breaks (Tecnalia, EU) – Series production started in March 2025
- Pending procurements:
  - ELM coils and feeders series production: tendering among suppliers having successfully completed qualification (i.e. Phase 2). Signature in 2026
  - IVC instrumentation: mass flow sensors (non-invasive)
    Common procurement with other ITER systems. Tendering in 2026

Divertor technical overview

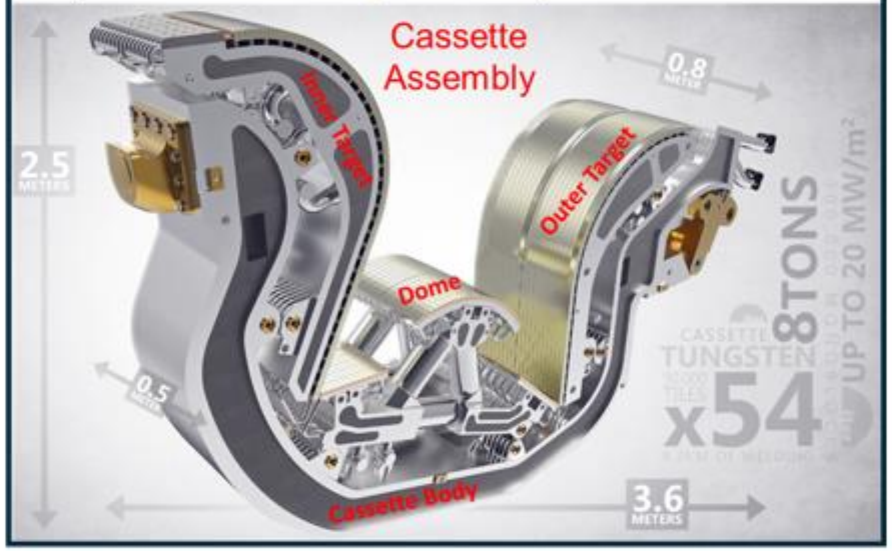


Divertor at the bottom of the plasma chamber

54 Cassettes Assemblies in the bottom part of the Vacuum Vessel, forming in a circular array held in position by two concentric toroidal rails *(F4E BtP)*



Cassette Assembly *(IO "DCAI" contract)*: a cassette body *(F4E BtP)* of cooled steel structure with 3 components mounted on top, covered by TUNGSTEN the Inner *(F4E BtP)* and Outer *(JADA BtP)* Vertical targets and the Dome *(RFDA BtP)*



Main Functions of the ITER Divertor

- Minimize the helium and impurities content in the plasma
- Contributor to providing shielding to reduce heat and neutron loads in the VV and ex-vessel components.
- Contributor to absorbing radiative and particle heat fluxes from the plasma.
- Exhaust part of the plasma thermal power

Some numbers:

- Number of Cassette Assemblies: 54
- Mass per Cassette Assembly: 8 tons
- Coverage: ~140 m^2
- Steel / heat sink / armor materials: 316L(N)-IG / CuCrZr / W
- Heat flux: up to 20 MW/m^2
- Cooling water conditions: 4 MPa and 70° C

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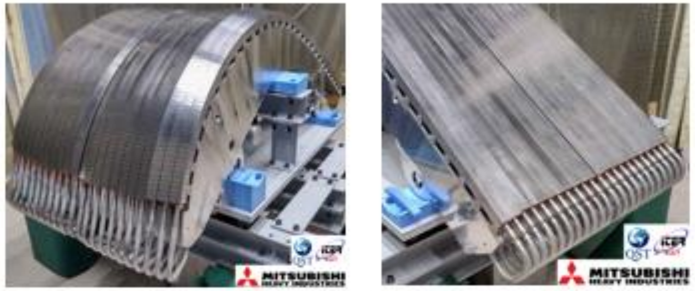
Divertor manufacturing

- DAs In-kind contribution:
  - Cassette Body - EUDA
  - Inner Vertical Target - EUDA
  - Outer Vertical Target - JADA
  - DOME – RFDA
  - High Heat Flux Test – RFDA
  - Rails – EUDA (to be transferred to IO)
- IO responsibility
  - Divertor Cassette Assembly Integration (DCAI)– in-cash
  - Blanket and Divertor Operational instrumentation

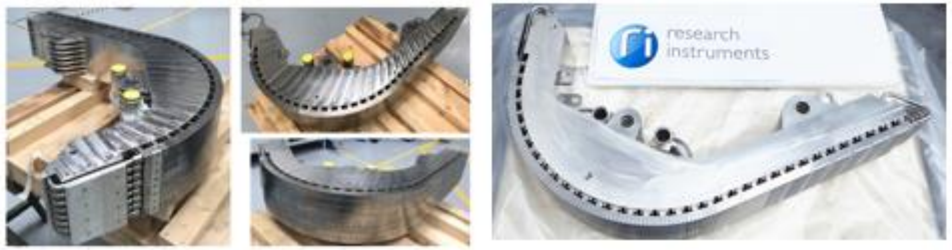
- Qualification phase for all components completed, the prototypes are in IO
- Serial production by DAs is ongoing
- DCAI: the contract was awarded (end 2024) to a Consortium lead by SWIP with CNI23 and CNPE (China National Nuclear Corporation)
- Delivery of the Integrated Cassette Assemblies to IO – end 2032

Cassette body prototypes



Outer target prototypes

DOME prototype



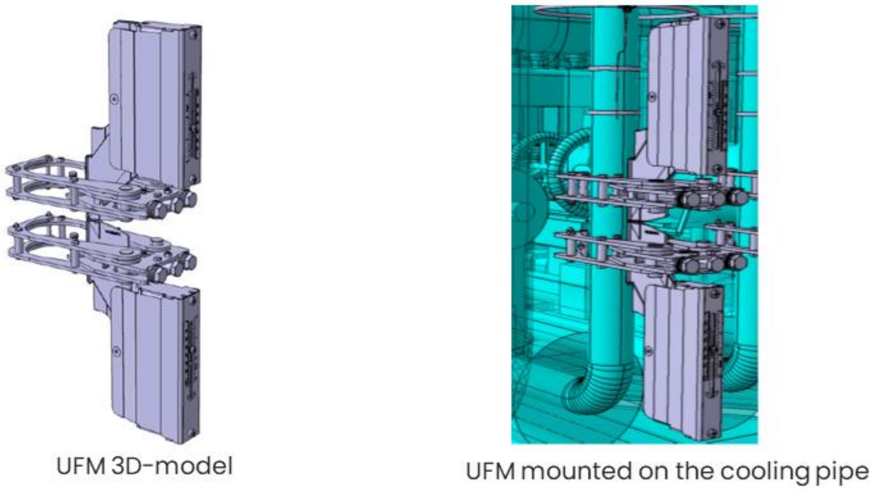
Inner target prototypes

Divertor instrumentation

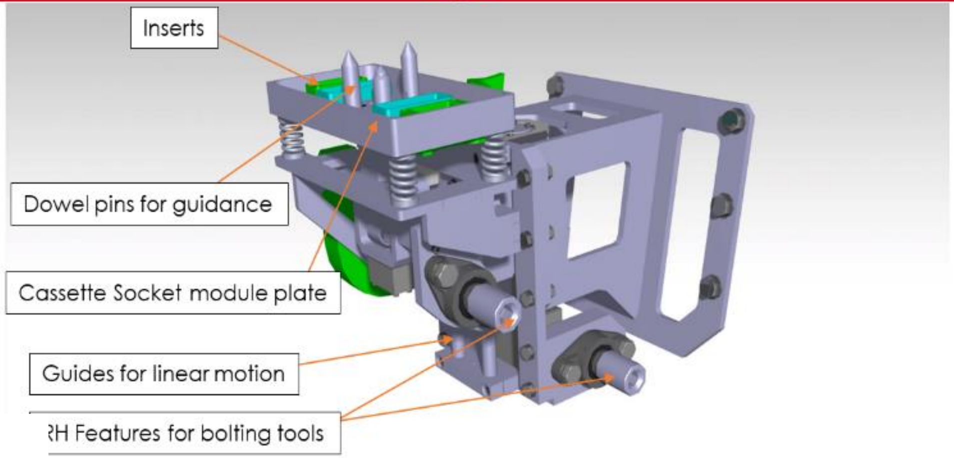
For Divertor instrumentation In 2026-2027 to be planned to procure:

- **Ultrasonic Flow Meters (UFM) for monitoring divertor and blanket coolant flow rate**

