THEMATIC WORKSHOP

Machine assembly program

Progress of ITER In-Vessel Assembly & Industry's Role

Anna ENCHEVA

ITER In-Vessel Components Project Leader, acting

Anna Encheva is an experienced engineer and project leader with 25 years of experience in engineering and industry. She has played a key role in design, R&D, procurement, manufacturing, integration, and assembly of various components, as well as in contract strategy development and large-scale installation oversight.

Prior to ITER, she gained valuable experience focusing on mechanical engineering and fluid mechanics, and working on magnetic diagnostics for ITER. Experienced across Europe and Asia, she is passionate about team leadership, innovation, and fostering high-performance work environments in large-scale engineering projects.

Emilio RUIZ

F4E Programme Manager for ITER Remote Handling

Emilio Ruiz is responsible for the European in-kind supply of key Remote Handling (RH) Systems for ITER, which include the Divertor RH System, the Neutral Beam RH System, the Cask & Plug RH System, and the diagnostic In-Vessel Viewing System.

Chairperson:

Paul Hieltjes
Dutch ILO

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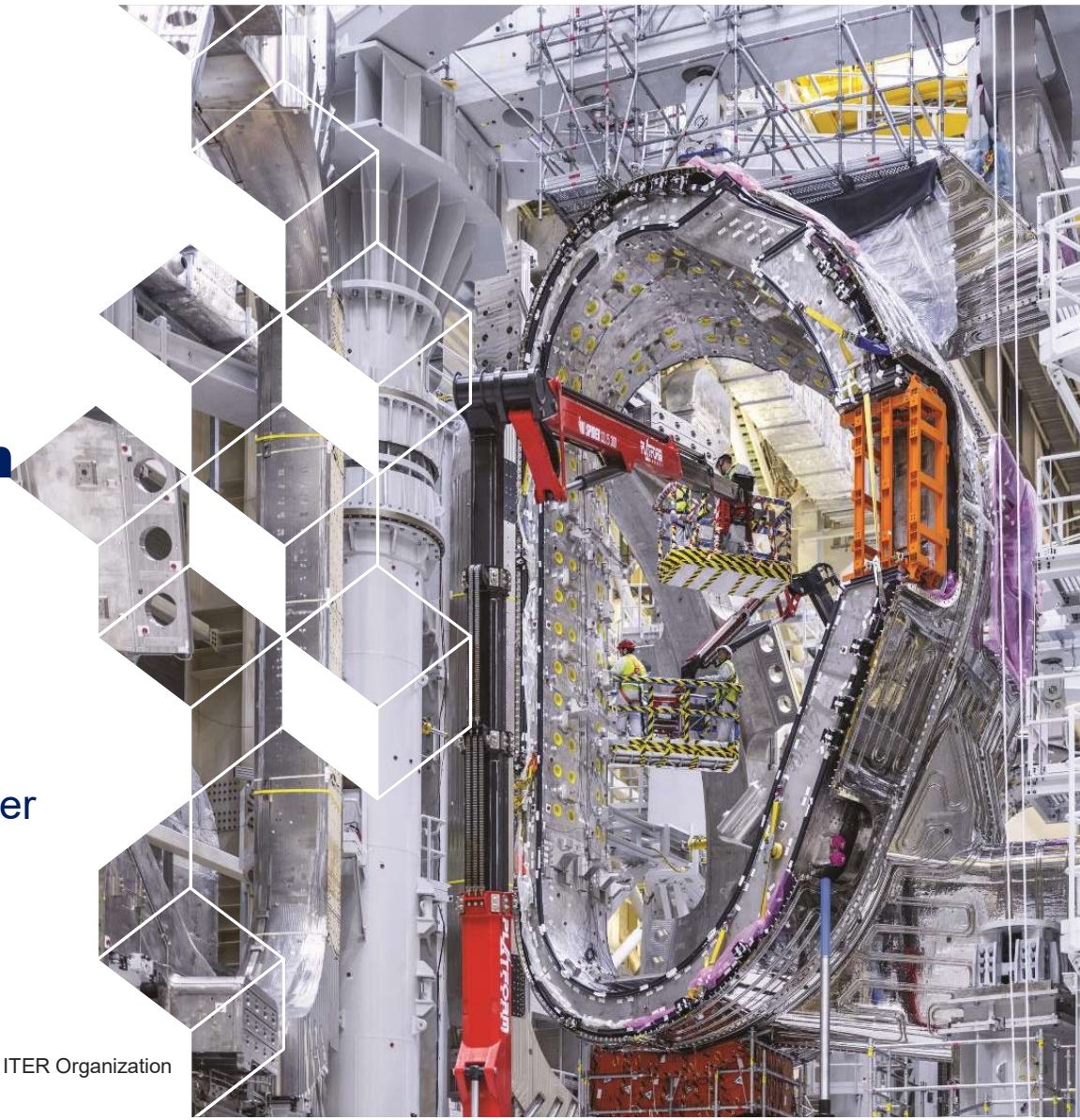
INTERNATIONAL ITER BUSINESS FORUM

Advancing ITER: Progress in In-Vessel Assembly and the Vital Role of Industry

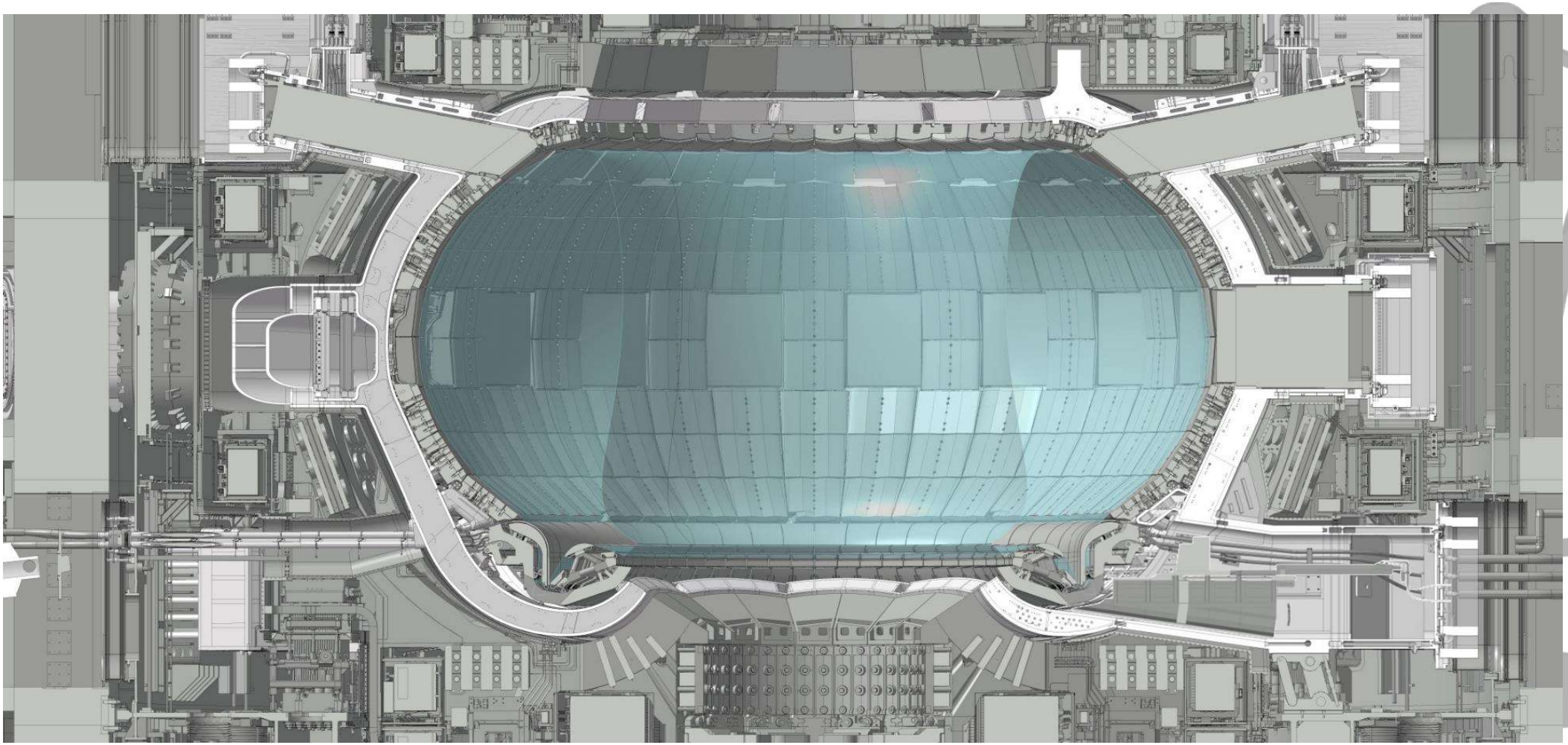


Anna Encheva

In-Vessel Assembly Project Leader

FRIDAY, 25 APRIL 2025

ITER In-Vessel Assembly scope



Together with industry

Engage Upstream
Early design and manufacturing of assembly tooling and process development

We Award
Progressively in stages based on maturity and performance

Develop in partnership
Qualify new technologies, techniques, processes. Key: Process qualification and personnel training

Execute in confidence
Reduced uncertainty, risk and cost control. Return of experience

Driving Fusion Forward – Together with Industry

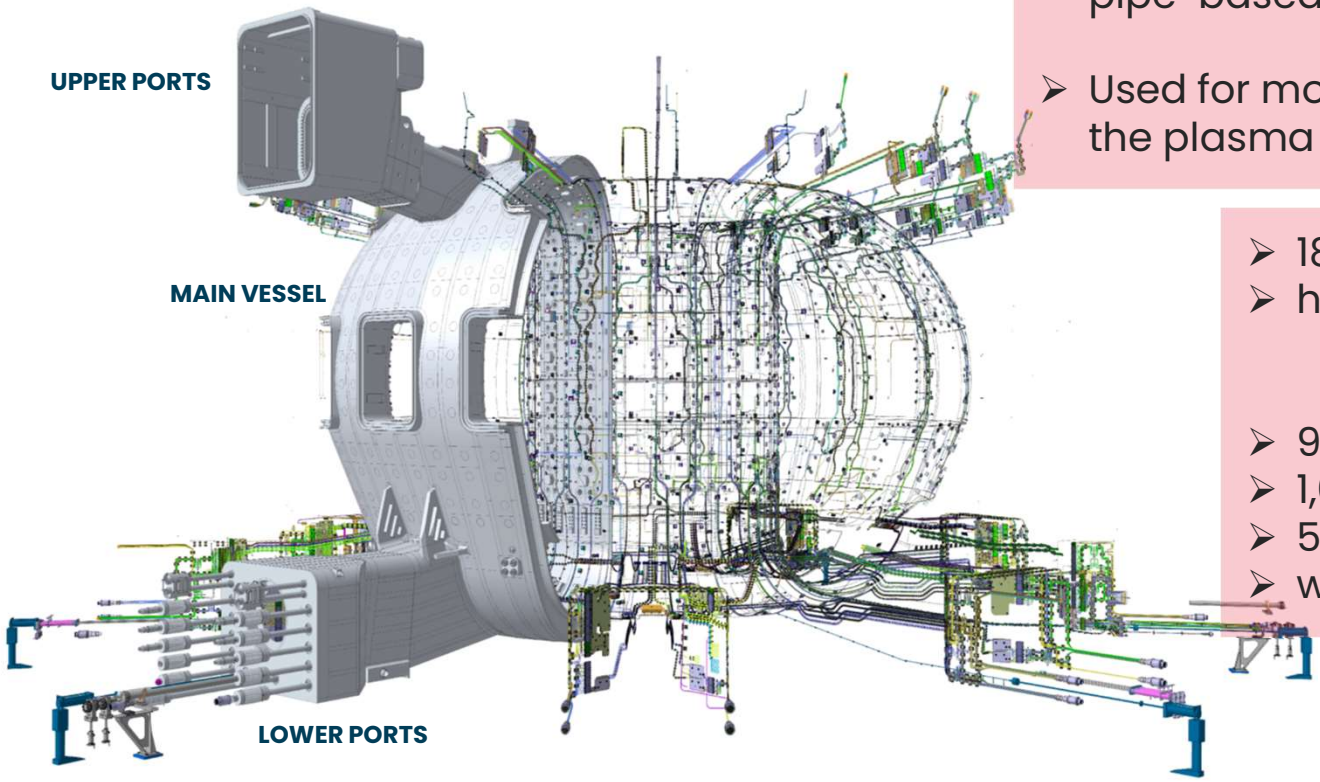
Partnering with industry to build on experience, speed up innovation, and share knowledge—paving the way for the next phase of fusion industrialization.

Main principles:

- Schedule driven, following installation sequence logic
- Splitting scope according to a set of skills and competences
- Minimizing co-activities across scopes and locations
- Complex custom tooling for the installation of large components
  - Main purpose-built installation tools should be supplied by the installation contractor;
  - It is preferable to involve the installation contractor and tool manufacturer(s), as early as possible, at the development phase

Instrumentation, Diagnostic and Fueling Systems

- Cables, sensors, instrumentation, pipe-based systems
- Used for monitoring and control of the plasma parameters

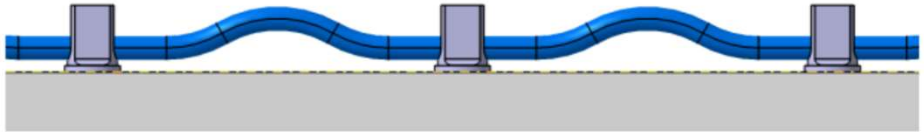


- 18 km of cables
- hand welded:
  - 100,000 clips
  - 21,000 bosses
- 9,000 cable clamps
- 1,000 sensors
- 500+ connector boxes
- waveguides

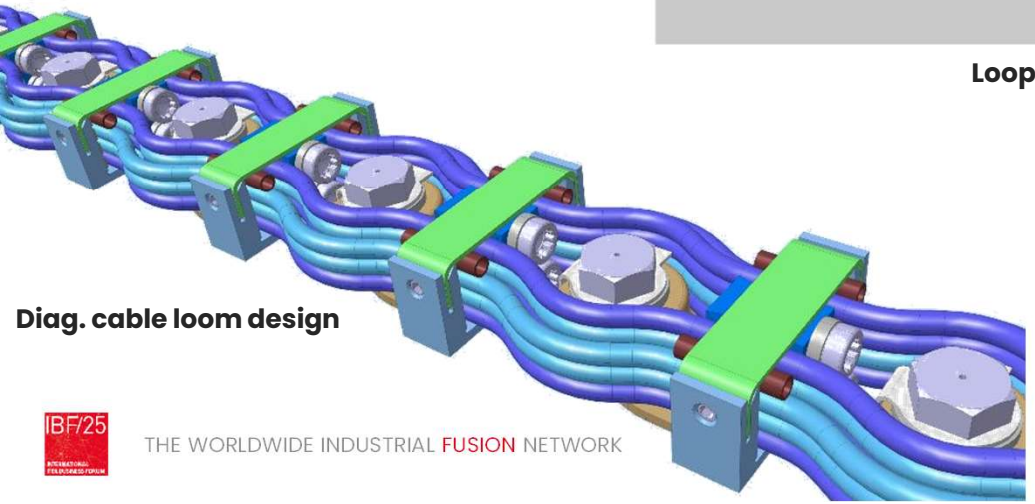
Instrumentation, Diagnostic and Fueling Systems

Qualification work → **Cable Looms and clips welding**

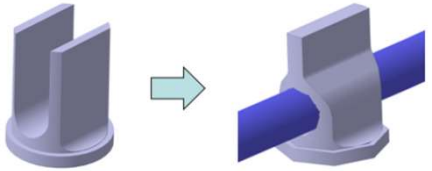
- **Awarded: ASIPP, China and ASG, Italy**.
- **Complex tasks**: cable clips stud-welding, repeated cable 'wobbling' following strict tolerances, large quantity of cables positioning and clamps assembly within narrow clearances
- **Objective**: develop reliable and repeatable processes, optimized installation duration, qualification and training of personnel