- **Remote Handling Connector (RHC) with optical and electrical sockets**



About **800 UFM** to be procured



Three divertor RHC to be procured

THANKS

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iter

VV Sector Welding

Westinghouse

Cédric MORGANO – Project Manager

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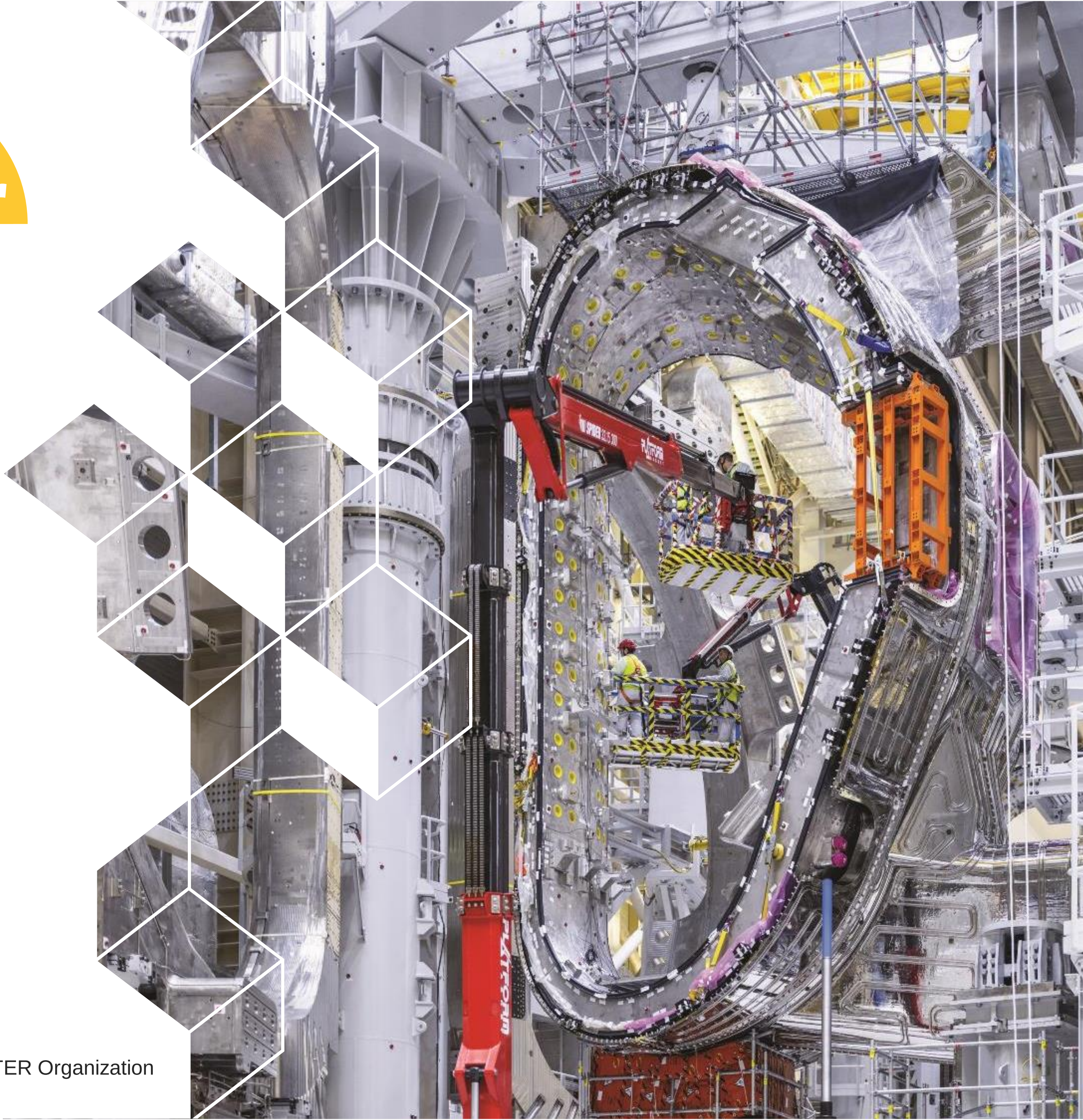
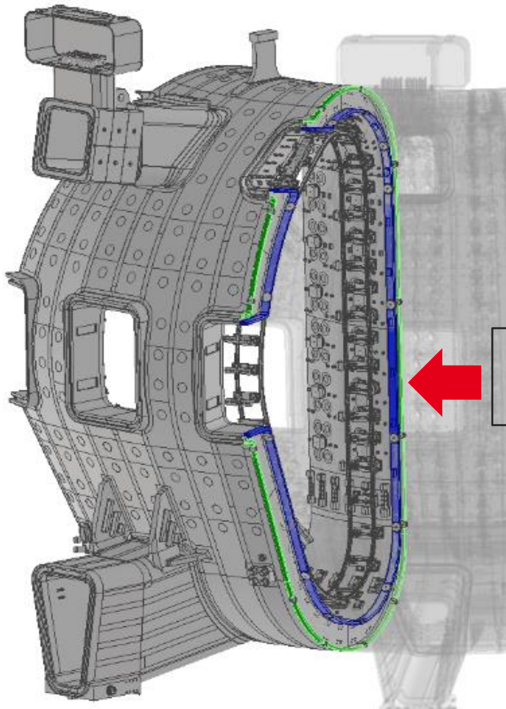


SW – Sectors Welding
Phases 1-2-3 Feasibility study
Phase 4 Pre-Qualification

Introduction of a new industrial scheme: technical validation, planning, technical concept, tooling,



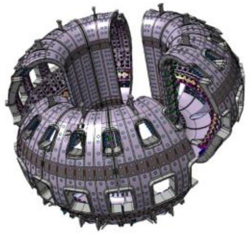
- Inner shell (blue)
- Outer shell (green)

10/2023 2024 3/2024 7/2024 10/2024 2025

Phase 1-2-3

Phase 4

October 2023
Phase 1 – UNDERSTANDING
ITER = feasibility study for the welding of the 9 VVS in parallel



March 2024
Phase 2 – ALTERNATIVE
for optimized schedule

July 2024
Phase 3 – TESTS PROGRAM
Pre-qualification program definition

September 2024
Phase 4 VVPQ – TRIALS
Mechanical, machining, reverse engineering, welding, NDT, RT-LINAC, logistic

SW – Sectors Welding
Phases 5 – Vaccuum Vessel Sectors Welding VVSW

2025 2026 2027 2028 2029 2030

Phase 4

Assembly VV Sectors Welding (x9)

Phase 5

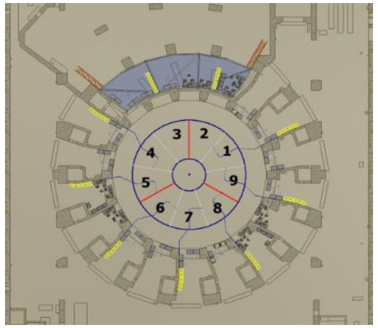
Preparation | **Welding phase**

Preparation
Qualification process
Resources training
Tooling procurement
Anticipated operations

Welding trials

Assembly VVSW scopes
Welding/machining operations
Non–Destructive examination

Final position of the 9 SM before welding operations



SW-Sector welding in some numbers

9 sectors welded «simultaneously» (9x450t)

Access only from the inside of the torus

45 robots installed (5 x 9FJ)

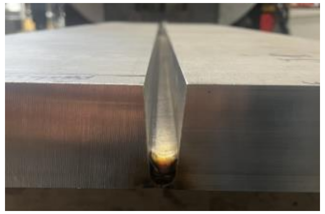
12 to 18 welding system used in parallel