Loops cable with clips

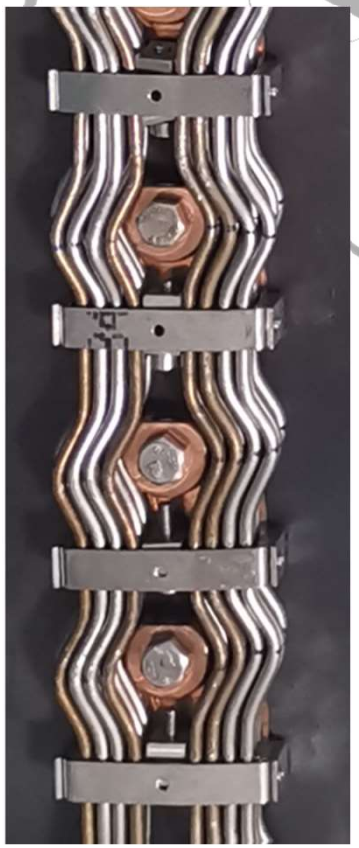


Diag. cable loom design

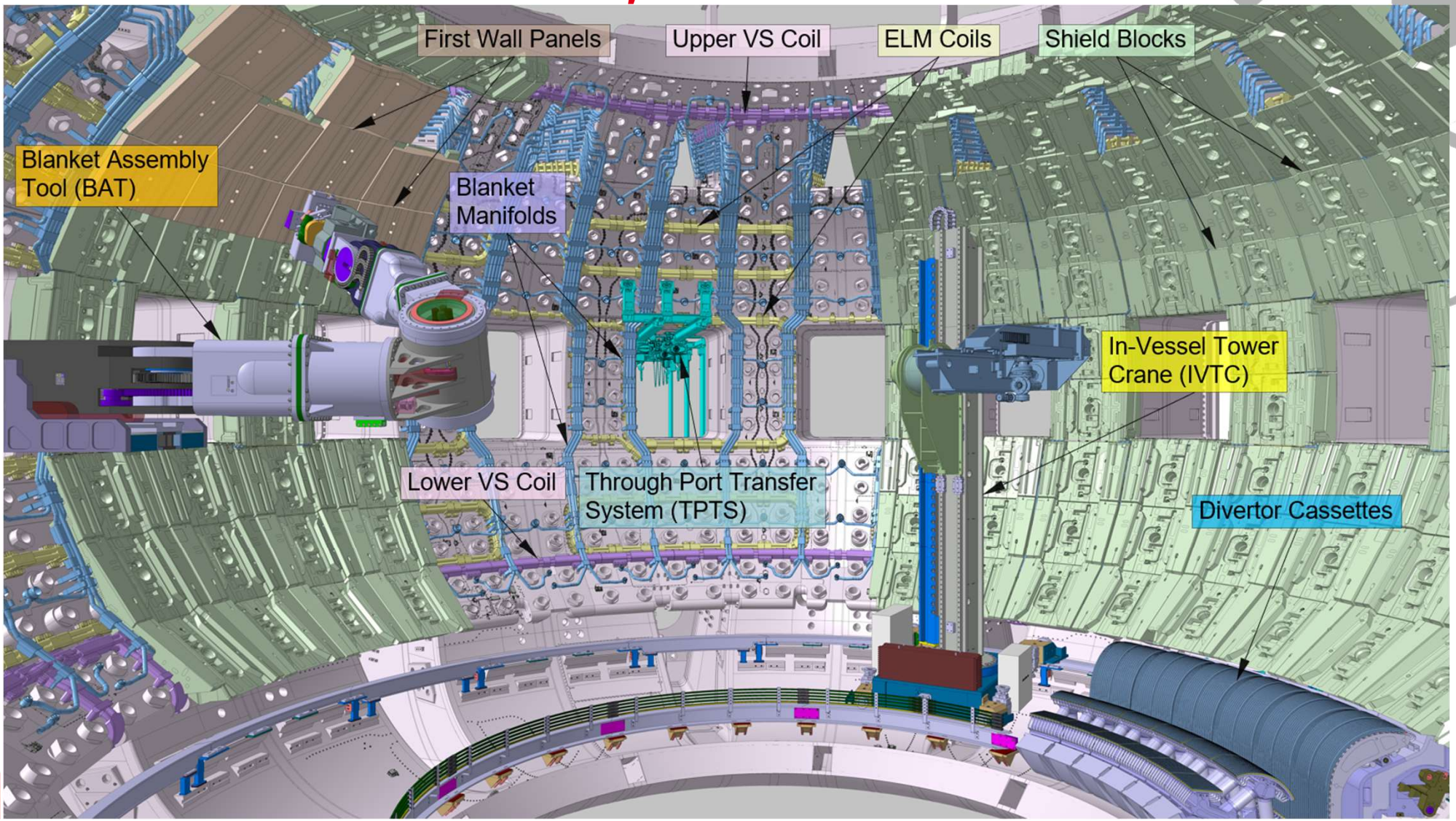


Cable clips assembly concept

Diag. cable loom mock-up



In-Vessel Coils, Blanket and Divertor



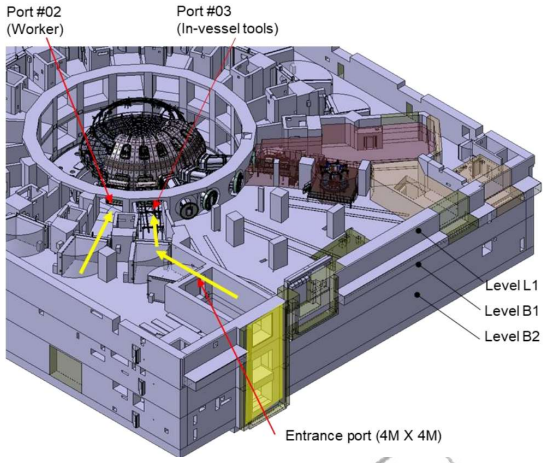
Vertical Stability Coils Installation

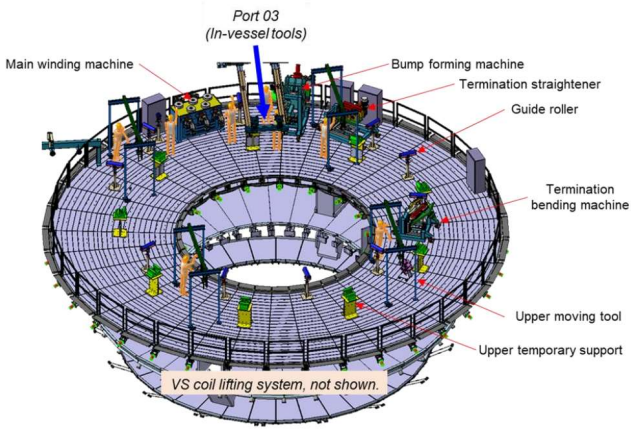
1) Work Space preparation in Tokamak Building

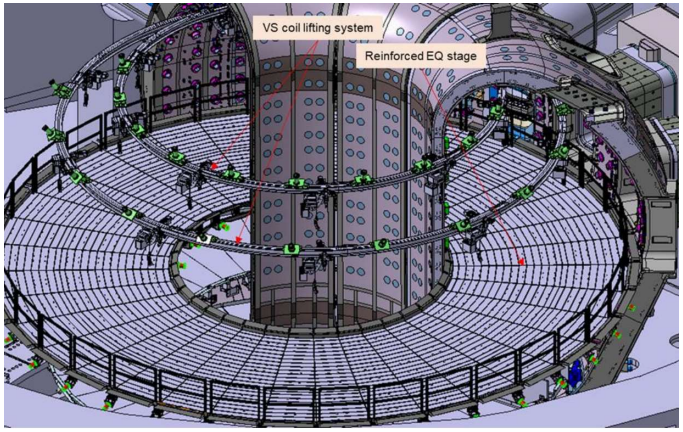
2) Installation of winding tools and control system;

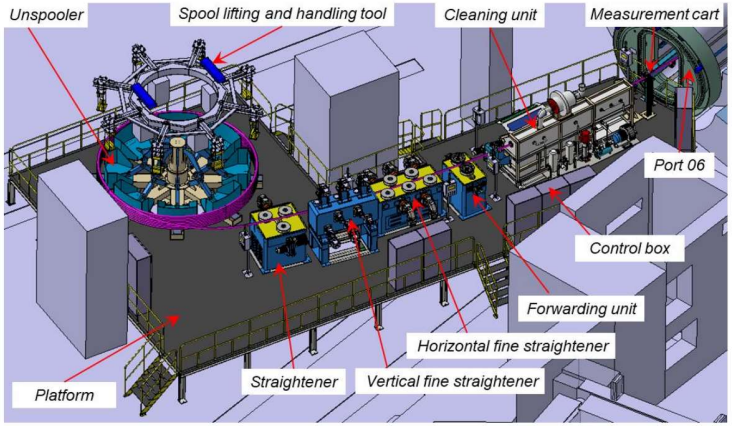
3) Installation of supporting equipment (Reinforced Staging, Lifting System);

4) Installation of winding tooling on Reinforced Staging, position according to metrology and final coils shape.







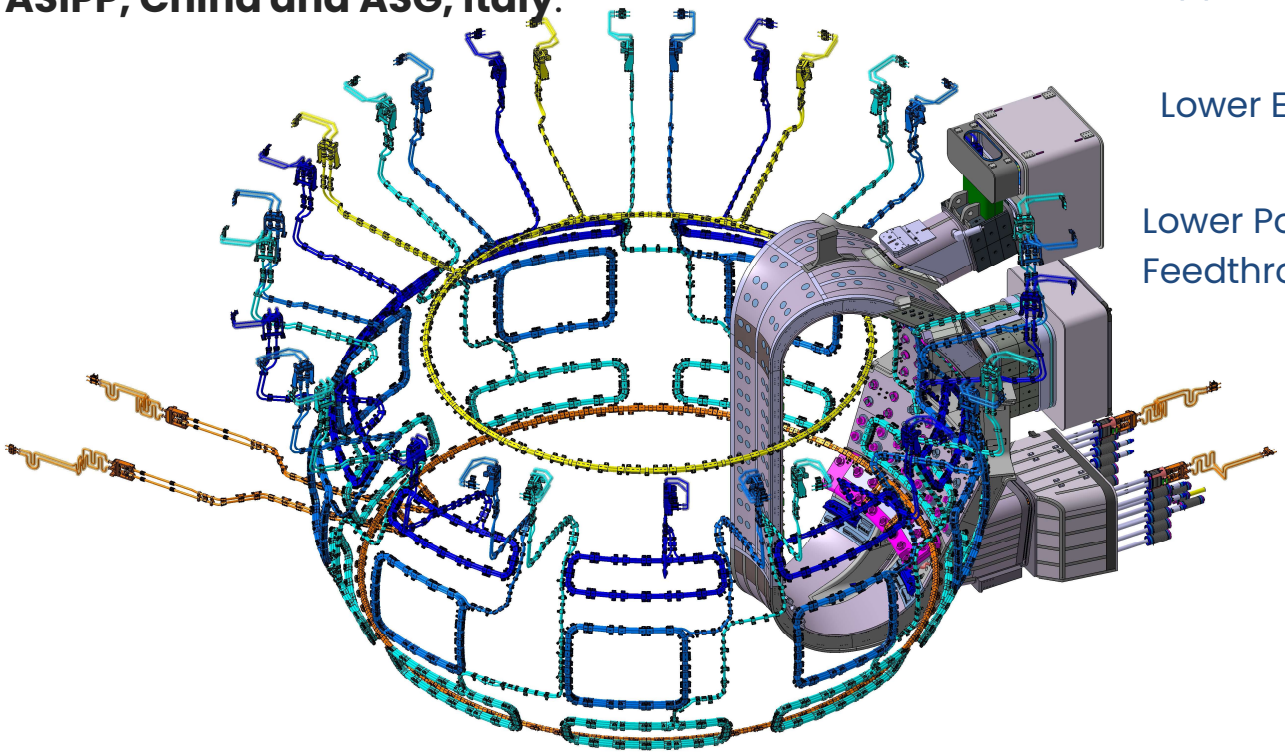


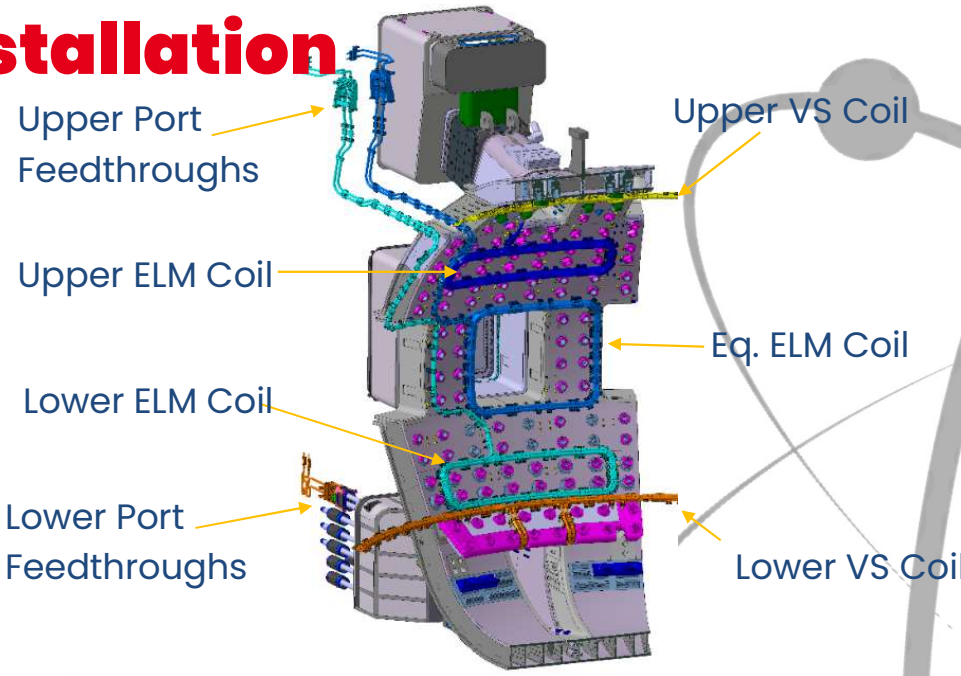
ELM Coils, feeders and joints Installation

ELM coils manufacturing:

Prototyping and tooling Manufacturing Phase

ASIPP, China and ASG, Italy.





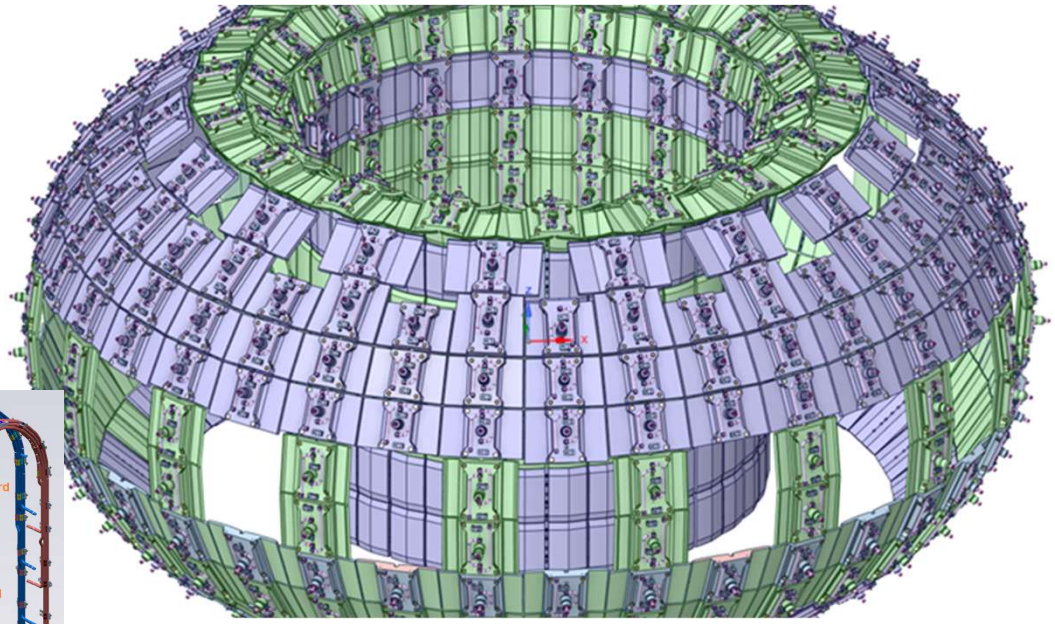
Installation scope:

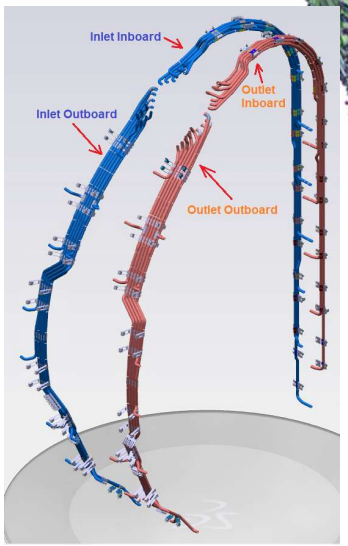
27 coils in total

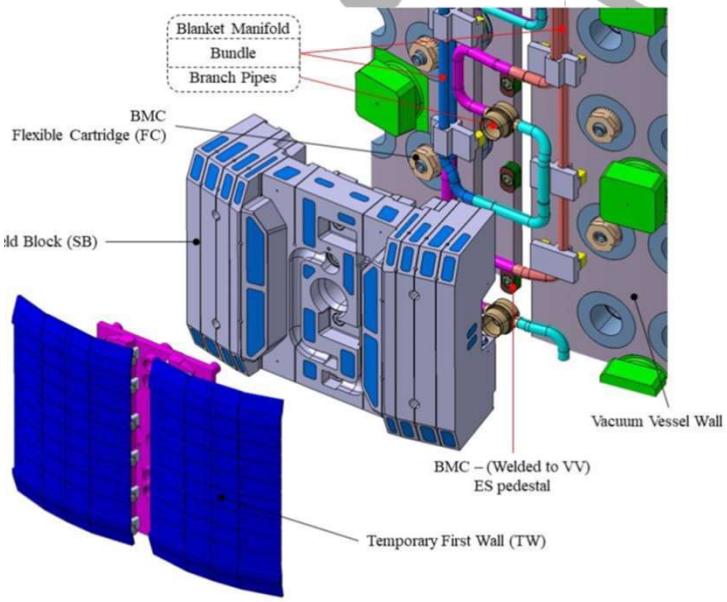
35 Feeder lines

176 in-situ joints

Blanket, First Wall and Blanket manifold installation







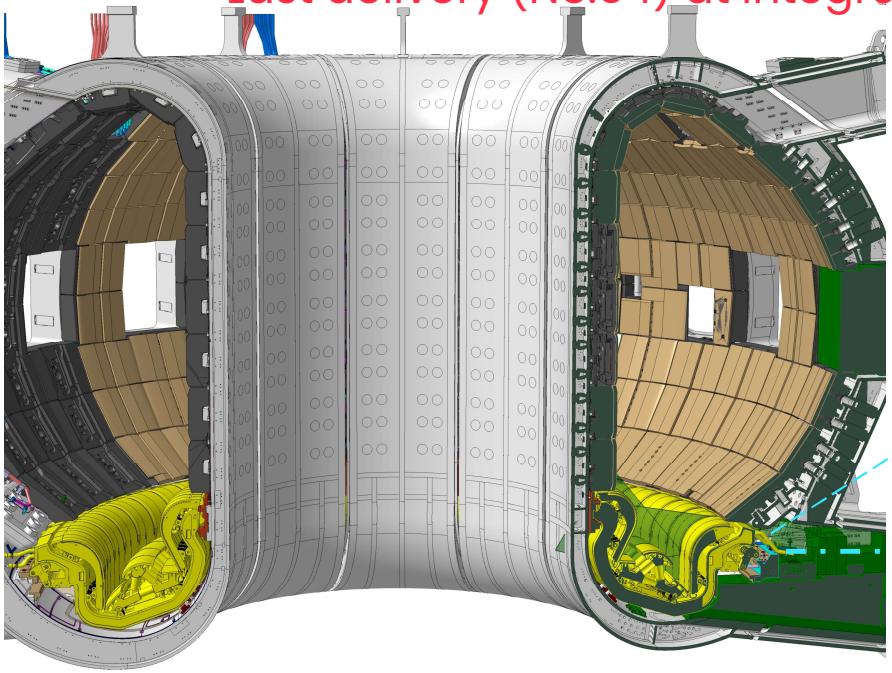
Total number of SB	Total number of variants	Dimensions (mm)			Individual Mass (Kg)
		Toroidal	Poloidal	Radial	
440	125	1238 - 2053	872 - 1270	321 - 933	1983 to 4000