290 splice plates and **247 biscuits**

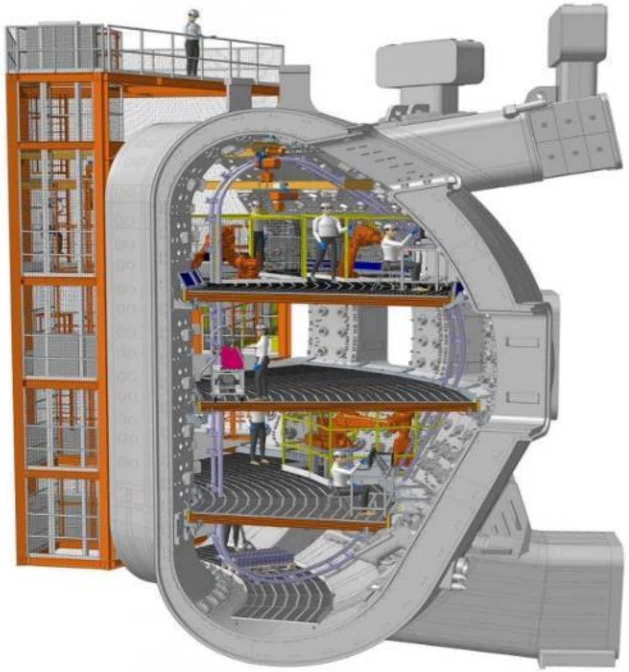
1 km of welding

10 tons of weld deposit on 60mm thickness

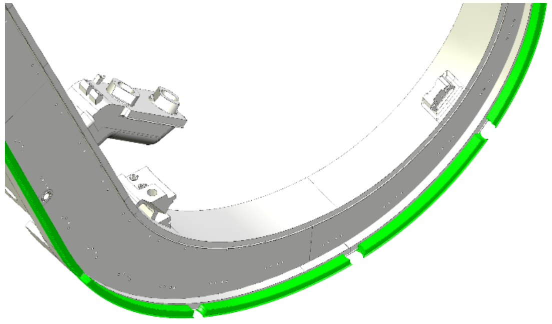
Weld in progress



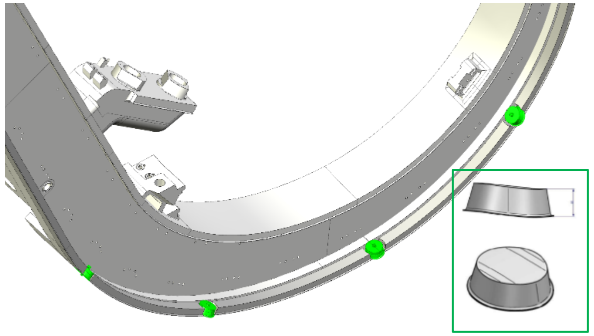
Welding robot



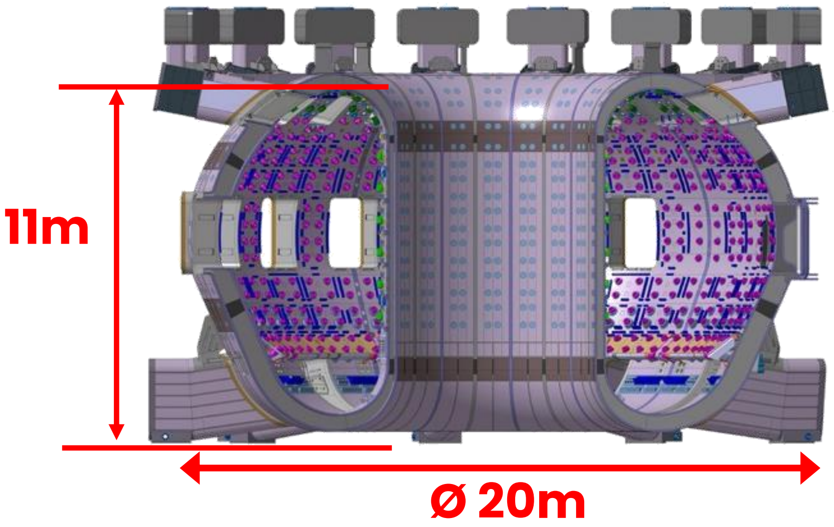
Plateforms



Splice plates



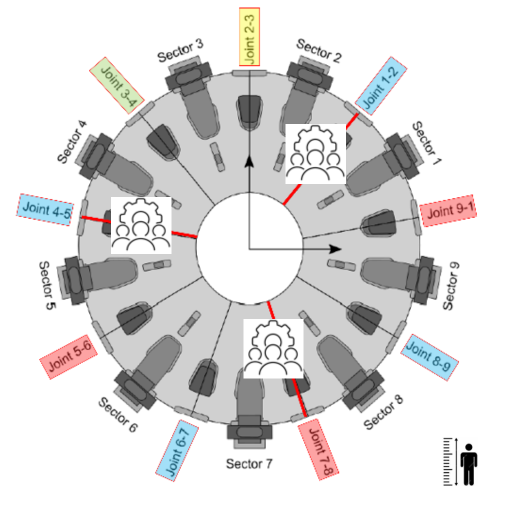
Biscuits



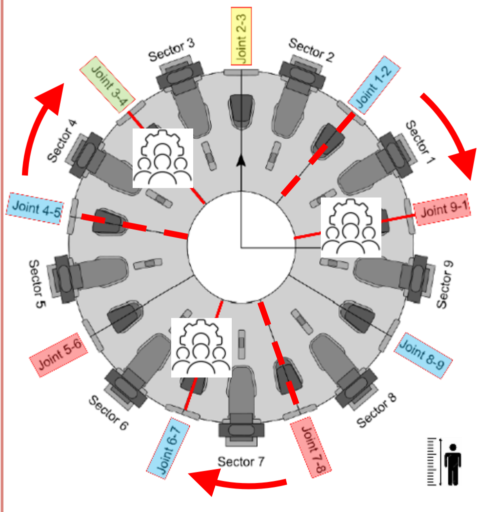
SW – ASSEMBLY SEQUENCE 3 by 3

Welding operation in 3 FJ simultaneously distributed every 120° and performed in 3 steps

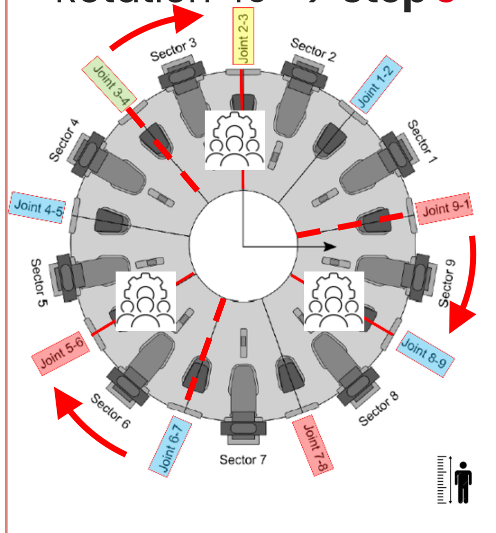
Step 1



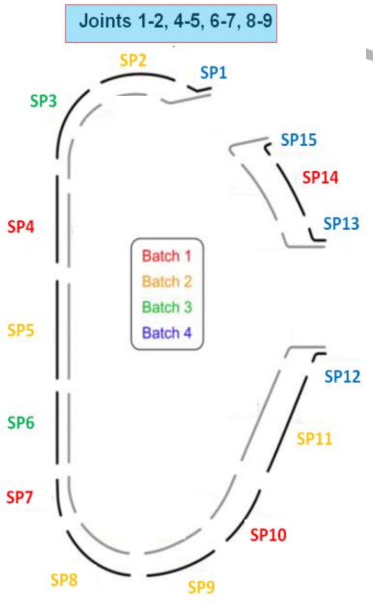
Operators and tooling Rotation 40° → Step 2



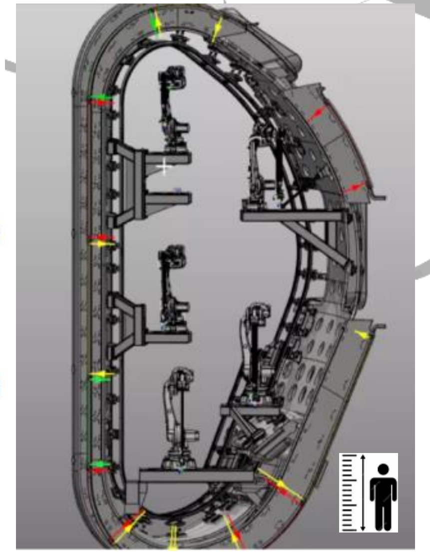
Operators and tooling Rotation 40° → Step 3



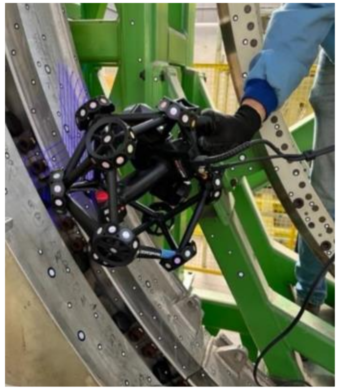
SP batches distribution



Robots on 1 FJ

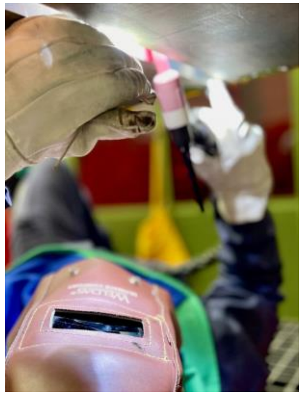


Scanning



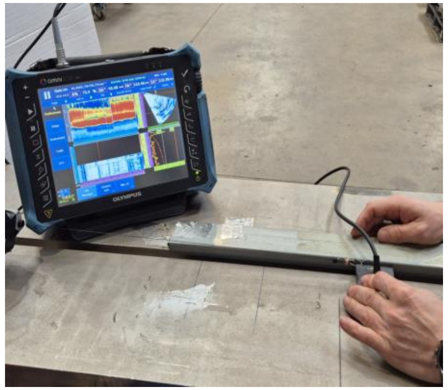
SP handling

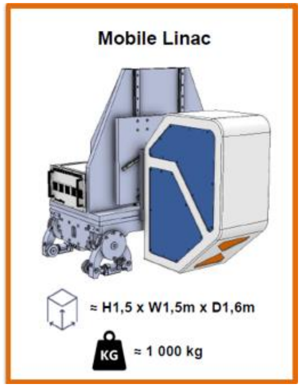
Welding



Machining

Non Destructive Examination





Key points of collaboration between IO and Westinghouse

Triggers of success:

1. Close relationship to support “hand by hand” ITER Project schedule and milestone objective
2. Specific Engineering skills to tackle all variables and technical challenges
3. On site Workshops to define disruptive assemply sequence and assumptions
4. Suitable atmosphere (trust/collaboration) for « first of a kind »
5. Efficient decision-making process

Partnership

THANKS

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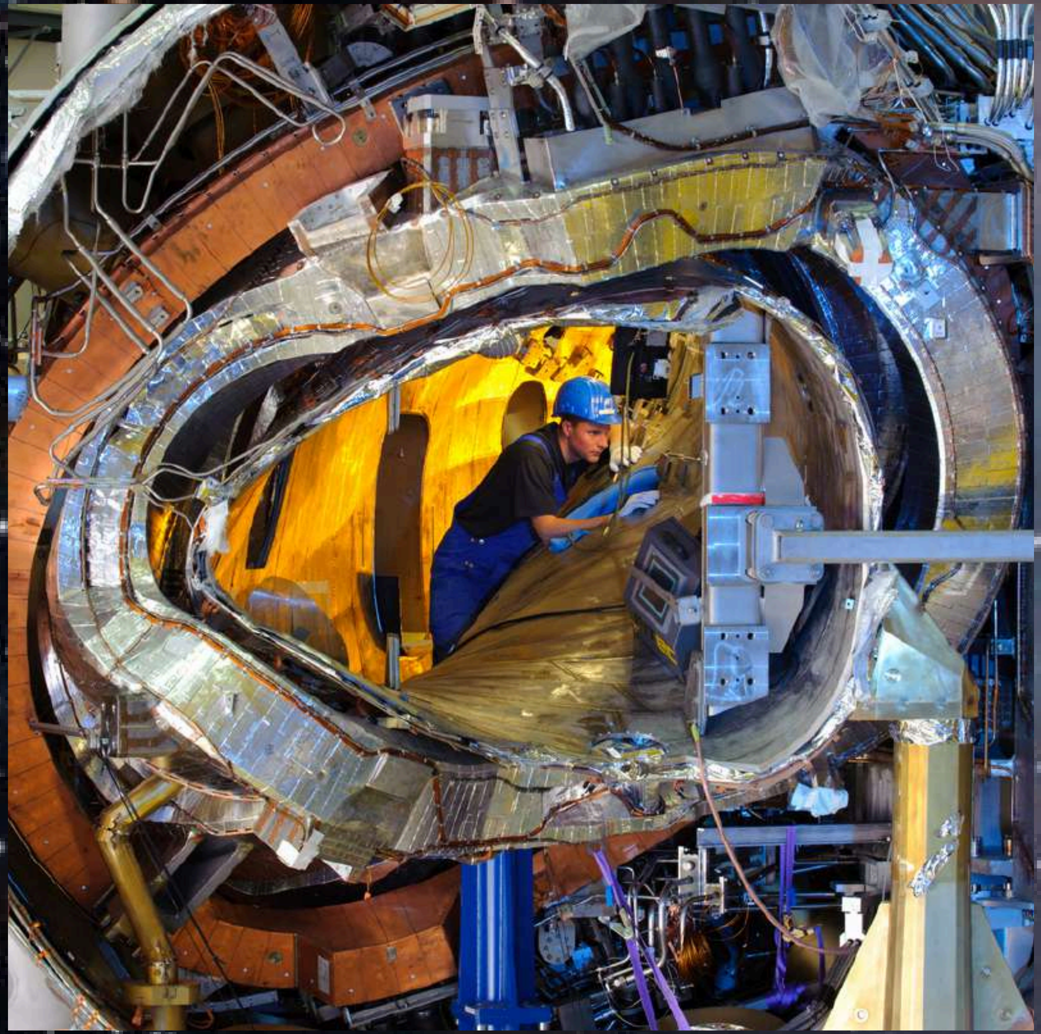
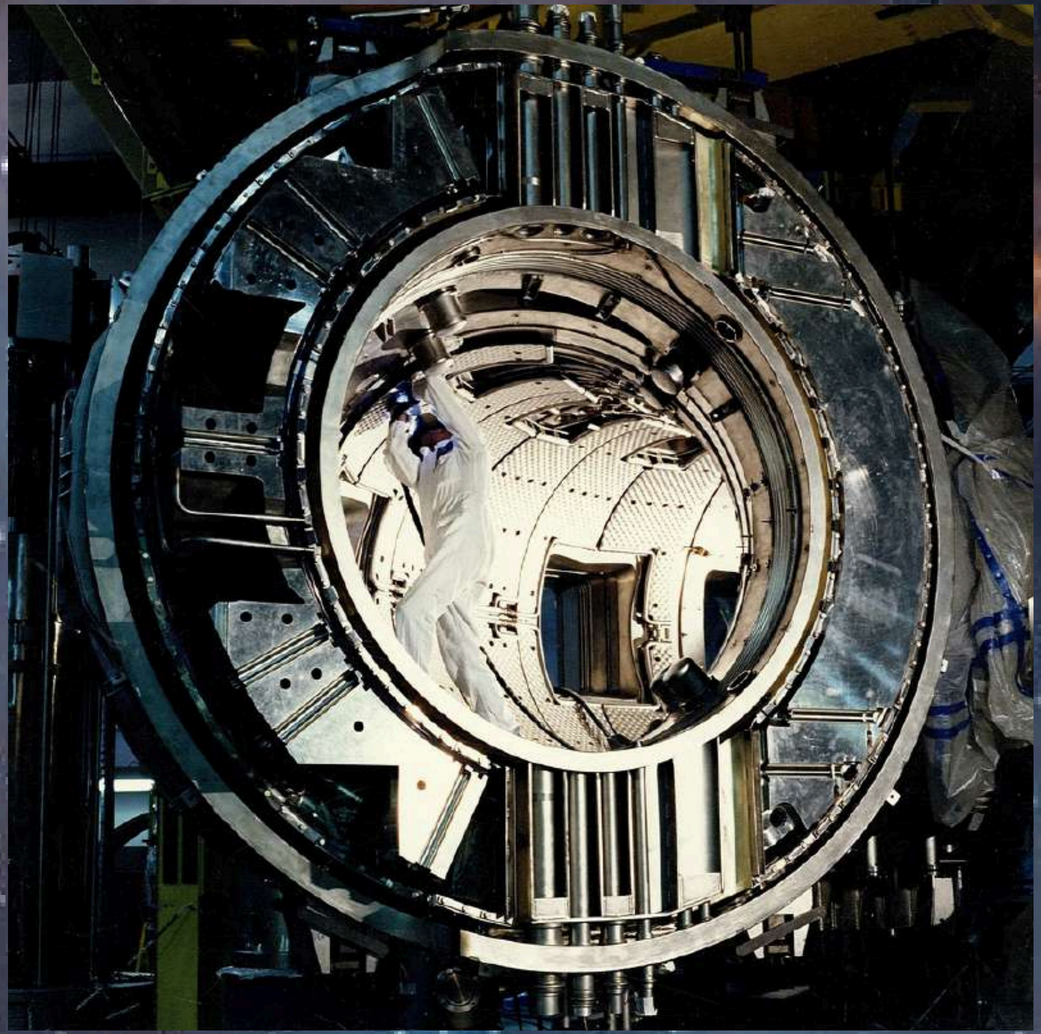
ITER BUSINESS FORUM 2025

Daniele Damiani
Magnet Engineer ASG Superconductors





JET

ITER

W7X

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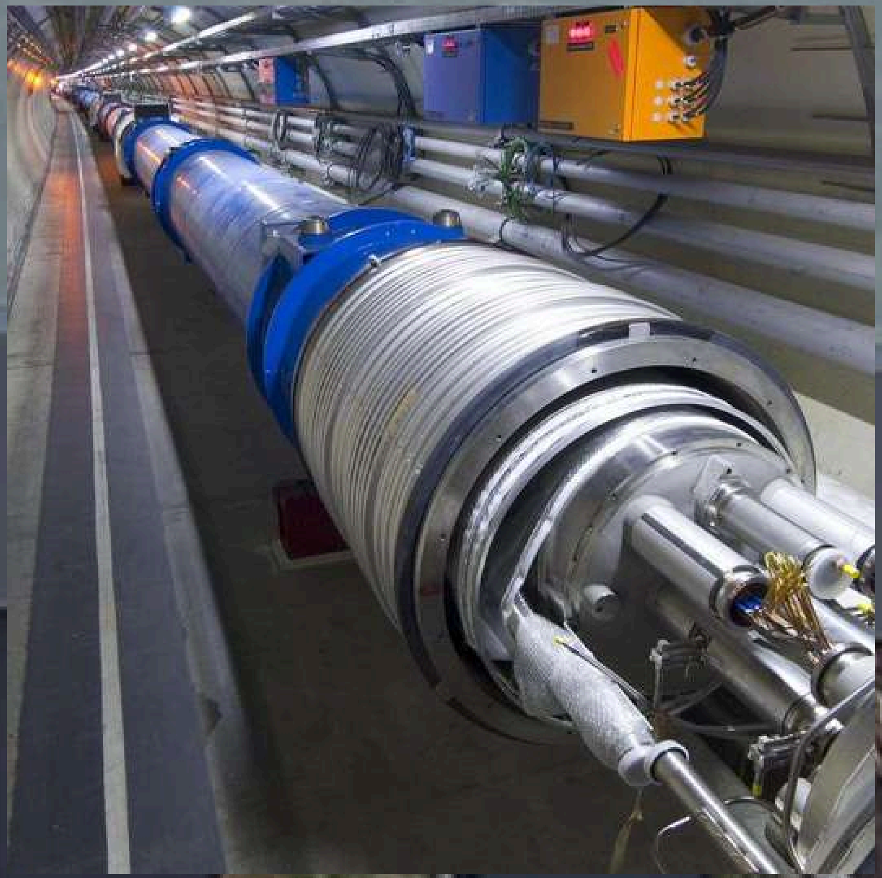
JT-60SA