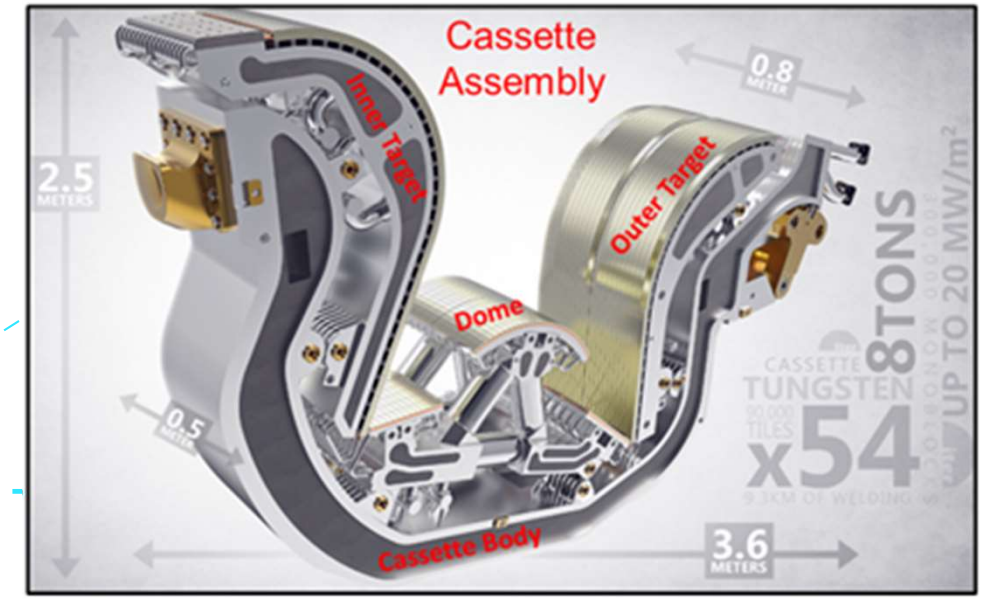
Divertor Cassettes Installation

Divertor will be settled in the bottom part of the Vacuum Vessel, consisting of 54 cassette assemblies, inserted through 3 lower ports

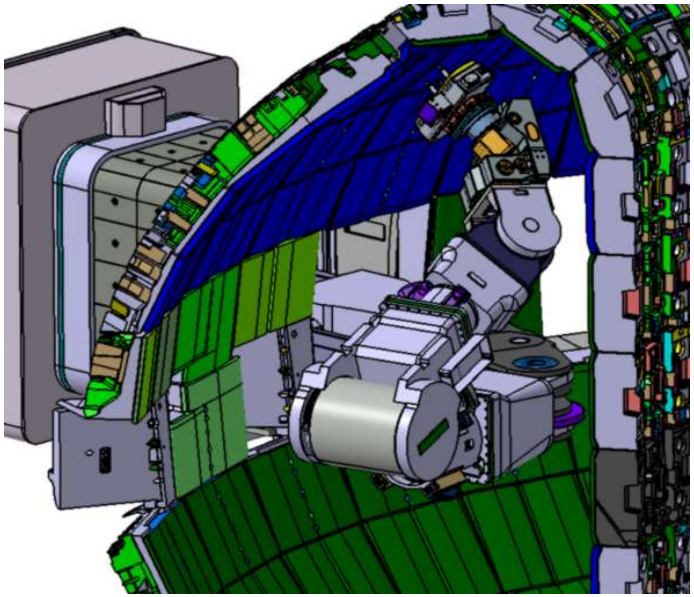
First delivery (No.1) at Integration Site: November 2026

Last delivery (No.54) at Integration Site: December 2031

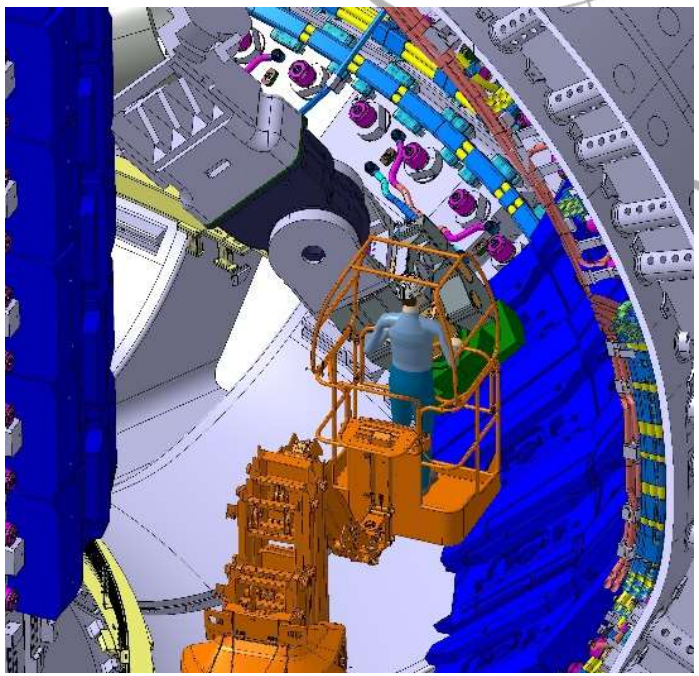




Blanket Assembly Transporter



*Blanket Assembly Transporters **BATs** are long-reach, serial robotic devices deployed in a cantilevered fashion from equatorial ports*



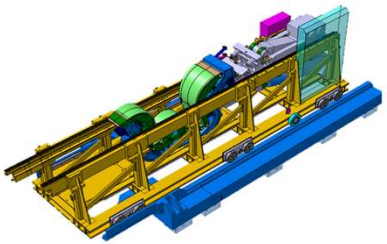
Contract for tool design and manufacturing awarded to Larsen & Toubro, India in April 2025.

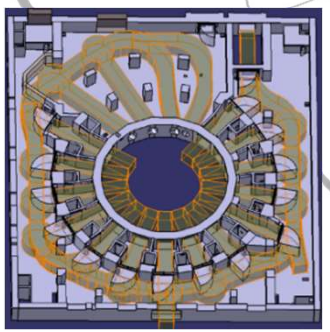
For more details, see the presentation by Vikram Sehgal (L&T).

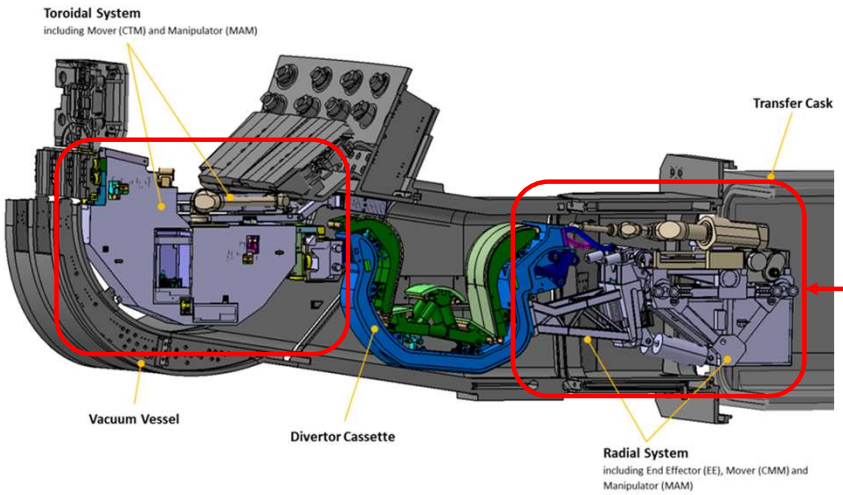
Divertor Assembly Transporter

- **Running procurement with European Domestic Agency: F4E**

CPD: **C**ask **P**latform for **D**ivertor : Transfer components (CMM, cassette, CTM) from Assembly Hall to Port Cells







- DAT-CTM (**C**assette **T**oroidal **M**over) transfer cassettes into VV

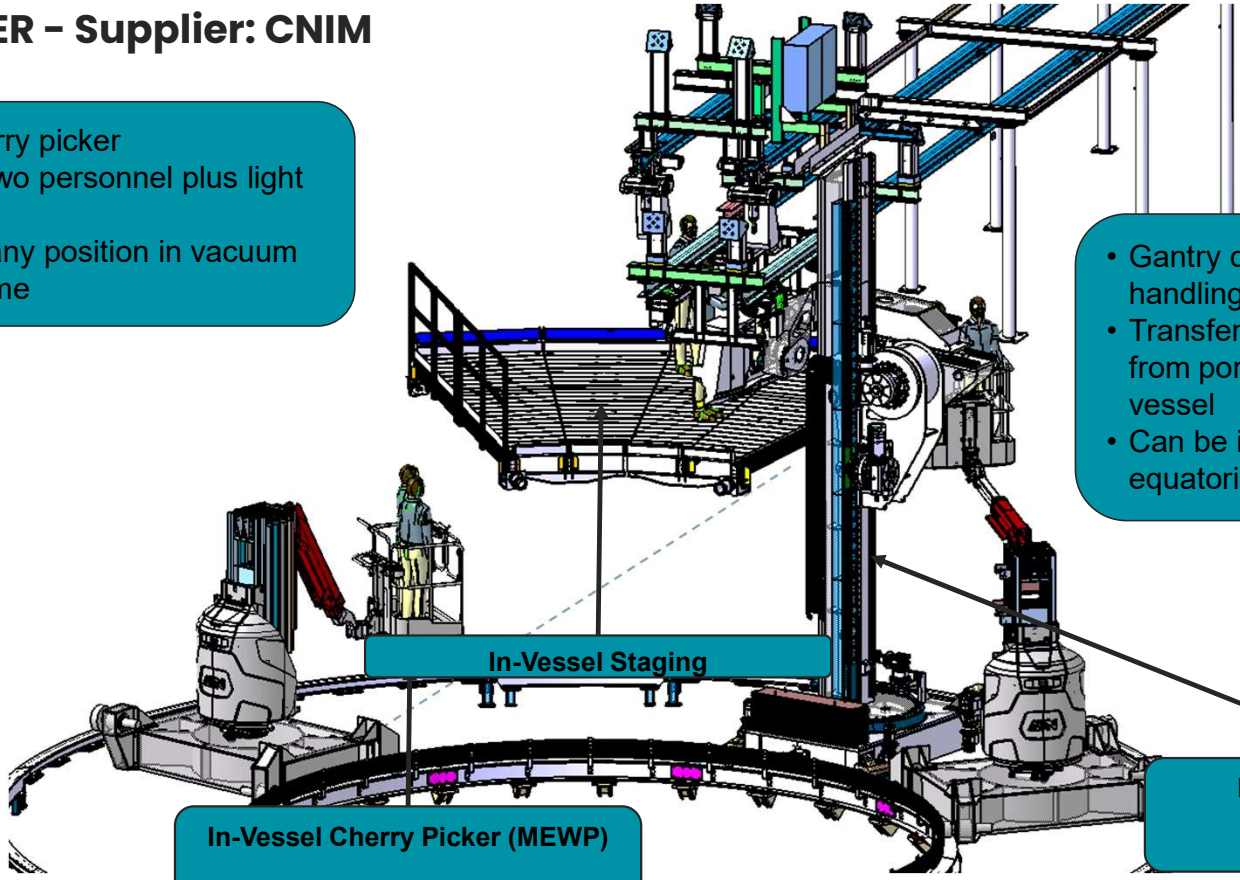
- DAT-CMM (**C**assette **M**ultifunctional **M**over) : Transfer cassettes or CTM from Port Cell to VV

For more details, see the presentation by Emilio Ruiz Morales (F4E)

In-Vessel Tower crane

- **Delivered at ITER - Supplier: CNIM**

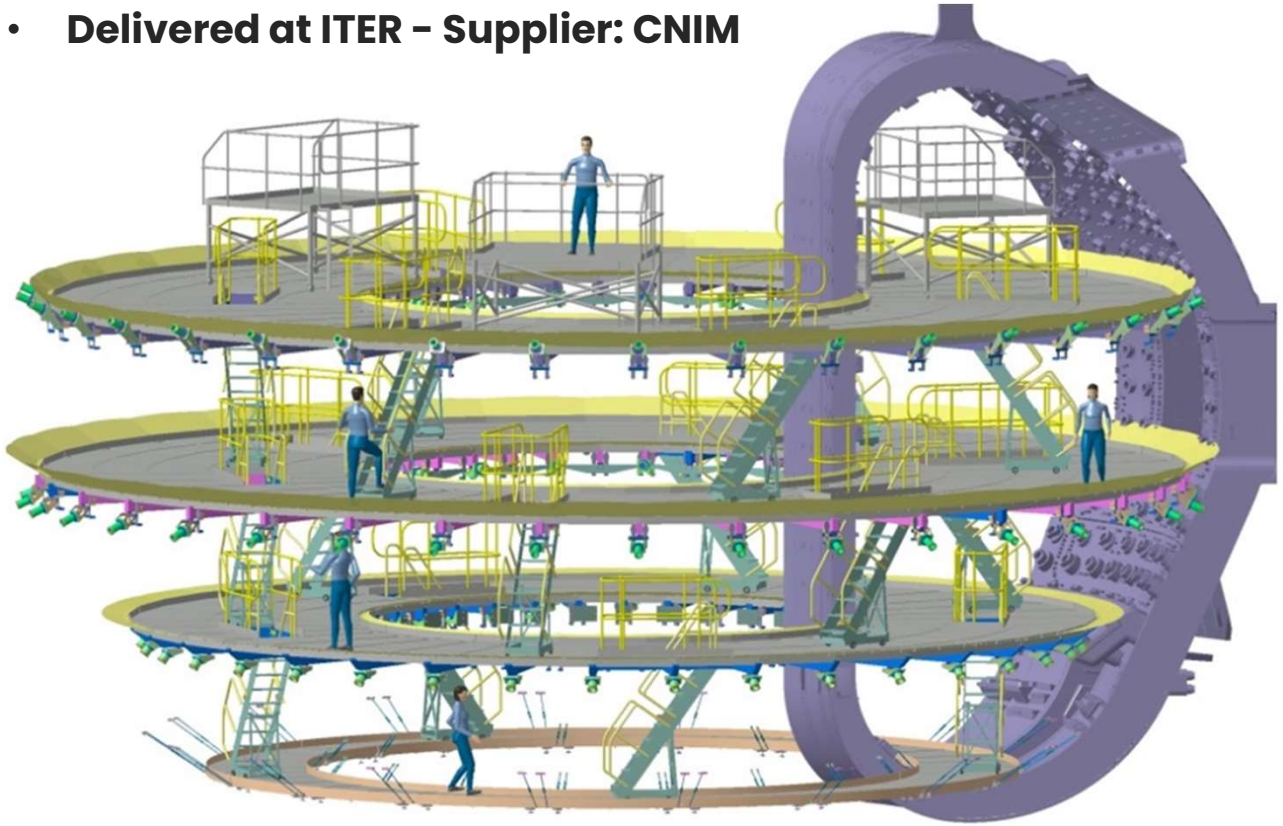
- Electric cherry picker
- Basket for two personnel plus light tools
- Can reach any position in vacuum vessel volume



- Gantry crane-style materials handling system
- Transfers tooling and components from port cell to interior of vacuum vessel
- Can be installed in any regular equatorial port