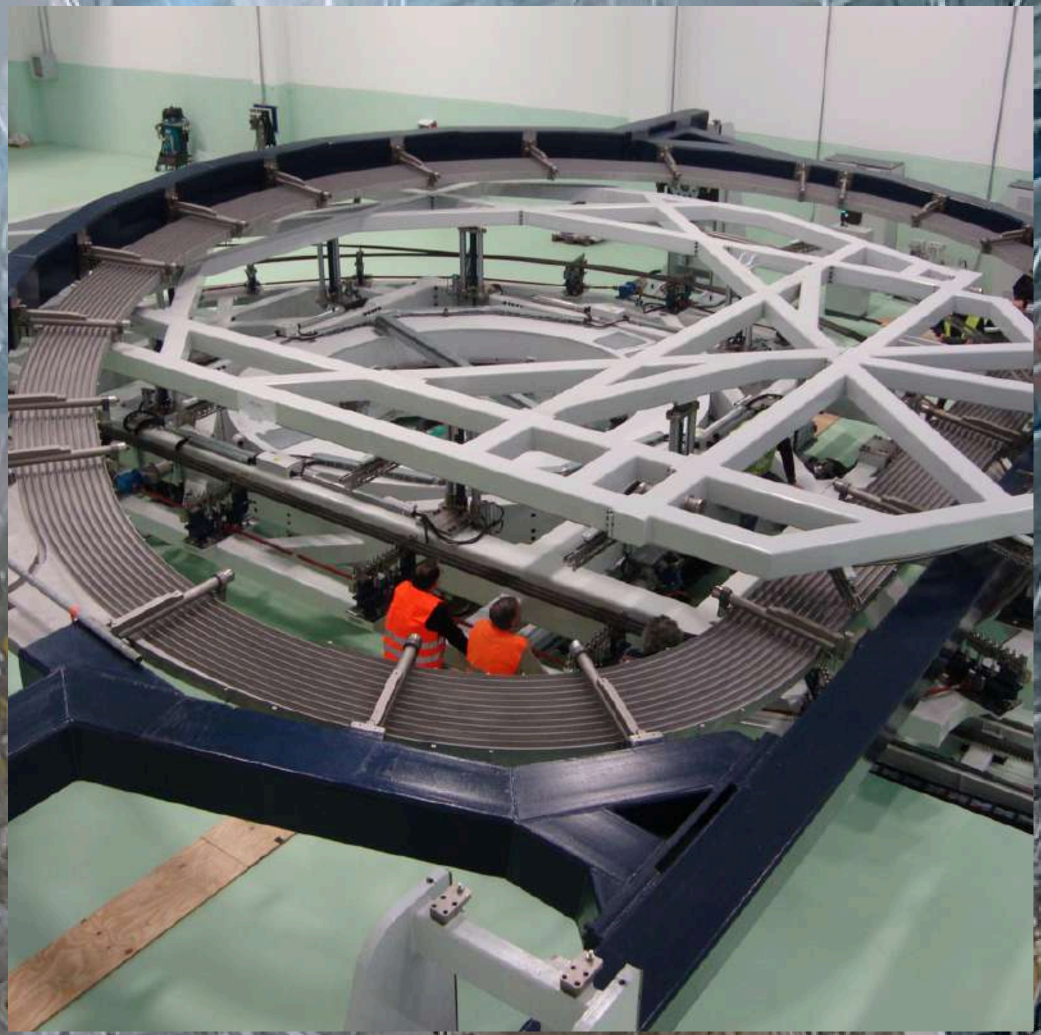
MORE THAN 50 YEARS ON MAGNETIC CONFINEMENT FOR FUSION

ASG SUPERCONDUCTORS



WHO WE ARE

ASG
SUPERCONDUCTORS



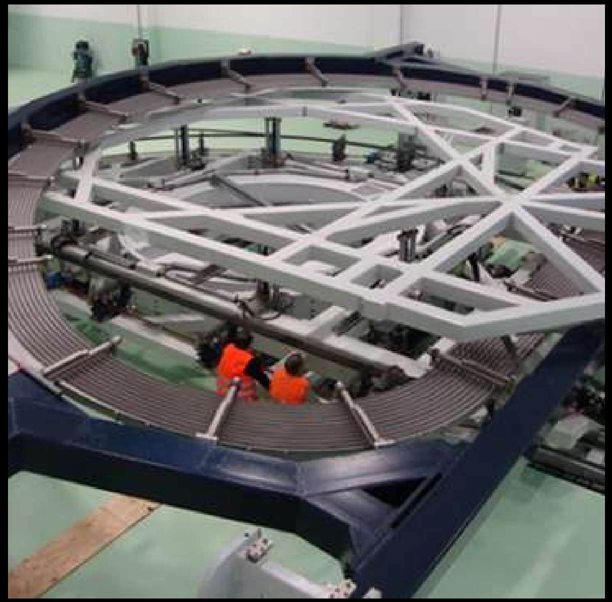
ITER, F4E AND ASG: A LONG TERM STORY OF CUTTING EDGE TECHNOLOGY FOR FUSION

ASG SUPERCONDUCTORS

TF COIL @ LA SPEZIA: A DEDICATED FACTORY

1. DP WINDING

2. CONDUCTOR HEAT TREATMENT



3. DP INSERTION INTO RP

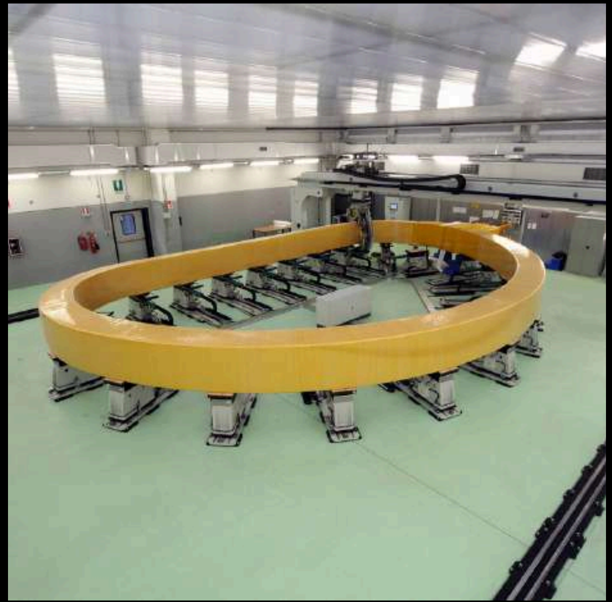
4. TURN INSULATION

5. COVER WELDING

6. DP GROUND INSULATION

7. DP VPI

8. DP STACKING



9. WP GROUND INSULATION

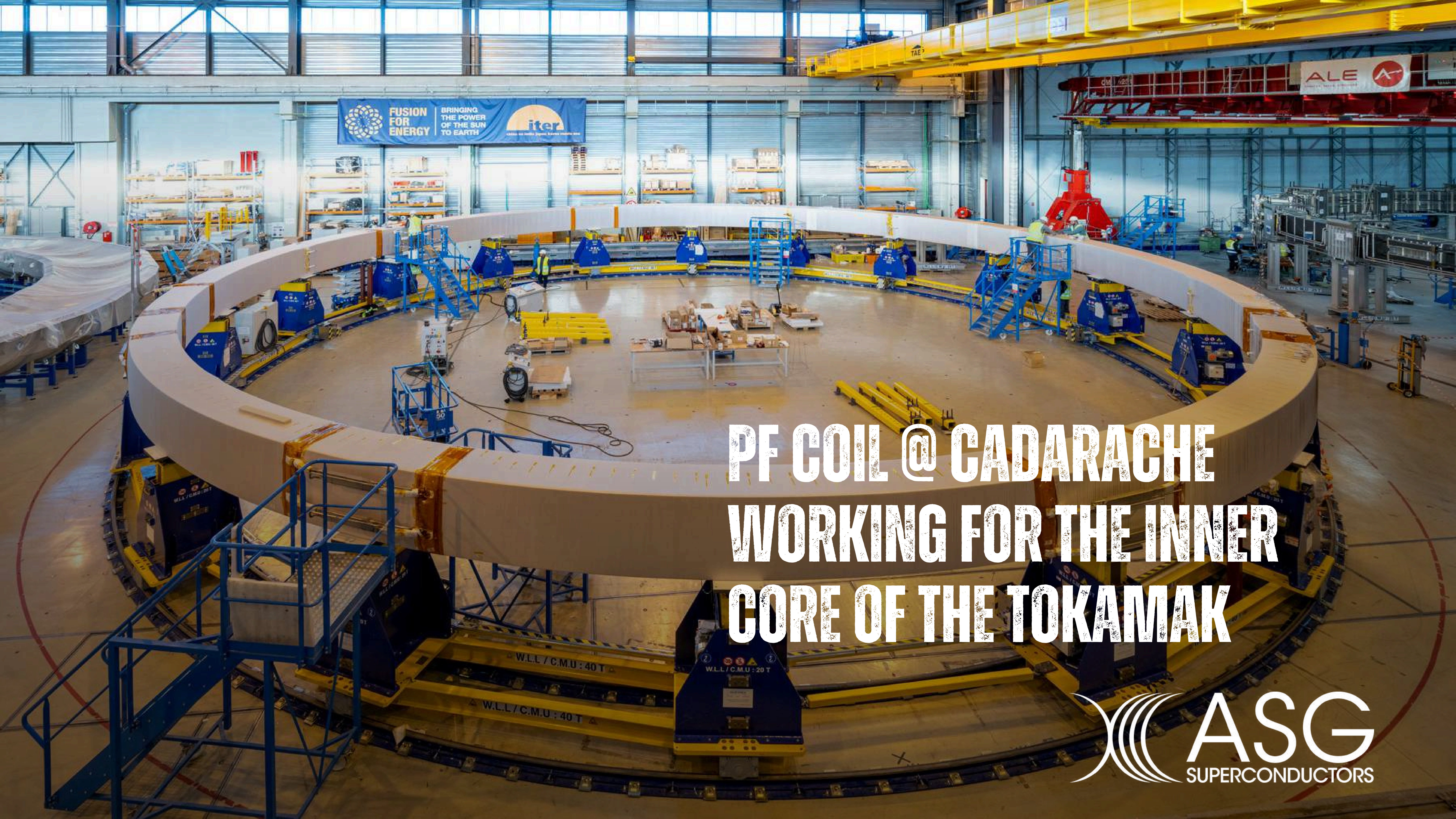
10. WP VPI

11. WP TEST

12. WP READY FOR SHIPPING

ASG SUPERCONDUCTORS

PF COIL @ CADARACHE WORKING FOR THE INNER CORE OF THE TOKAMAK

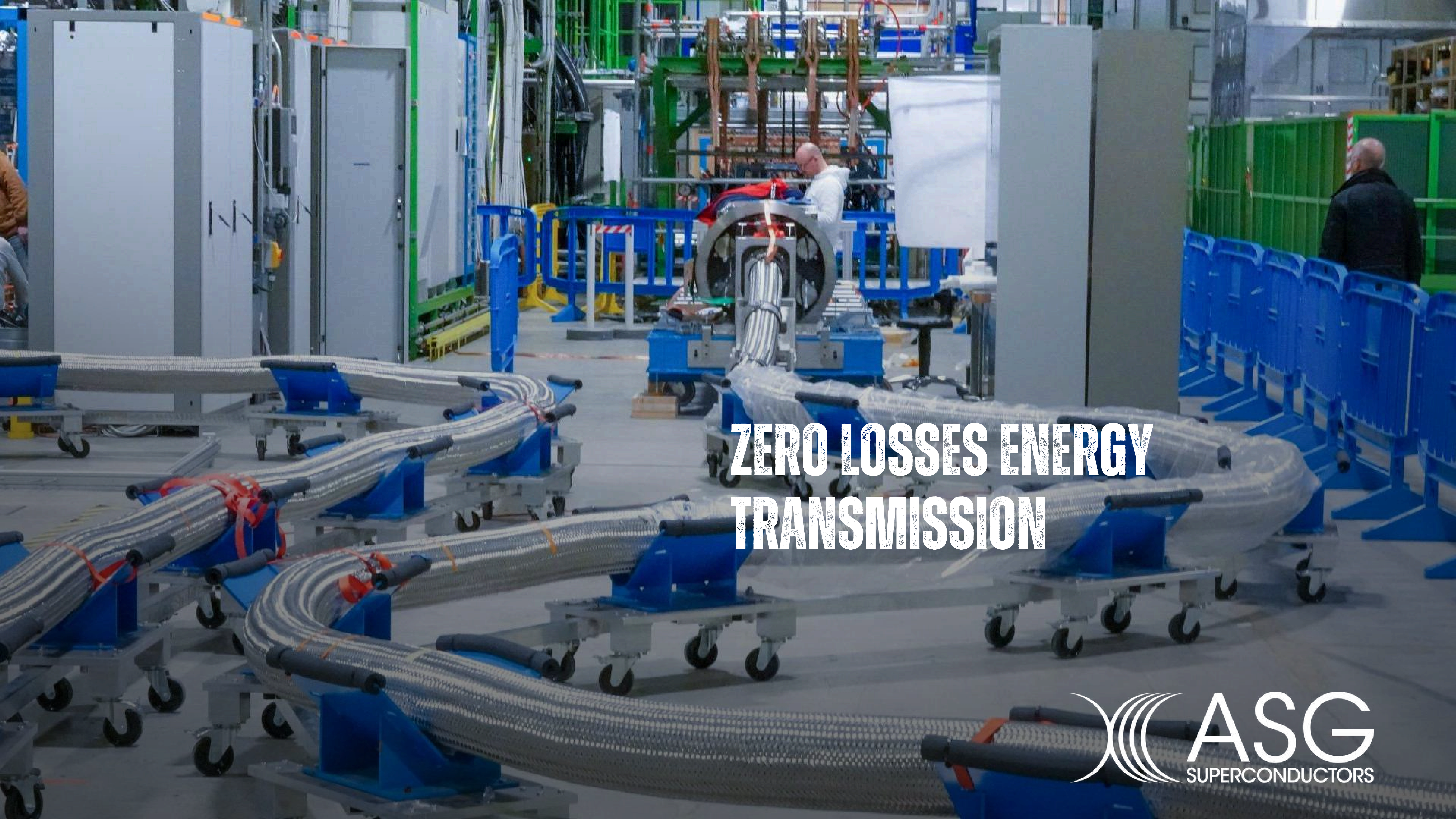


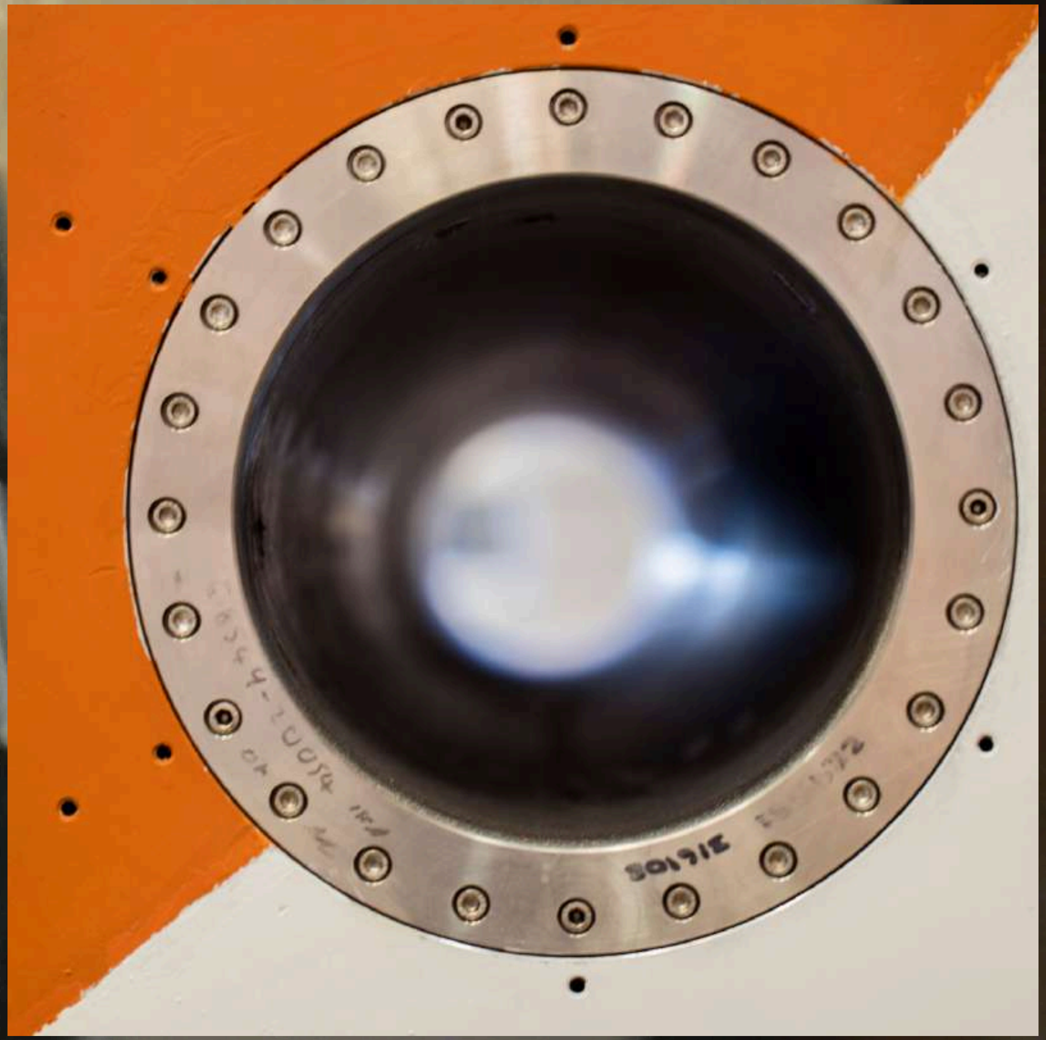
ASG SUPERCONDUCTORS

LESSON LEARNT: THE VALUE OF INTERNATIONAL COOPERATION

FROM RESEARCH TO EVERYDAY LIFE APPLICATION

ASG
SUPERCONDUCTORS


ZERO LOSSES ENERGY TRANSMISSION
ASG
SUPERCONDUCTORS

MEDICAL: MRI DIAGNOSTICS, THERAPY AND UHF

ASG
SUPERCONDUCTORS

ASG SUPERCONDUCTORS

IBF/25 ITER BUSINESS FORUM

THE FUSION ENERGY PATH FOR THE FUTURE: STRONGER TOGETHER

IBF MARSEILLE 24-25 APRIL 2025

SIMIC

since 1977

SIMIC GROUP AT A GLANCE

Since 1977, SIMIC is an Italian diversified company with two main Business Units:
Design and Manufacturing of critical equipment & Assembly and Maintenance of industrial plants.

Main Products: High **Pressure Vessels, Reactors, Heat Exchangers, Vacuum Vessels, Cryogenic Equipment & complex mechanical components with strict tolerances**.

Main sectors:
Oil & Gas - Fertilizers - Nuclear - Fusion Energy - Power Generation - Aerospace
Scientific Research - Renewable Energy – Food & Pharma

Business size of the Group (2023):
340 M € year turnover
48 M € EBIT
1070 manpower units

Industrial sites in Italy:
- **Camerana** (Cuneo) Workshops and Headquarters
- **Marghera** (Venice) High-capacity Workshops, direct dock access
- **Schio** (Vicenza) Workshop