In-Vessel Staging

- **Delivered at ITER - Supplier: CNIM**

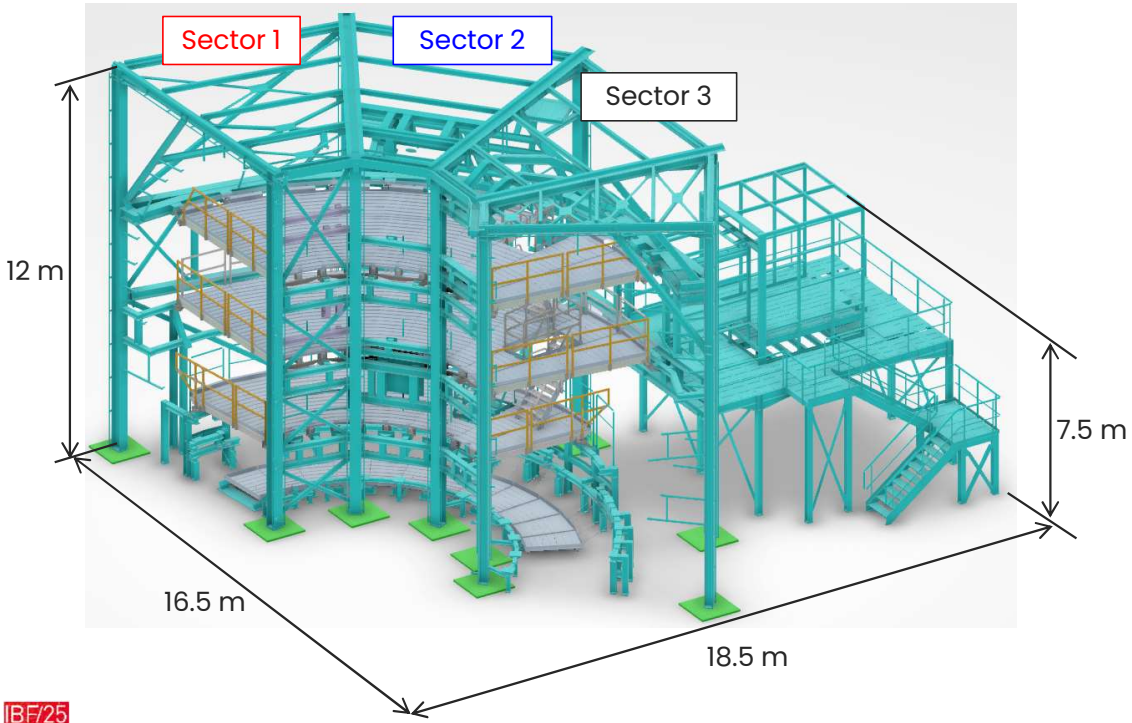


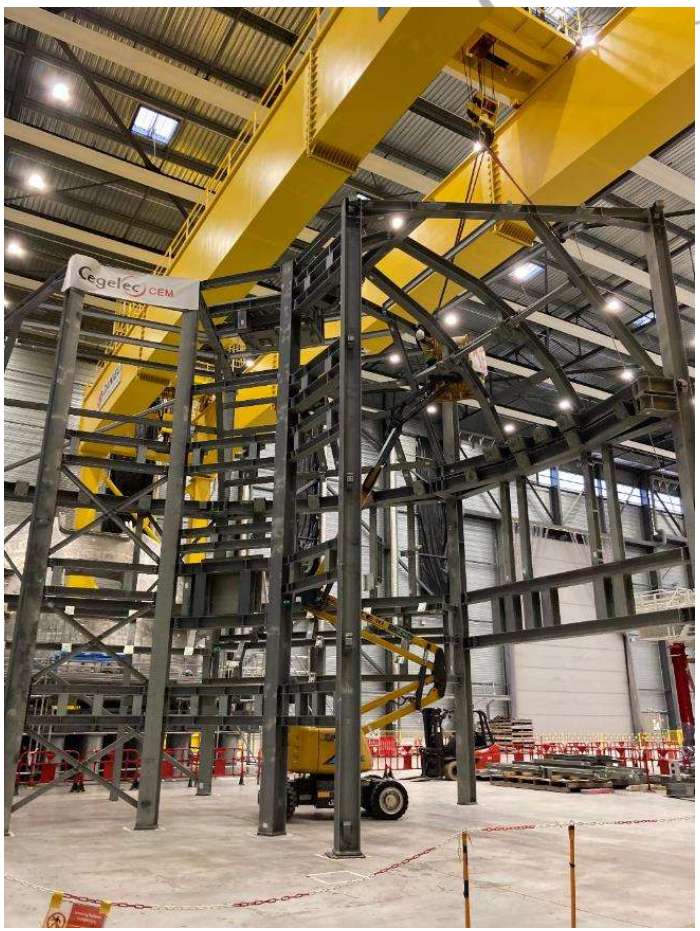
The staging is designed so manual access is possible to all areas of the VV inner wall.

This staging is lightweight and modular, so it can be manually assembled and disassembled.

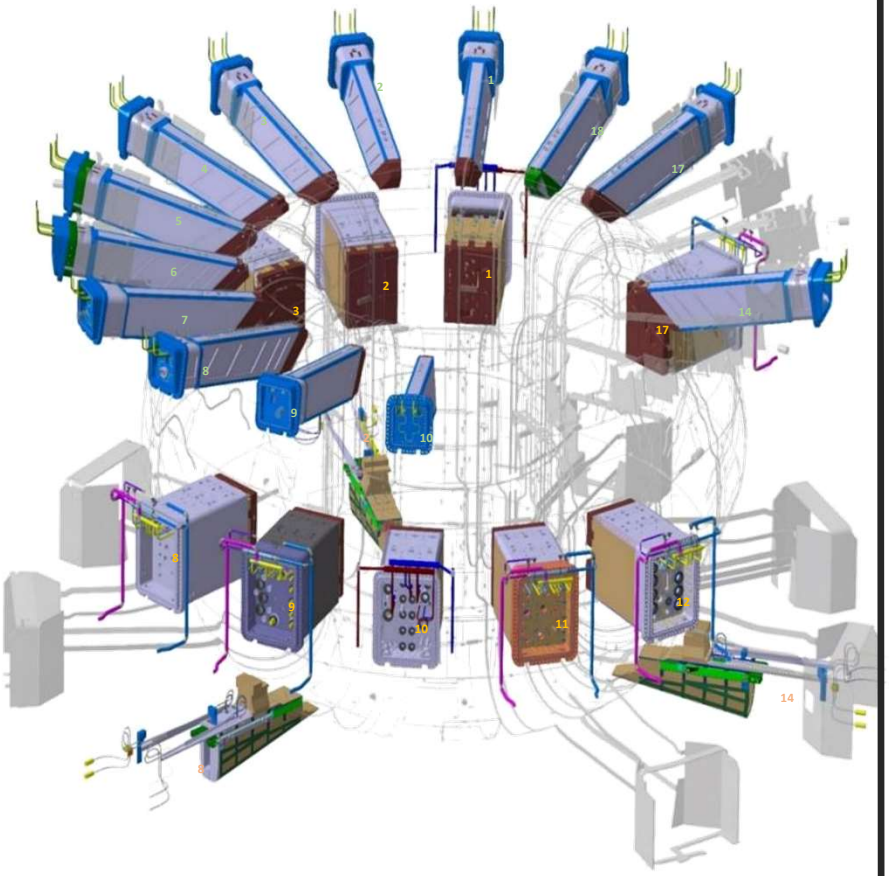
Trial, Test and Training Facility

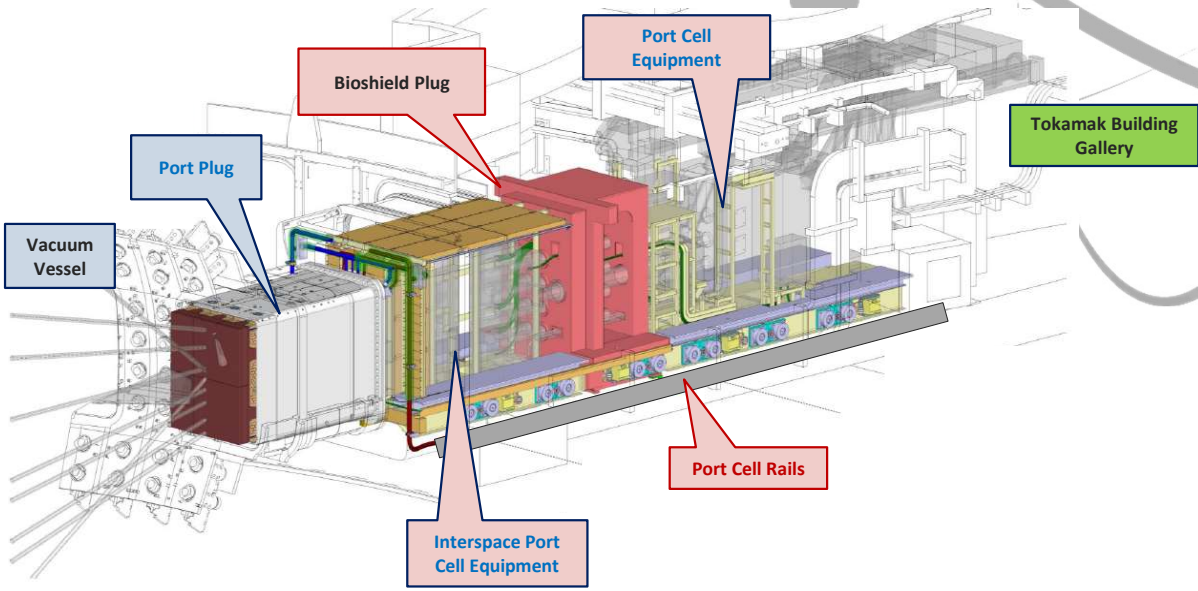
- The purpose of the Trial, Test and Training Facility (TTTF) is to qualify and test the tools dedicated to the assembly of components inside the Vacuum Vessel (VV) of the ITER plant.
- **Delivered at ITER – Supplier: CNIM**





Port Plugs, Interspace and Port Cell Installation





- 36 Port plugs (Diagnostics and Heating): Top, mid and lower level
- Integration of core Technologies with a first representative batch of tooling.
- Partnership with Industrial partner sought to collaborate early.

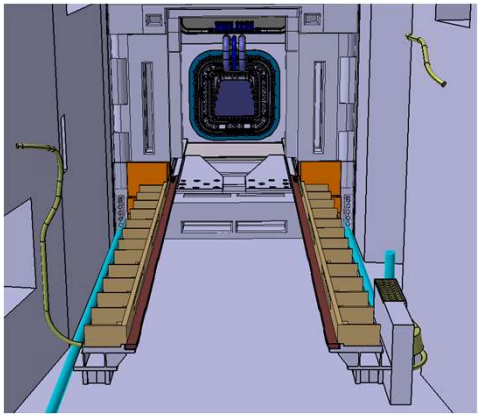
PORT CELL RAILS

Scope:

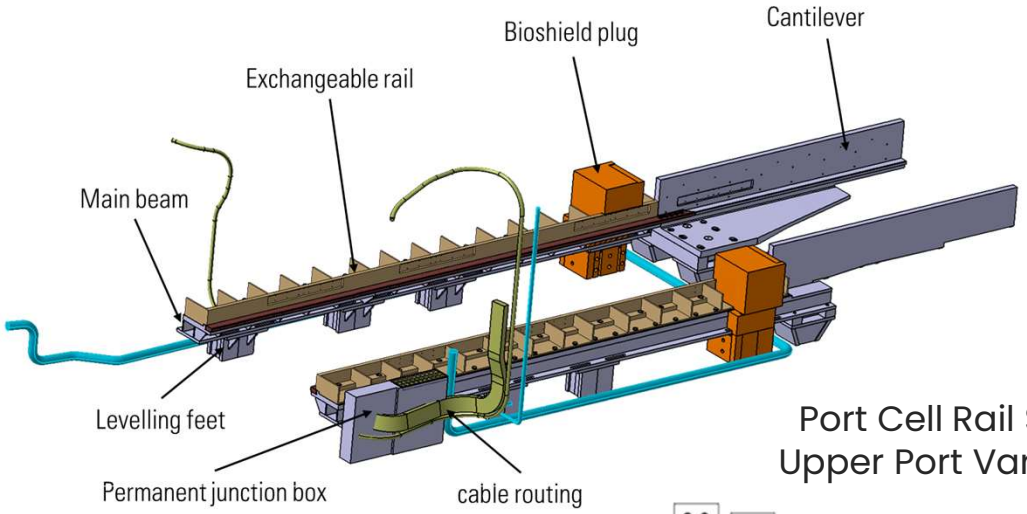
- Detailed design and manufacture of up to 37 sets of Port cell Rails (11 variants)

Characteristics:

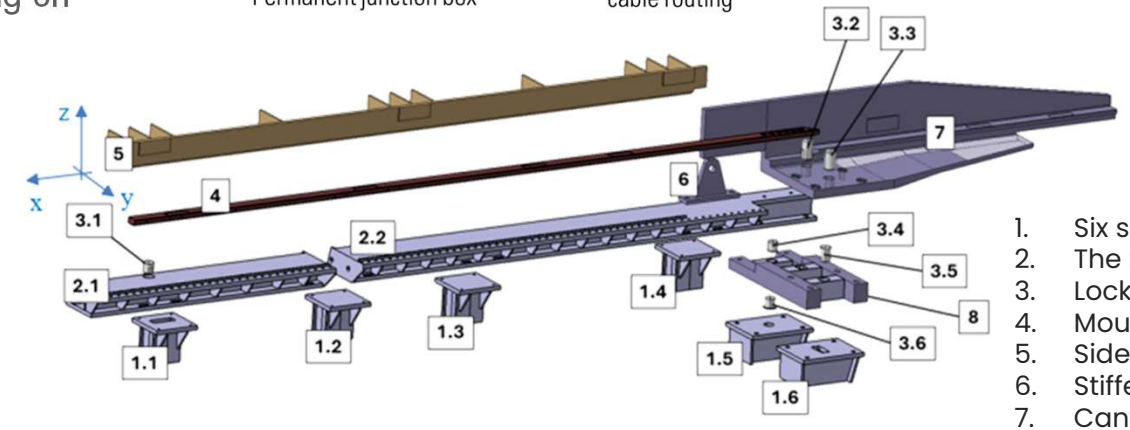
- Fabricated Carbon steel structures
- Anti-corrosion coating suitable also for decontamination
- 10 – 20 tonnnes per rail pair (depending on port cell)



Port Cell Rails in context



Port Cell Rail Set
Upper Port Variant



1. Six supporting feet
2. The main beam
3. Locking pins
4. Mounting rail.
5. Side rail
6. Stiffening feature.
7. Cantilever board.
8. Cantilever support.

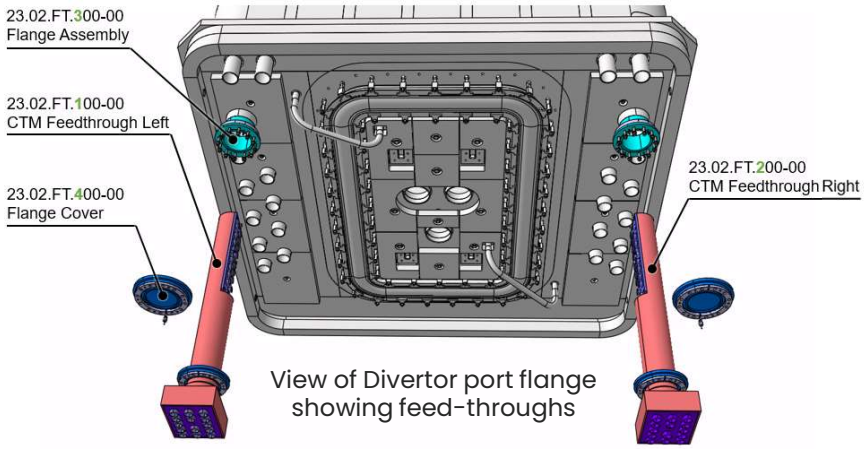
Divertor RH Feed-throughs

Scope:

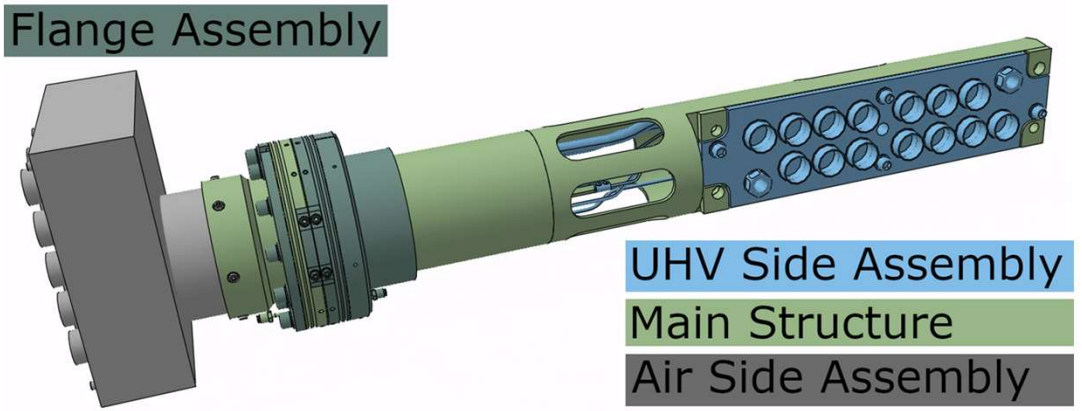
- Detailed design and manufacture of 6 electrical feed-through units (2 per port)

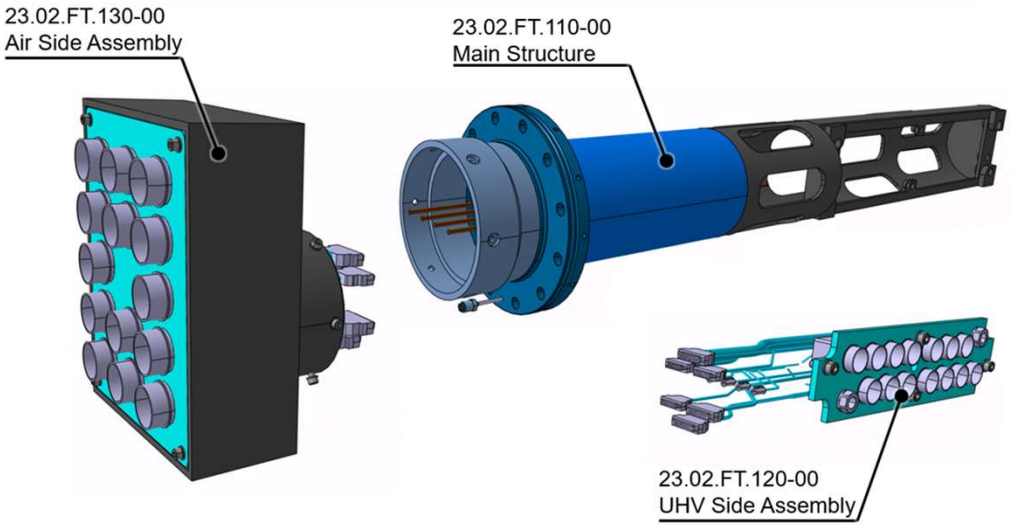
Characteristics:

- Vacuum feed-through from port cell to in-vessel environment
- Stainless materials
- Protection Important Component



View of Divertor port flange showing feed-throughs



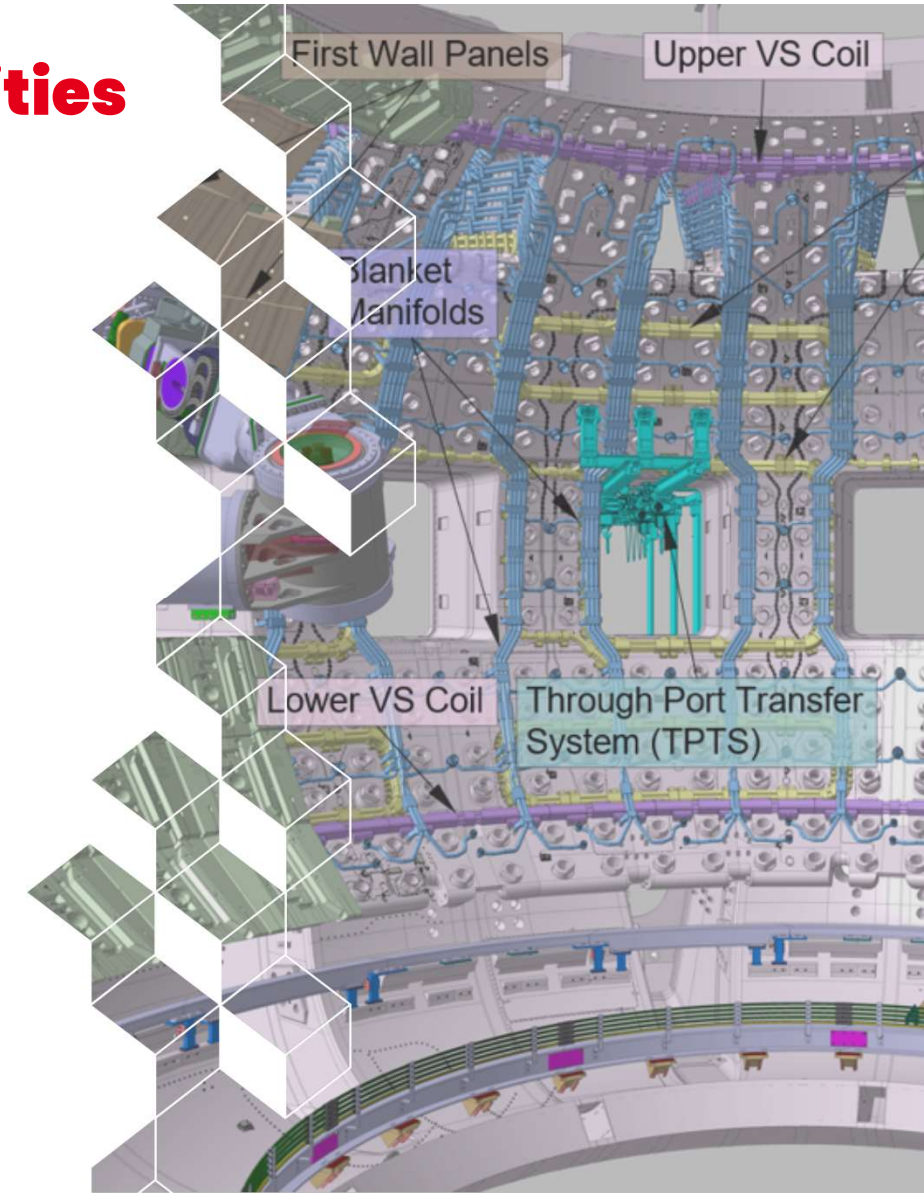


Near-future Industrial Opportunities

- **In-Vessel Tower Crane upgrade** → S2 2025
- **Blanket Manifolds customization** → S2 2025
- **Non-destructive testing** → S2 2025
- **He Leak testing development** → S2 2025/2026
- **Welding of primary vacuum boundary components, subject to RCC-MR** → 2028
- **Port plug tilting tools, lifting frames, installation tools** → Q1 2026 – Q3 2027
- **Port Plug lifting and installation** → 2028/2029
- **Port Cell equipment installation** → 2028/2029
- **Port sealing** → 2028/2029

Assembly and Installation opportunities for further phases of **the In-Vessel Assembly.**

<u>Timeline:</u> from now until 2030



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THANKS

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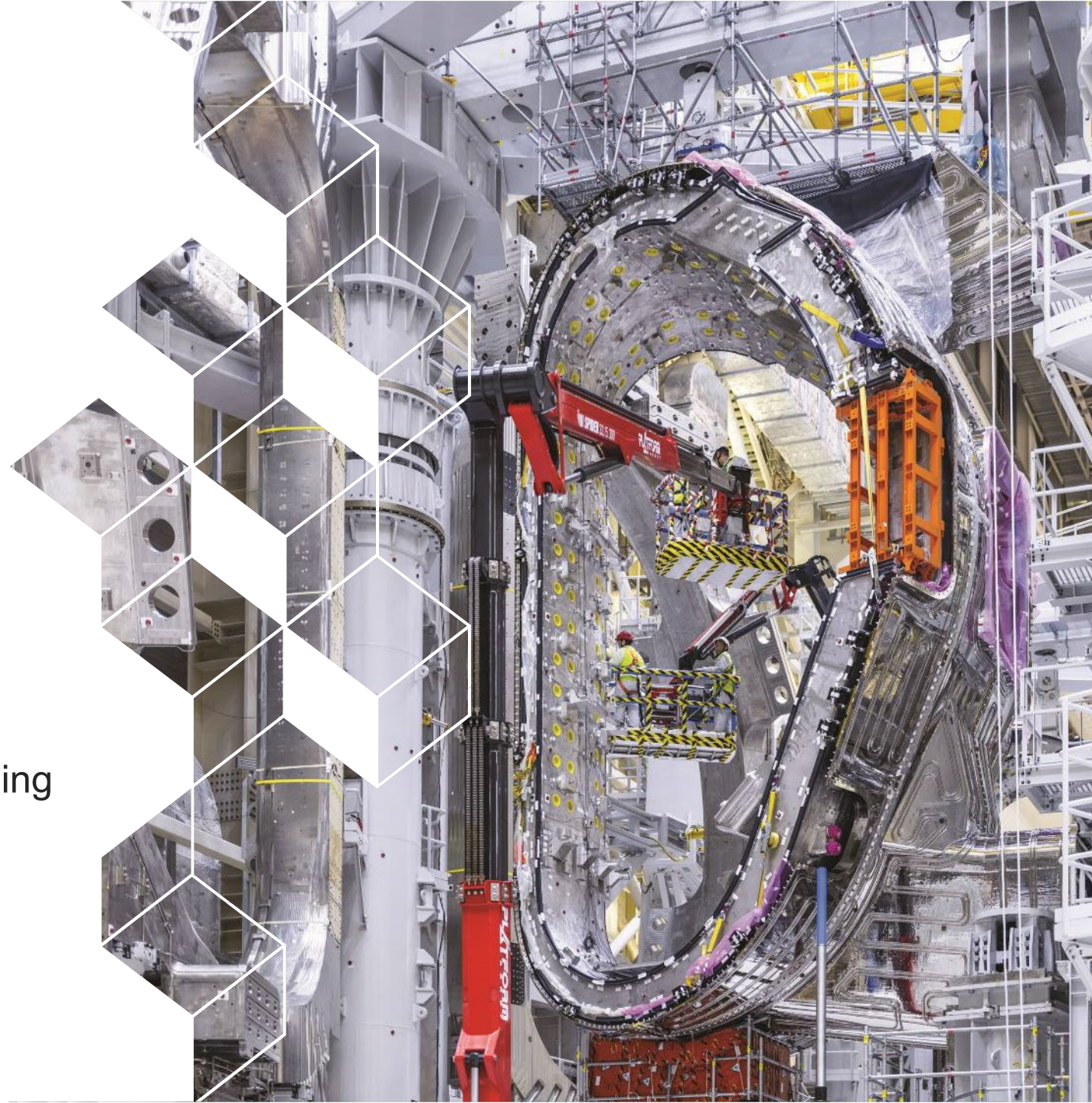
F4E Remote Handling Procurements during the ITER assembly time-frame

Emilio Ruiz Morales

Fusion For Energy – Remote Handling Programme Manager

FRIDAY APRIL 25th

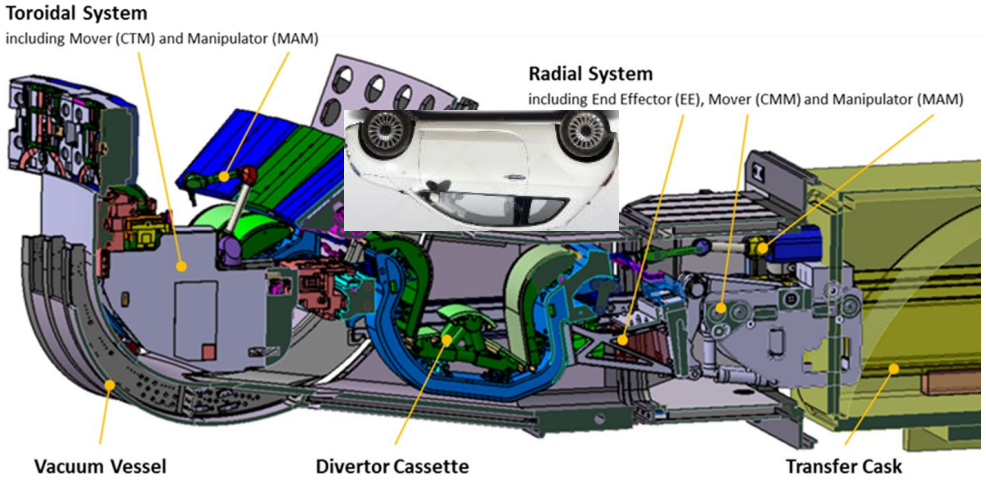


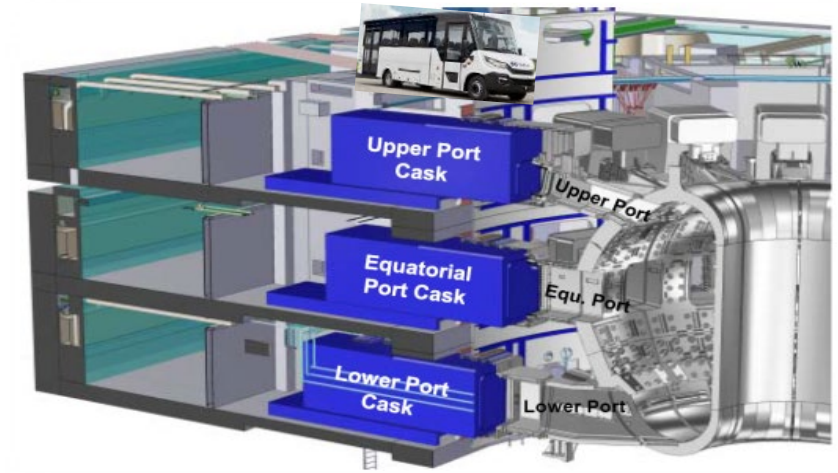
Outline

1. Overview on the F4E Remote Handling scope for the Nuclear Phase (DT-1/2)
2. F4E Remote Handling scope for ITER Assembly Phase
3. Current main contractual tool for Assembly Systems
4. Business opportunity left on F4E RH Scope for ITER Assembly
5. DRHS, CPRHS and NBRHS Business Opportunities in the ITER Assembly Time-Frame
6. Technology Development Program opportunities on Remote Handling
7. Conclusions

1. Overview on the F4E Remote Handling Scope

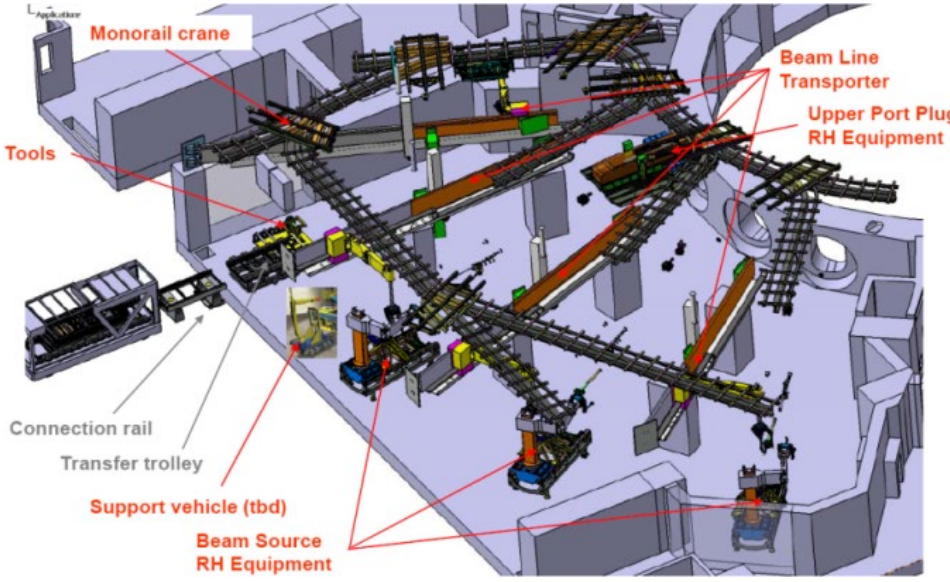
Divertor Remote Handling System (DRHS)

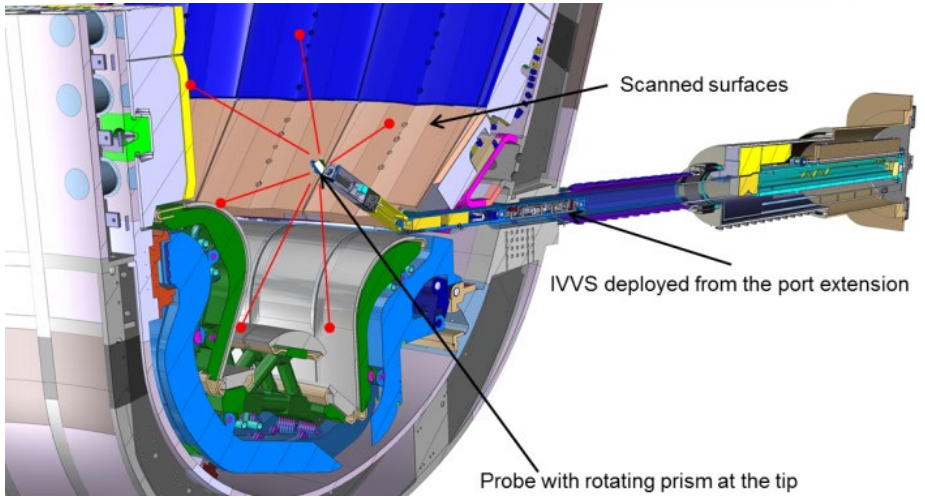




Cask & Plug Remote Handling Systems (CPRHS)

Neutral Beam Remote Handling System (NBRHS)





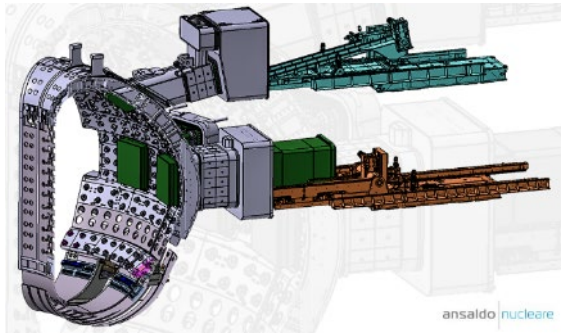
In-Vessel Viewing System (IVVS)

F4E in charge of the procurement in-kind of 4 packages

1. General F4E Remote Handling Scope

ITER remote maintenance is a complex, integrated and diffused system embedded in the nuclear plant (it includes many subsystems) and spread across various buildings

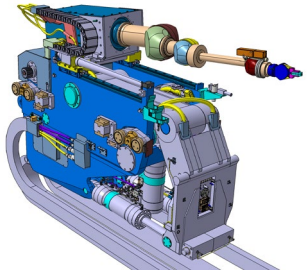
2. F4E RH Scope for ITER Assembly

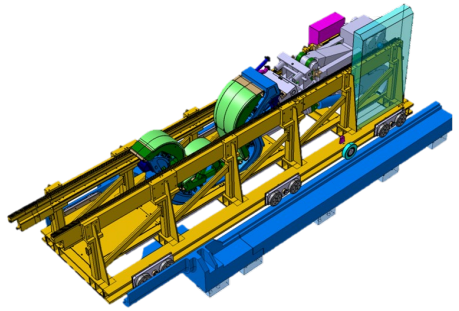


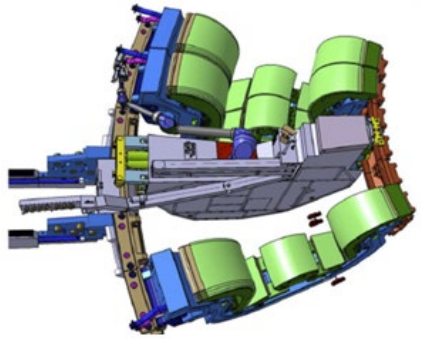
1rst Assembly Cask platform for Equatorial and Upper Port Plugs installation

Ongoing F4E contract OMF-1034-01-06

(end date: mid 2026)



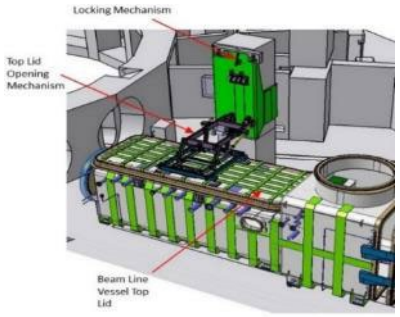




Divertor Assembly Radial and Toroidal Transporters and Cask Platform

Under OMF-1609 in 2026 (need date: mid 2030)