Present **Italy, France, Germany, Belgium, Romania, U.K., Turkey, Saudi Arabia, US, Canada, Mexico, Brazil and Chile.**

OUR CONTRIBUTION FOR ITER Project

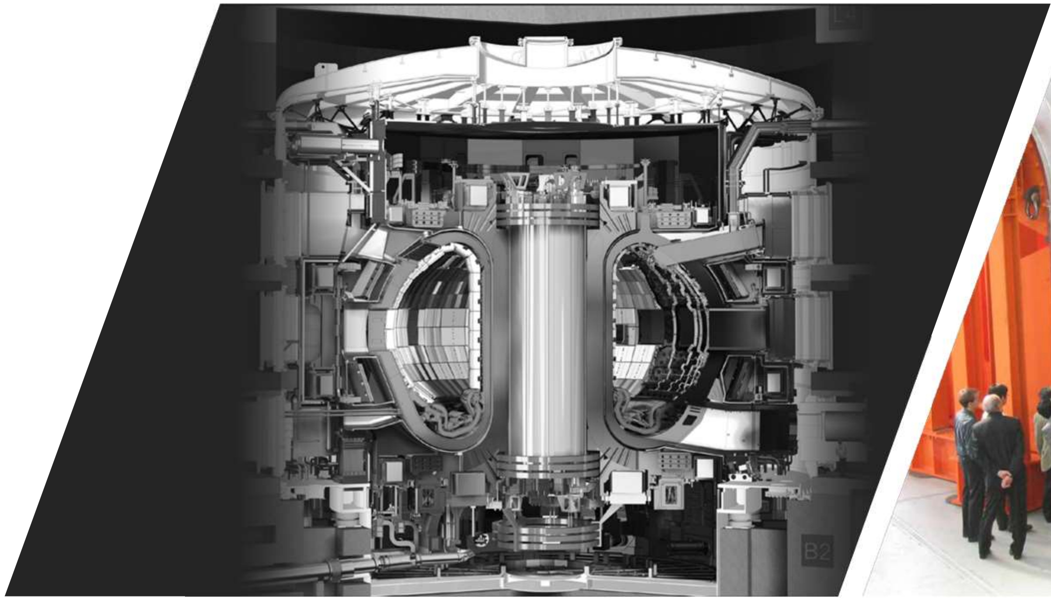
Our collaboration with ITER start back in 2004, more than 20 years ago with the manufacturing of complex prototypes such as:

VACUUM VESSEL prototypes (PSM)

- Material: AISI 316 LN IG (ITER Grade)
- Weight: 23 Tons + 70 Tons
- Narrow Gap Tig Welding Process Thickness 60 mm

DIVERTOR PROTOTYPES

- Inner Vertical Target protyope
- Outer Vertical Target protyope
- Dome Liner



DIVERTOR COMPONENTS (ONGOING)

Manufacturing of ITER Divertor components
Cassette Body Series Production (4+15 units)

iter

FUSION FOR ENERGY

SIMIC

PRODUCTION CAPACITY IN FUSION ENERGY / ITER Project

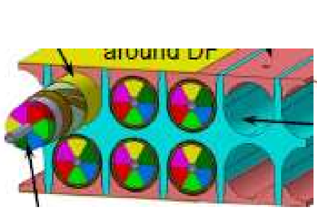
RADIAL PLATE SERIES PRODUCTION (Completed in 2017)

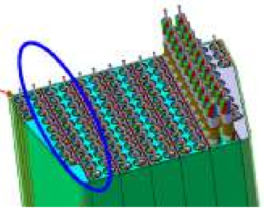
Fusion for Energy awarded to the consortium SIMIC-CNIM the contract to manufacture **70 radial plates** for ITER. The contract lasted more than 4 years and is among the biggest industrial contributions of Europe’s share. In May 2017 the last Radial Plate has been successfully delivered to ITER.

The radial plates are «D» shaped mechanical structures (**13.8 m x 8.7 m x 112 mm**).

They are made from **316LN stainless steel** and they will form the ‘backbone’ of the 18 field magnets needed to keep the plasma confined within the ITER vacuum chamber.

The radial plates have on each side spiral round-shaped grooves which are closed by cover plates.





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FUSION FOR ENERGY

ITER Project

WP COLD TEST & INSERTION INTO TF COIL CASES (10 TF COILS)

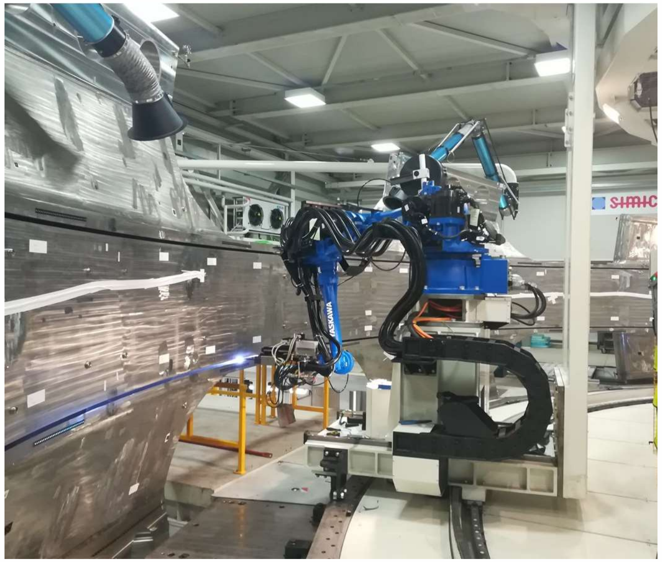
Completed in 2024

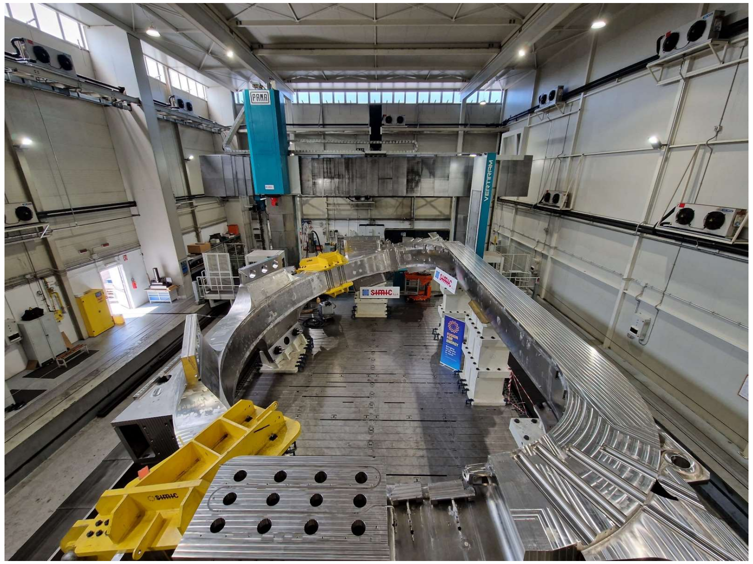
SIMIC performed the Cold Test of 10 Winding Packs and supplied the **10 European Toroidal Field Coils of ITER**.