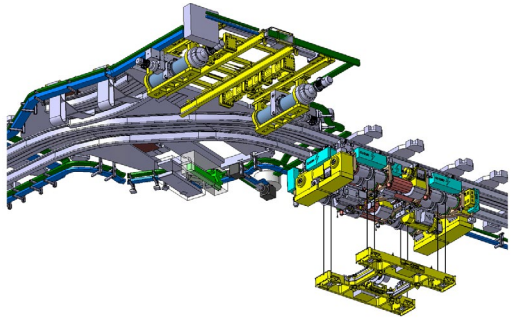
Assembly Tools for In-Vessel Assembly



Neutral Beam Top Lid Opening Mechanism - *no nuclear safety function, limited radiation resistance*

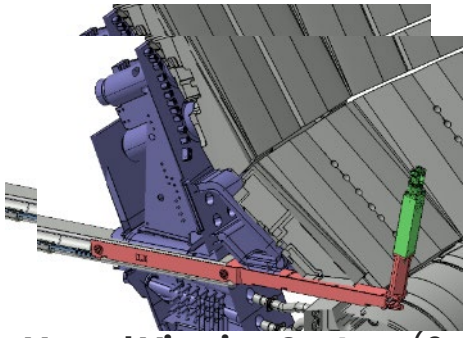
Under OMF-1609 (need date: mid 2031)

Nuclear-grade systems to be installed during ITER Assembly



Neutral Beam Maintenance Crane - *PIC feed-through , limited radiation resistance*

Under OMF-1609 (need date: mid 2031)



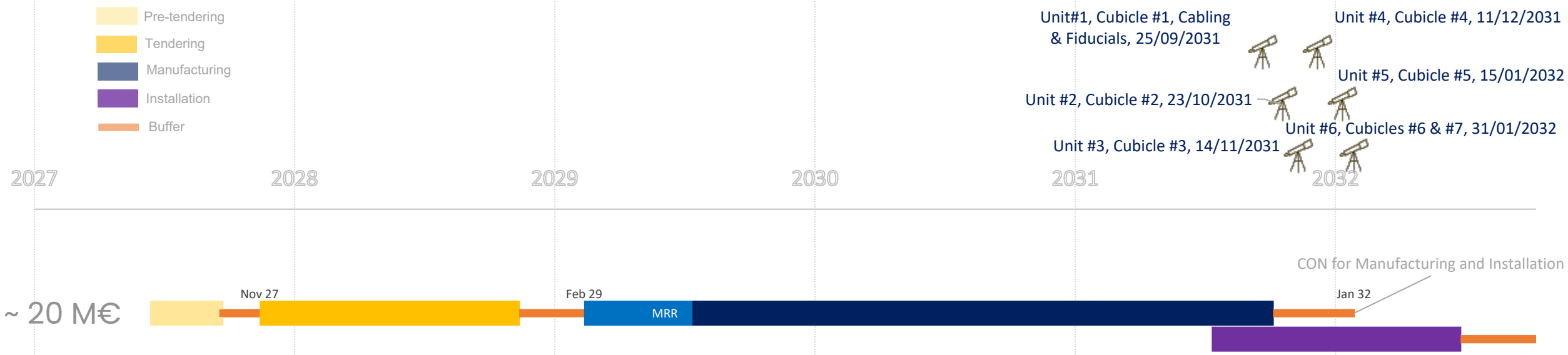
In-Vessel Viewing System (6 units) - *optical probe, machine, PIC feed-through, radiation resistant components already selected*

Procurement to be launched in 2027 by F4E (need date: end 2031)

3. Current main contractual tool for Assembly Systems: the OMF-1609 Framework Contract

- Multiple Framework Contract with reopening of competition at each task order
- Scope: final design and manufacturing of Divertor Assembly Transporters, Cask Platforms, NBRHS Crane System and TLOM, and other tools, components, mock-ups and installation platforms
- Framework duration: 5 years + 4 renewals of 1 year
- Task orders for of key Sub-Systems. Request for task Offers expected to be launched every 3~6months from early 2026.
- Minimum 4 task orders in 2026, selection of max. 5 suppliers
- Overall budget up to 2027: ~18M€ in 2026; ~11M€ in 2027
- Status: call for tender with business case launched in October 2024, under evaluation, contract signature expected in Q4 2025 → unfortunately there is no any longer business opportunities for main companies other than those that are participating in this call.
- However, still opportunities for niche SMEs related to mech. analysis, operations simulations, detail engineering etc.

4. Business opportunity left on F4E RH Scope for ITER Assembly: 6 IVV Units



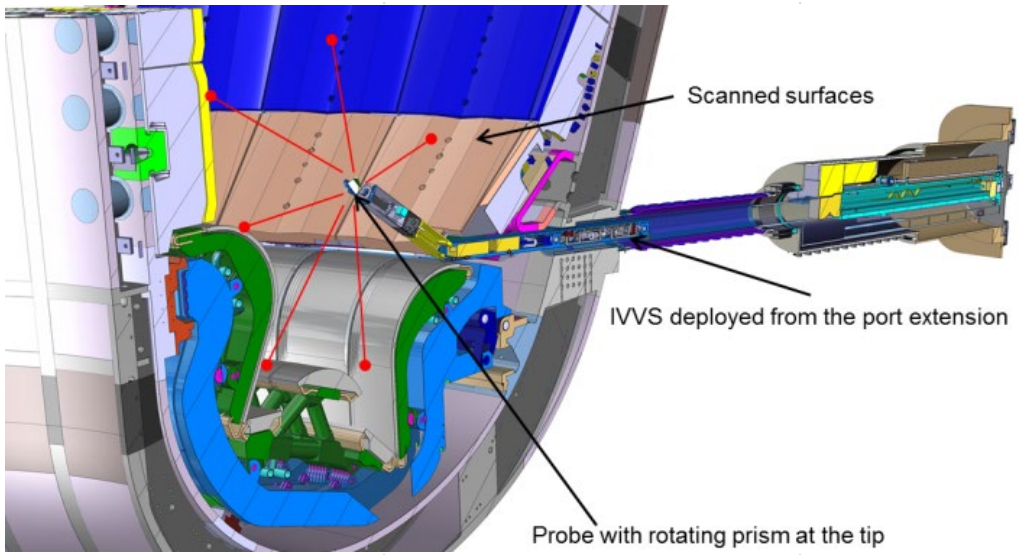
In-Vessel Viewing System (**6 units**) - *optical probe, machine, PIC feed-through, radiation resistant components already selected.*

Current project status:

- ***under Final Design to be completed in early 2027***
- ***Main IVVS components have been prototyped and tested***

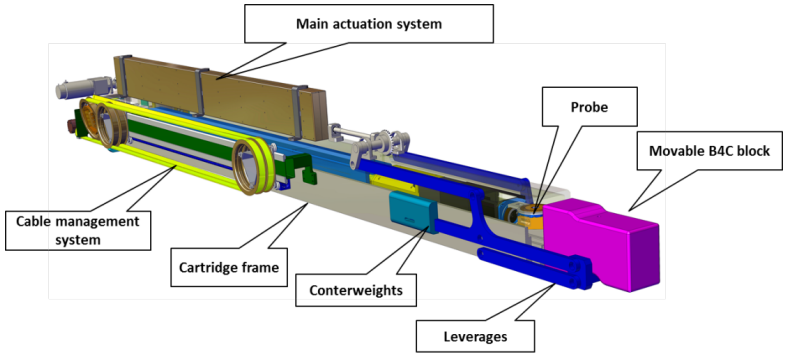
Manufacturing Procurement to be launched in 2027 by F4E

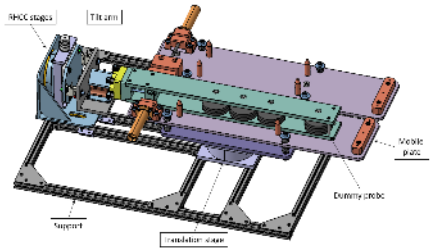
(need dates: end 2031-32)



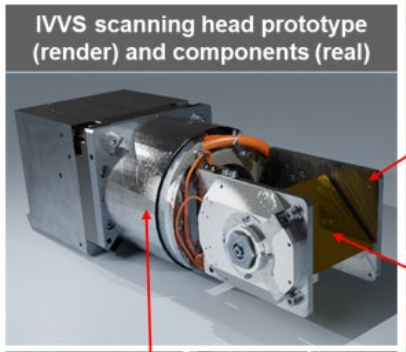
- **IVVS consists of 6 remotely actuated endoscopes able to perform in-vessel viewing and metrology (~0.1mm) between plasma pulses**
- Near infrared, amplitude modulated, laser scan
- It must be compatible with B, T, UHV, neutrons and gammas

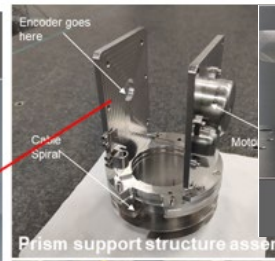
4. IVVS – Prototyping and design status

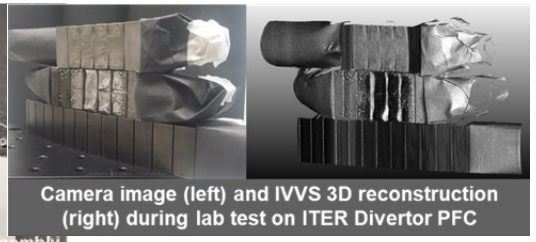


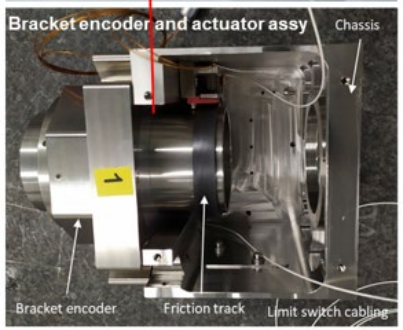


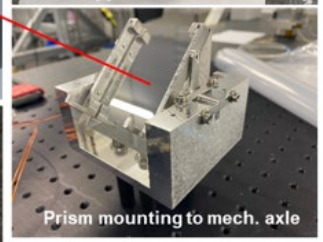
Probe replacement tool design and cable management system prototyped and successfully tested

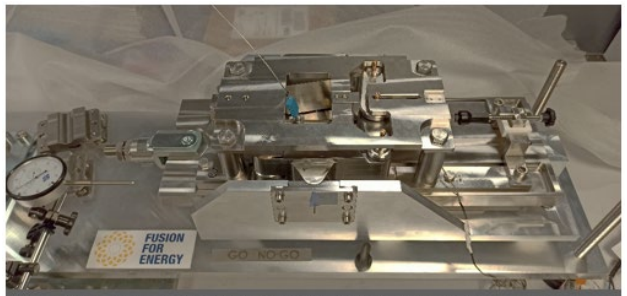








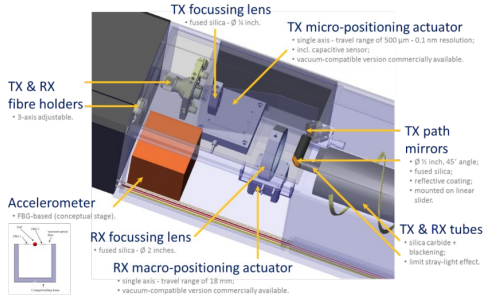




IVVS – Full-scale prototype of the Traverse Latch – it is the seismic-resistant, magnetic field compatible and radiation tolerant device that locks the IVVS in position during a scan

IVVS Thermal Outgassing Rig (TOR) procured to validate the compatibility of IVVS components with the ITER vacuum

IVVS – Full-scale prototype of the Remote-handing Compatible Connector – it is the high-density electrical/optical connector assembly that services the IVVS Cartridge when installed; it must be connected/disconnected via remote tooling located in the CPRHS



5.1 DRHS Business Opportunities in the ITER Assembly Time-Frame

Pre-tendering
Prep../Tendering
FD
Manufacturing
Installation
Buffer

2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040

CTM/CMM/Tooling 16/07/2037

CTM/CMM Spares 16/07/2039

DIVERTOR CTM / CMM /TOOLING AND SPARES

~ 15 M€

F4E-IO Upgrade FD internally + spec. | Jun 33 | May 34 | FDR | Jan 35 | MRR | Jul 37

TO (FWC-1347) for CTM and Tool Final Design and Manufacturing

Jul 39

CTM Spares

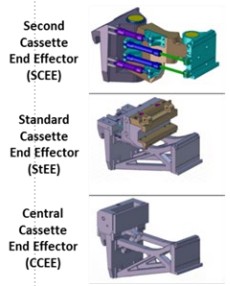
~ 15 M€

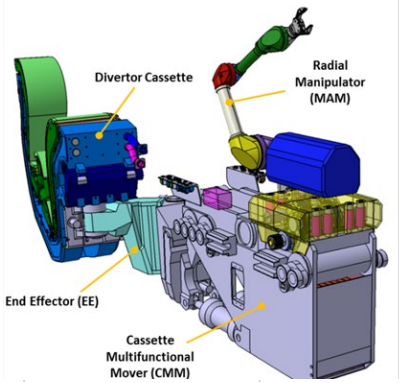
F4E-IO Upgrade FD internally + spec. | Jun 33 | May 34 | FDR | Jan 35 | MRR | Jul 37

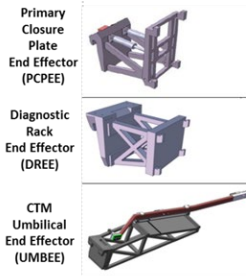
TO (FWC-1347) for CMM Final Design and Manufacturing

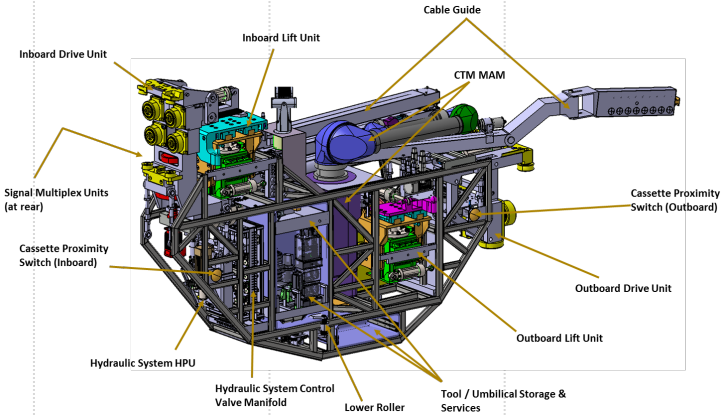
Jul 39

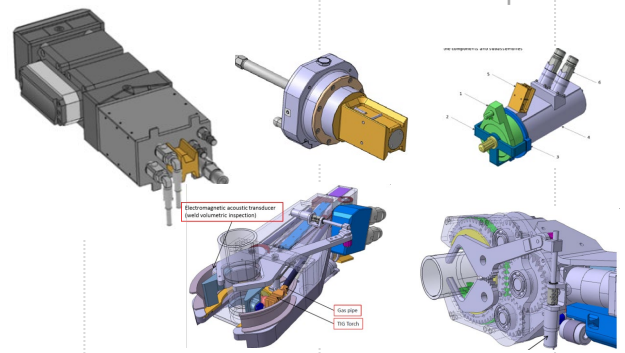
CMM Spares







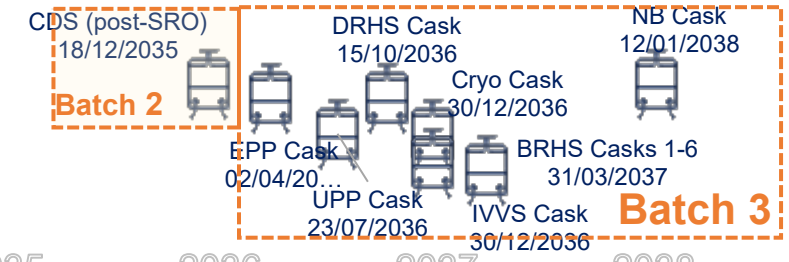


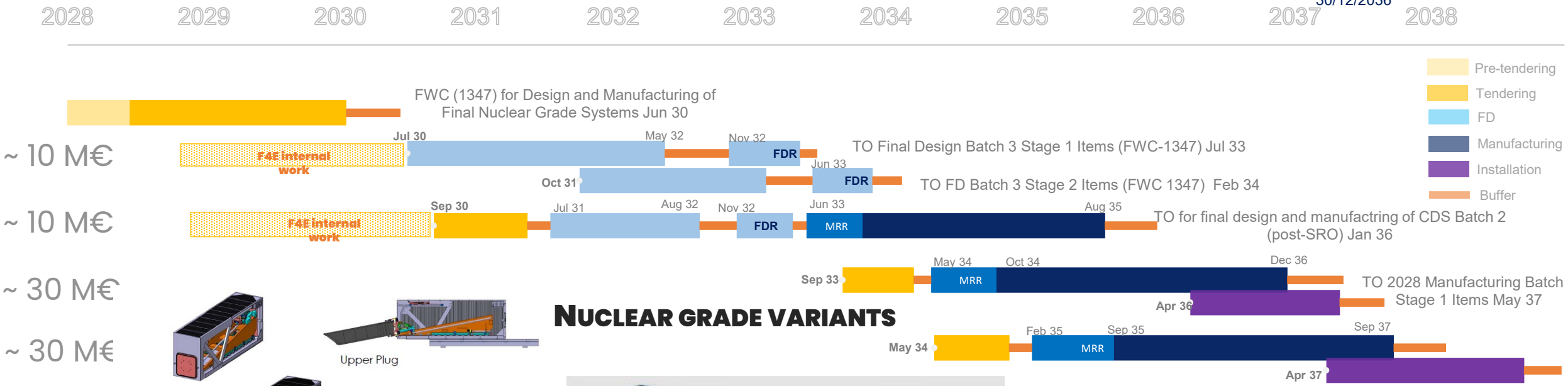


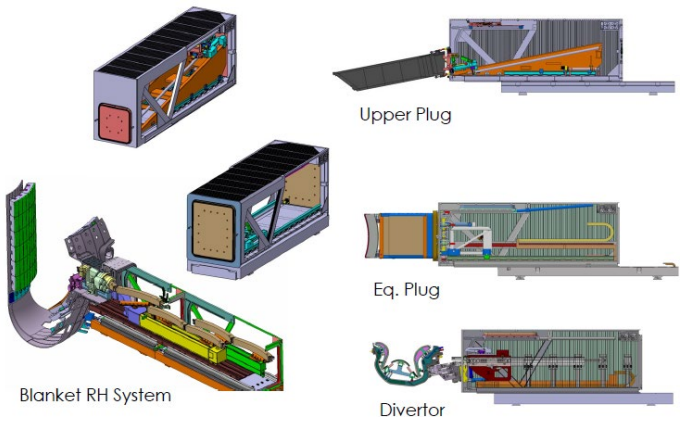
DRHS tools for the divertor cassette locking system and for pipes cutting, welding and NDE

5.2 CPRHS Business Opportunities in the ITER Assembly Time-Frame

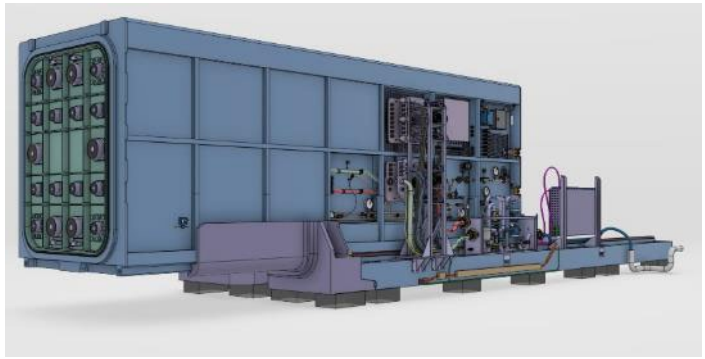
CPRHS consists of a fleet of 15 casks, of different typologies, travelling across TKM and HC buildings for confined transportation of activated/contaminated components and other RH systems







NUCLEAR GRADE VARIANTS



5.3 NBRHS Business Opportunities in the ITER Assembly Time-Frame

BLT/BSRHE/Transfer Systems + Tooling

BSRHE full
15/10/2036

BLT full
15/09/2033

Tooling
15/10/2036

Transfer Sys
01/04/2037

2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038

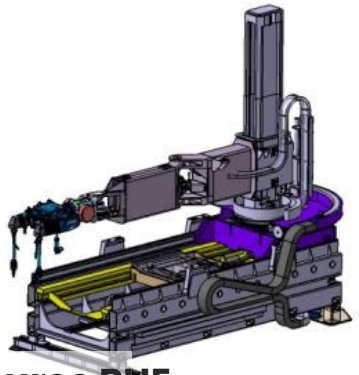
~ 20 M€

Sep 28 — Sep 30 — FDR — MRR — Feb 34 — BLT FD + Manufacturing

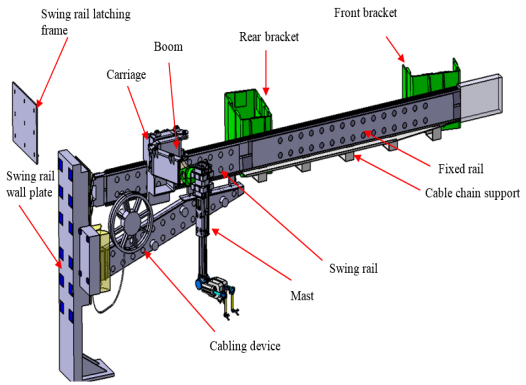
~ 30 M€

Oct 30 — Apr 32 — PDR — May 34 — FDR — MRR — Apr 37 — BSRHE, Transfer system and tooling PD + FD + Manufacturing

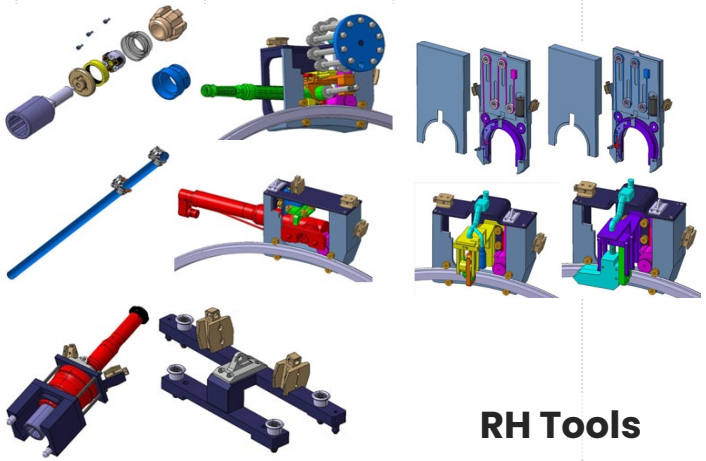
Tendering
PD
FD
Manufacturing
Buffer



Beam Source RHE



Beam Line Transporter (BLT)



RH Tools

NBRHS is a diffused, hot-cell like, multiple system, in a $10^3 m^2$-scale complex area, shared with other plant systems (HNB, DNB, upper plugs, VVPSS…), largely inaccessible during ITER shutdown.

6. F4E's Technology Development Program opportunities on Remote Handling

- Candidate Remote Handling technologies currently under assessment

- Examples of potential Topics: Development, qualification and integration in real/demonstrators of
  - in-bore and orbital tools for pipes cutting, welding and Non-Destructive Essays
  - gamma and neutron radiation-hard sensors, actuators (e.g. piezo motors), and BiSS remote I/O modules
  - FM LIDAR
  - Robotics joints
  - Etc.

- Projects to be defined in the course of 2025, calls from 2026 onwards

7. Conclusions on Business Opportunities

- Previous slides shows a significant number of tenders: typically > 10M€ < 30M €, for final design and/or manufacturing, to be launched between 2027-2031, during the ITER assembly time frame
- Opportunities will come through the Technology Development Program
- We definitively need, and privilege, an open and dynamic approach to our collaboration with industries
- Stay tuned on our call for tenders and updates in next IBFs

IBF/25

INTERNATIONAL ITER BUSINESS FORUM

THANKS

TO BE PART OF THE WORLDWIDE **FUSION** NETWORK

Experience of an SME with validating maintenance procedures

ITER Business Forum 2025 - Thematic workshop: Machine Assembly Program n°2

dr. C.J.M. Heemskerk www.heemskerk-innovative.nl

Agenda

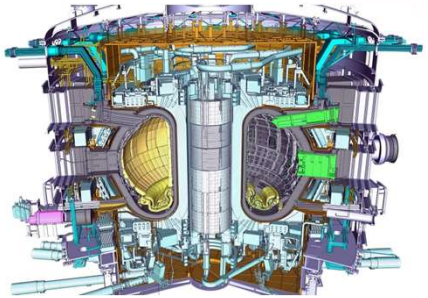
1. Company
2. Using Virtual Reality in Remote Handling Maintenance – Virtual Mockups
3. Virtual reality in Hands-on Maintenance
4. Application in Big Science

HIT

- Full name: Heemskerk Innovative Technology BV
- SME, established 2007
- 12 employees (2 PhD, 5 MSc, 5 BSc), 9 FTE, >60 years experience
- Plus 5-10 graduate & undergraduate students

Location: Delft, The Netherlands

Core business: consultancy in remote handling



Partners & Clients

VR techniques in Remote Handling - Virtual Mock-ups

- **Prepare for shutdown maintenance**
  - New machine, new plant, high investments, pressure on MTTR
  - While the machine or plant is still in operation
  - When shutdown conditions are unique
- **Develop and validate procedures**
  - Avoid expensive 1:1 scale hardware mock-ups
  - Validate complex procedures
  - Get early feedback on practical maintainability
- **Train and support the operators**
  - Large teams to be prepared for the shutdown
  - Nominal procedure training: multiple views
  - Non-nominal procedures, safety training

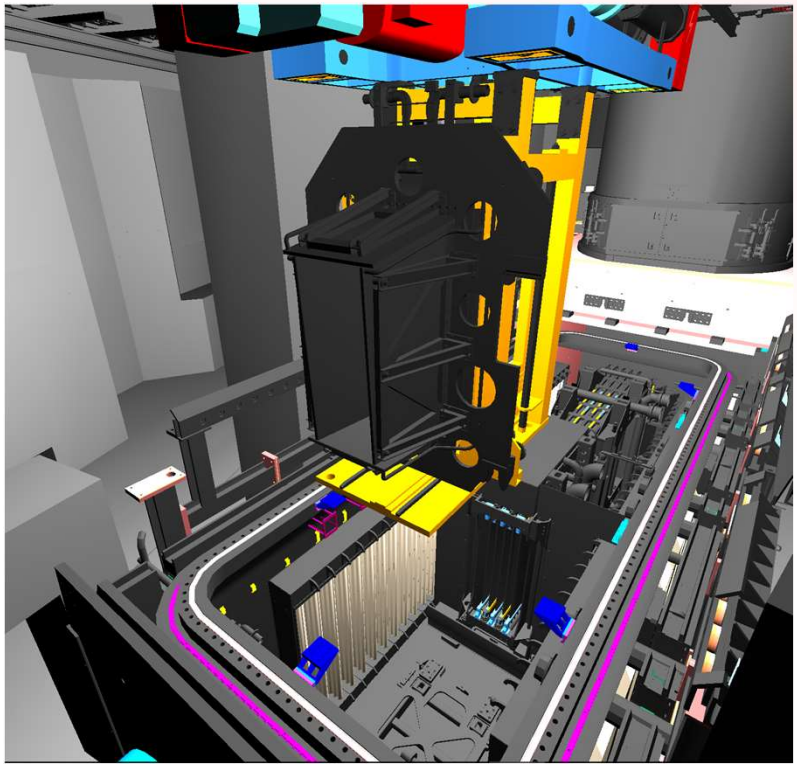
Example: Neutral Beam Exit Scraper

Customer: F4E \ AMEC (ABC)

Task: Analyse concepts for NB exit scraper replacement

Results:

- Analysis using a Virtual Mock-up
- Realistic behaviour in the interaction
- Several design recommendations to avoid/ correct misalignment
- Need for Augmented Reality ***during operations***



VR techniques for Manual Maintenance

- Comply with the ALARA principle: Limit dose rates and exposure times by design, long before the actual exposure of these human workers
- Developments in quality of head mounted displays now also allow for first-person hands-on assessment. Key contributions:
  - VR provides new means to **judge feasibility** of maintenance operations
  - VR helps to make more **realistic estimates of maintenance times**
  - VR helps to **verify component designs** and develop tooling
  - VR helps to **verify maintenance procedures**
  - VR helps to **train operators** and make actual operations more efficient

Example: EC Equatorial Port Cell Maintenance

Customer: ITER IO

Task:

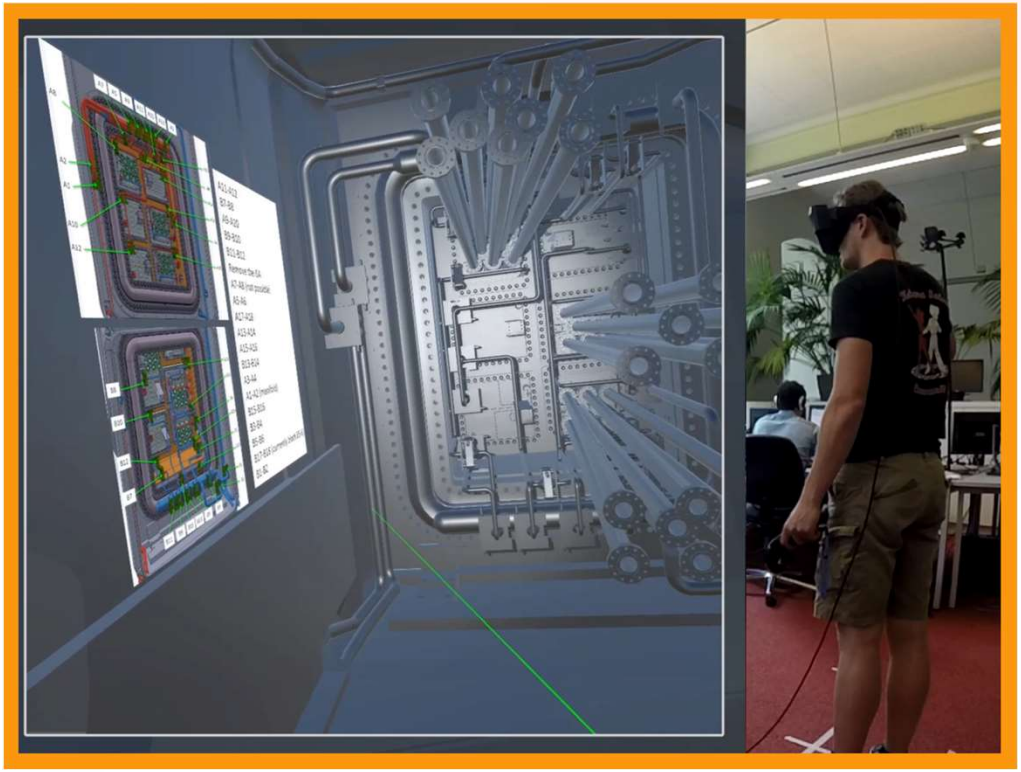
- Analyse port cell maintenance procedures

Tool:

- Virtual Mock-up of EC port Cell
- VR headset

Results:

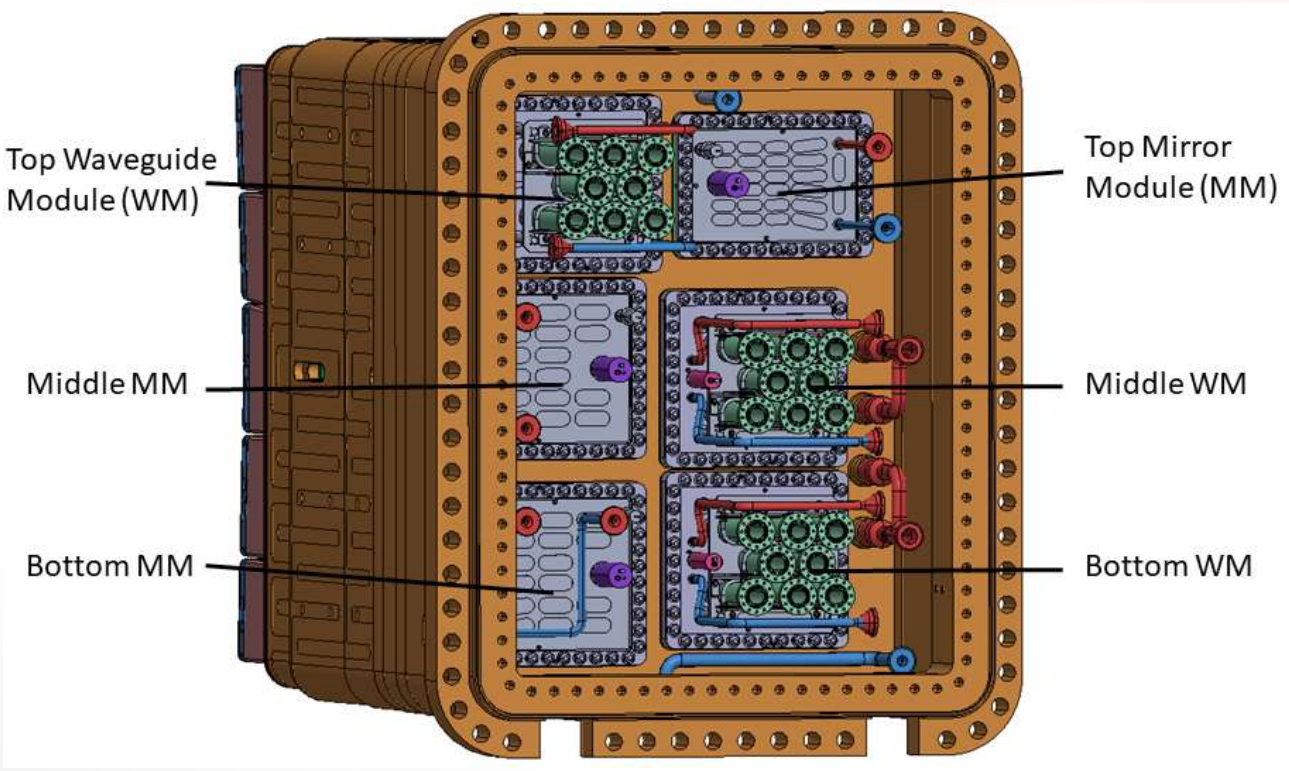
- Check on procedure feasibility
- Port Cell Access Constraints
- Working at heights
- Dose rate prediction



VR Setup

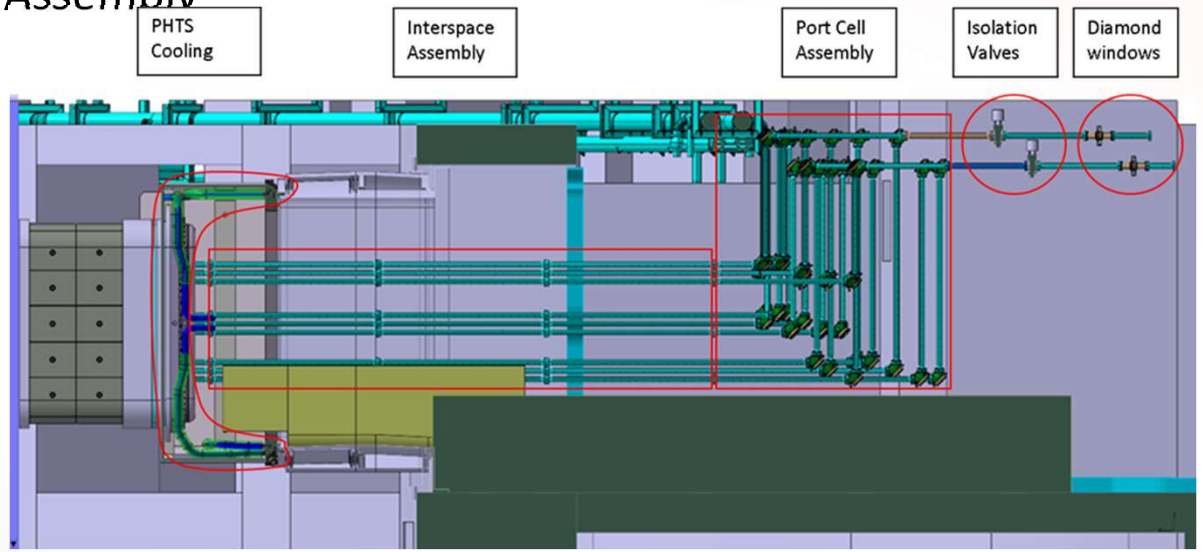
- HTC Vive pro kit
- CPU: Intel core i7-8700 CPU at 3.20Ghz
- RAM: 32 GB
- GPU: Nvidia GeForce GTX1660 Ti graphics card
- Unity
- CAD models prepared for VR use.