The most critical aspects:

- Impressive **size & weight** 14 m x 9 m;
- 320 tons each TF
- **variable thickness** along the perimeter, 40 - 130 mm
- weld **difficult to inspect**
- **tight tolerances**
- control of **deformations** during welding of the case
- **production rate** very demanding

WP COLD TEST & INSERTION INTO TF COIL CASES (10 TF COILS) Completed in 2024



CRYOGENIC PLANTS AND DISTRIBUTION BOXES (Completed in 2025)

SIMIC takes part, with Linde Kryotechnik, to the manufacturing of 5 large Distribution Boxes for the ITER Cryodistribution plant. The units are complete of internal piping and super-insulation suitable to achieve cryogenic temperatures. The Vacuum Vessel will be leak tested, while the piping will be pressure tested.

BLANKET MANIFOLD COOLING SYSTEM (ONGOING)

SIMIC has been awarded by Fusion for Energy the qualification and manufacturing of Blanket Cooling Manifold Task 1. The Blanket Cooling Manifolds (BCM) delivers pressurized cooling water to the Blanket Modules (BMs). This system consists of 8.5 km of seamless 316L stainless steel pipes supported by highly complex custom components that ensure thermal conductivity, electrical insulation, and magnetic shielding. To meet the demanding requirements of this task, SIMIC developed and qualified a series of advanced processes, including:

- 🧪 Alumina and copper deposition
- 🔧 Electron Beam (EB) welding
- ⚙️ Orbital and manual TIG welding
- 🛠️ Precision milling
- 🔥 Hot Radial Pressing (HRP) in a vacuum furnace at 700°C
- 📏 3D bending with tight tolerances

PRODUCTION CAPACITY IN FUSION ENERGY / ITER Project

VACUUM VESSEL BEVEL REPAIR (ONGOING)

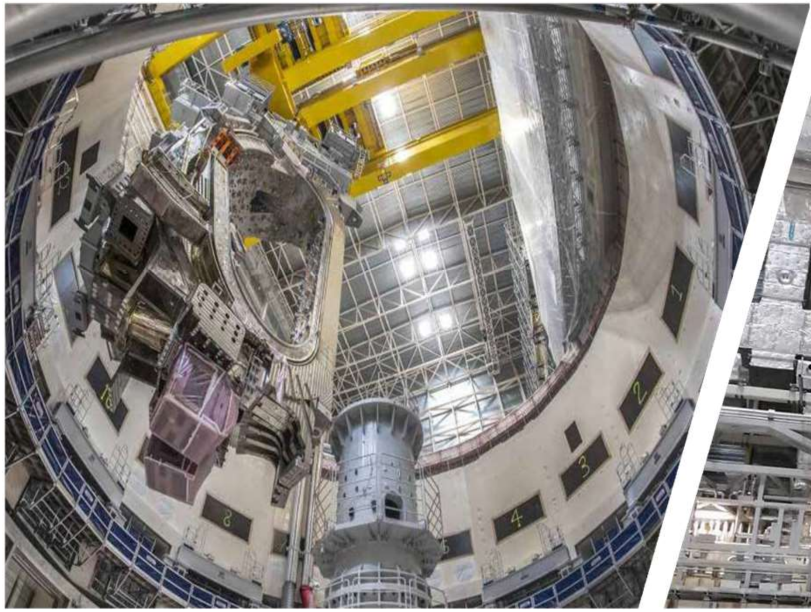
SIMIC has been selected to perform the on-site repair activities of the ITER Vacuum Vessel sectors 6, 7, 8 and 1, toghether with Ansaldo Nucleare. We takes care of this challenging job, according to the most stringent technical and quality requirements by ITER, ESPN and RCC-MR codes and standards. The scope includes the engineering studies and qualifications required for the on-site operations, including metrology, reverse engineering, high technology weld build up and local machining necessary to bring the sectors to the required tolerances.

2 Sectors have been completed and other 2 are in progress.

SECTOR MODULES SUB-ASSEMBLY (SMSA)

Thanks to the technical experience of SIMIC at ITER Site, SIMIC is collaborating with CNPE Consortium, for the SMSA mechanical installation works.

ONGOING PROJECT



SECTOR MODULES IN PIT ASSEMBLY (SMPA)

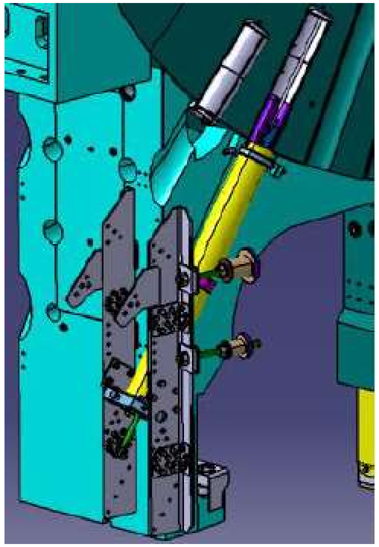
SIMIC, with CNPE Consortium, has been awarded the SMPA contract by the ITER Organization.

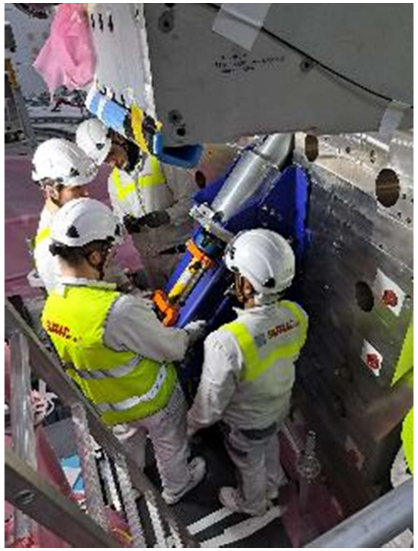
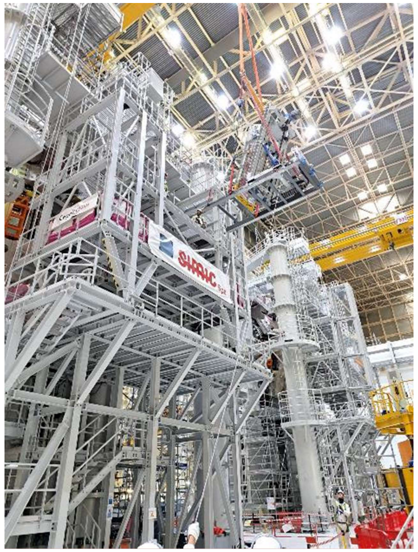
The consortium carries out the assembly of the 9 Sector Modules of the Vacuum Vessel before they are welded inside the PIT.

ONGOING PROJECT

SECTOR MODULES SUB-ASSEMBLY (SMSA) & SECOTOR MODULES IN PIT ASSEMBLY (SMPA) PROJECT - ONGOING

- For SMSA, Simic is leading the precision installation of intercoil structures—critical components that ensure the stability and performance of TF Coils in the Machine Assembly Programme. This includes precise metrology surveys and custom machining to fit tight tolerances and prepare Sector Modules before installation in the PIT. Assembly on SSAT of the the first Sector Module (SM7) achieved in March 28th.
- For SMPA, the assembly continues inside the PIT between adjacent modules.
- Sector 7 has been installed in the Pit on April 10th ahead of schedule!



MAIN CHALLENGES

- Technical complexity and requirements are a great challenge at ITER
- First of Kind components adding a high level of risk for the companies and for ITER
- High level of bureaucracy, which leads to inefficiency
- High amount of paperwork and procedures, which leads to inefficiency
- Complex standards and multiple interfaces
- High investments needed to participate to tenders and tight budgets

LESSON LEARNED AND RECCOMENDATIONS

- During the last 2 years great efforts have been done accomplishing important Milestones for the project
- Avoid over requirements
- Responsible staff shall have leadership and decision-making capabilities to unlock situations and move forward.
- Further simplify structure, bureaucracy for a better efficiency and performance

SIMIC AND THE ITER PROJECT

A long journey, made of challenges, growth, reciprocal trust and great collaboration!


iter FUSION FOR ENERGY

Thank you for your attention!

Thank you to Fusion for Energy!

Thank you to ITER Organization!

www.simic.it

since 1977

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