Back end of the EC EL port plug



RH and HO/MA Maintenance tasks

- Removal of the Port Plug
- Replace an Isolation Valve
- Replace a Diamond Window
- Remove the Port Cell Assembly
- Remove the Interspace Assembly
- Remove the water connections
- Remove all the ancillaries

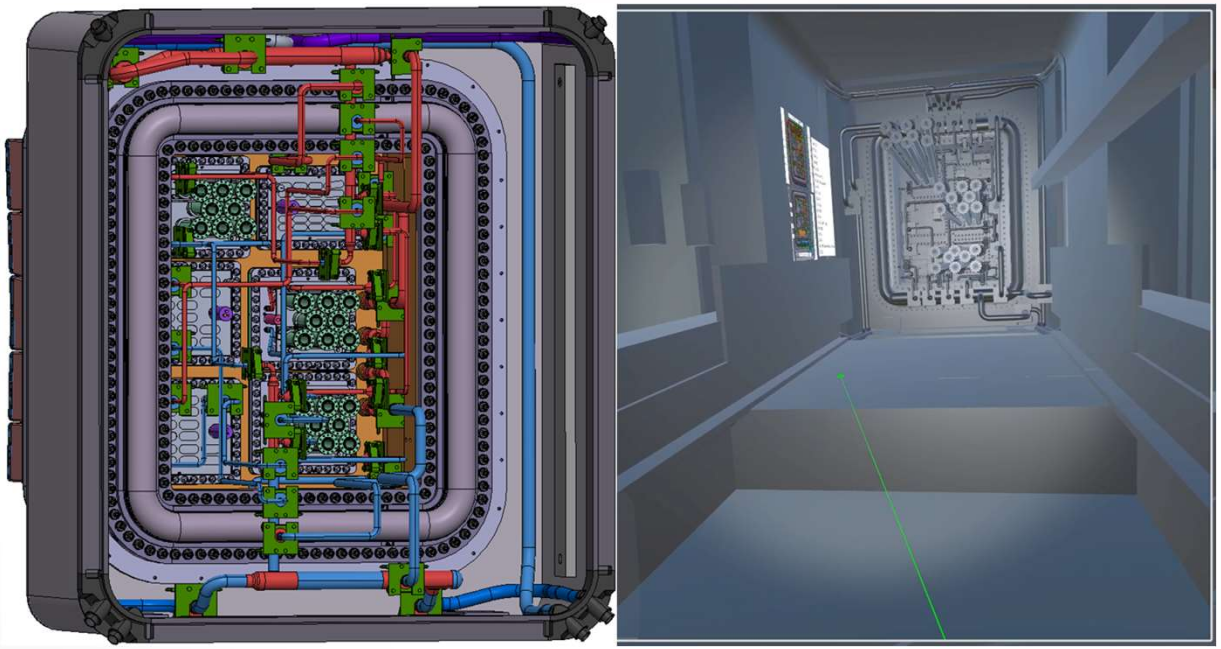


Immersion in the scene

- Intuitive perception of object size and size of the surroundings (5meter high ceiling).
- Better feeling and understanding for reach of the operator, given the different objects.
- Easy and intuitive to move around objects around different axis in 6DOF.

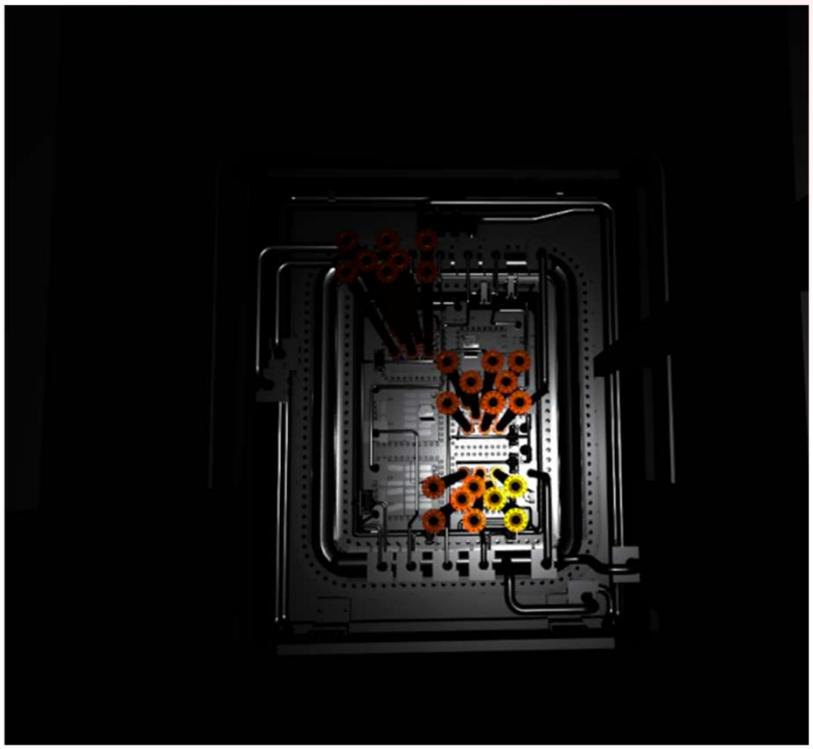
Differences with CAD model

- CAD models typically use artificial colours. In (virtual) reality we see steel on steel, making it much harder to recognize and distinguish parts.



Realistic light conditions

- Visual realism
  directly highlights the need for
  proper lighting
- Either installed on the spot
  or carried by the operator

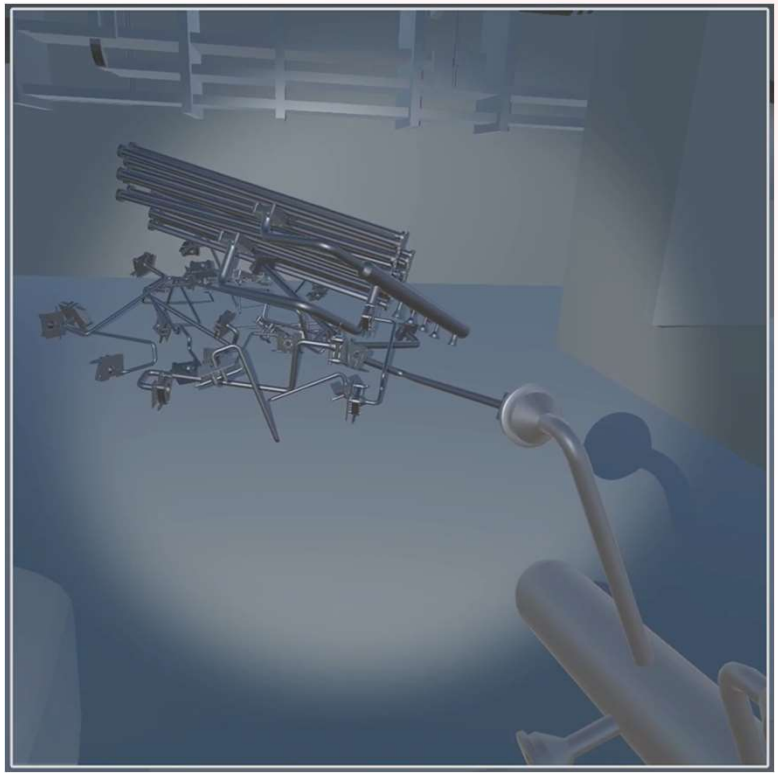


Intuitive respect for physical constraints

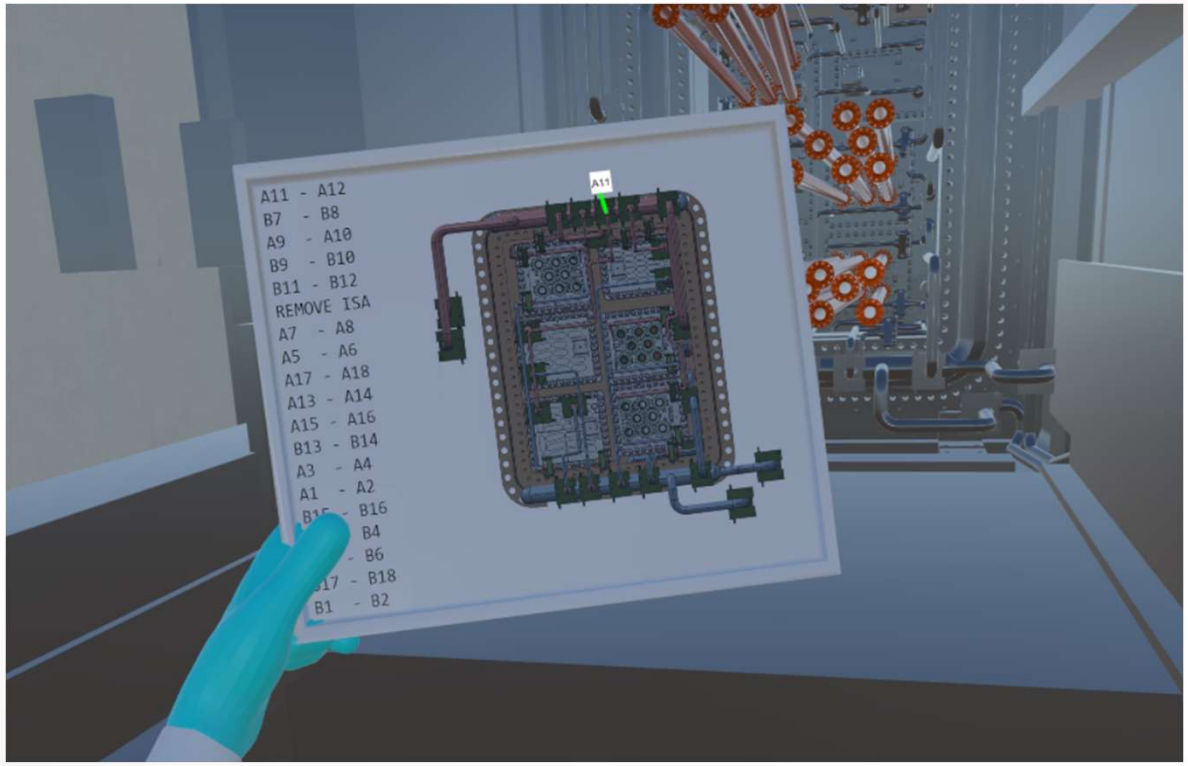
- Users tend to respect real-life physical constraints, even without actual physical limitations to go there.
- Users intuitively crouch and bend along obstacles.
- Similar behaviour when working at height.

Need for storage and support tools

- Embedded VR simulation forces users to think about logistics, as objects and tools should not appear out of or disappear into nowhere as they might do in a simple CAD software sequence.



Train and verify complex procedures



Conclusion

- Modern VR techniques can help to drive out feasibility issues on the sequence, access and sequence constraints, ergonomics and missing tools.
- Recent improvements in immersion helps to gain relative spatial awareness and provides an idea on the overhead of logistics and an actual representation of the scene.
- Added value of using VR techniques to analyse maintenance scenarios:
  - Very little training required to experience the process first-hand
  - Based on the actual CAD models
  - Assess geometrically complex maintenance sequencing
  - Less need for expensive hardware mock-ups
  - Considerations for details such as lighting, storage, tools logistics, etc.

Questions

1. How can IO/F4E keep SMEs involved?
   - This is where the real innovations takes place. Not only at the start but also during the ride.
   - In recent industry sessions, F4E seems to pay more explicit attention to this. How does that translate concretely to the RH domain?
   - HIT is good at making (VR) simulations – for design feedback, procedure validation, but also to prepare for installation, support during installation and operator training.
   - But most of these activities go right across into the large Procurements and is never a separate procurement.
2. Adequate procurement strategy with regard to the large RH contracts?
   - In Divertor, CPRHS, and NBRHS, previously selected RH consortia have caused problems.
   - Is there any introspection (especially at IO/F4E) about where and why it did not go well?
   - How are they going to tackle it now? Can SME's help?
   - How are they going to deal with the loss of UK?
3. What is the IO/F4E policy regarding standardization of procedures and tooling?
   - Is there a policy? Would they like some help with this?

"Bridging the gap between science and industry.
Making complex technology work."

IBF/25

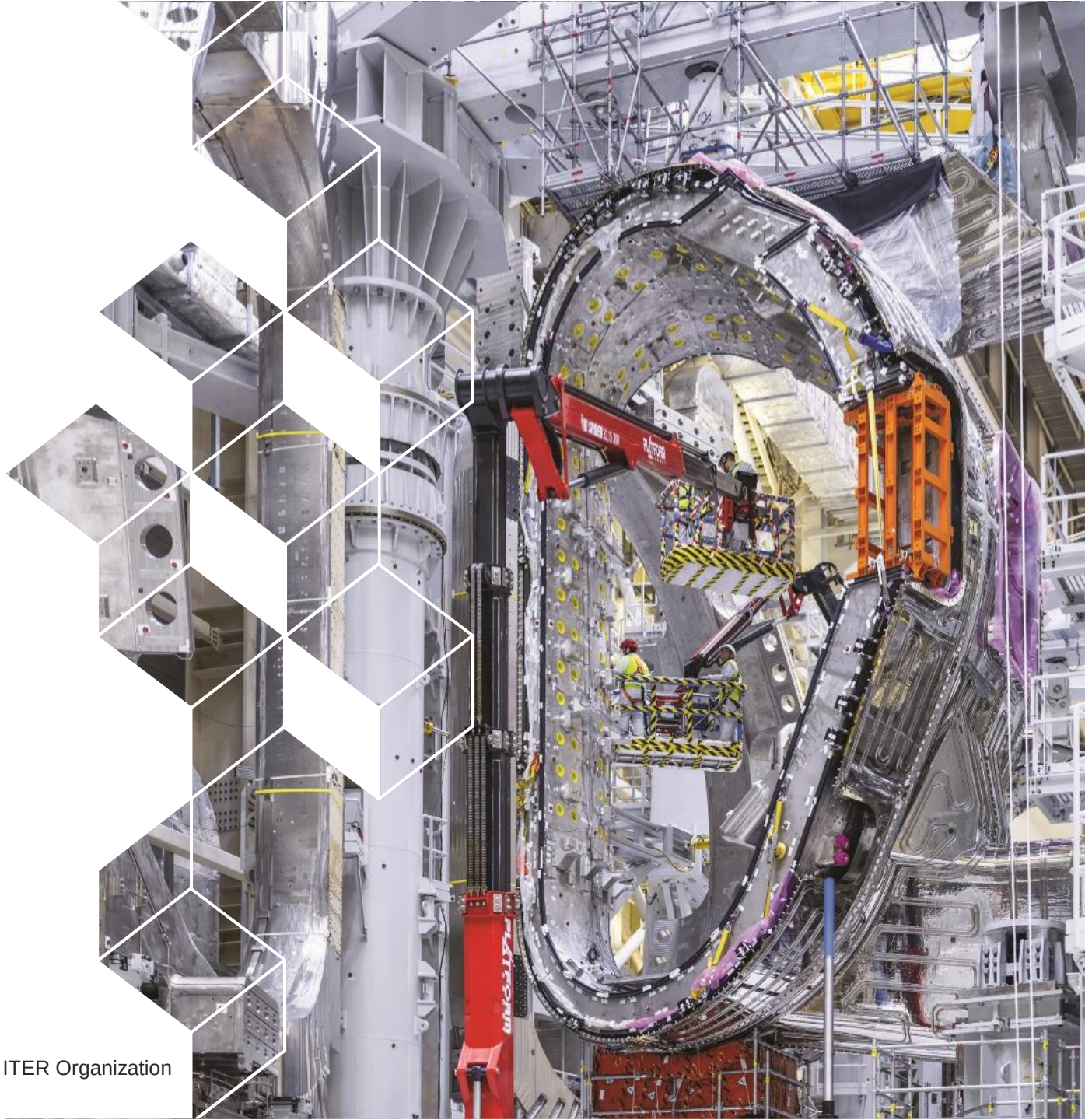
INTERNATIONAL ITER BUSINESS FORUM

OVERVIEW OF CURRENT NIKIET ACTIVITY FOR ITER PROJECT

Ivan Poddubnyi

NIKIET JSC,

Deputy head of department/ head of group

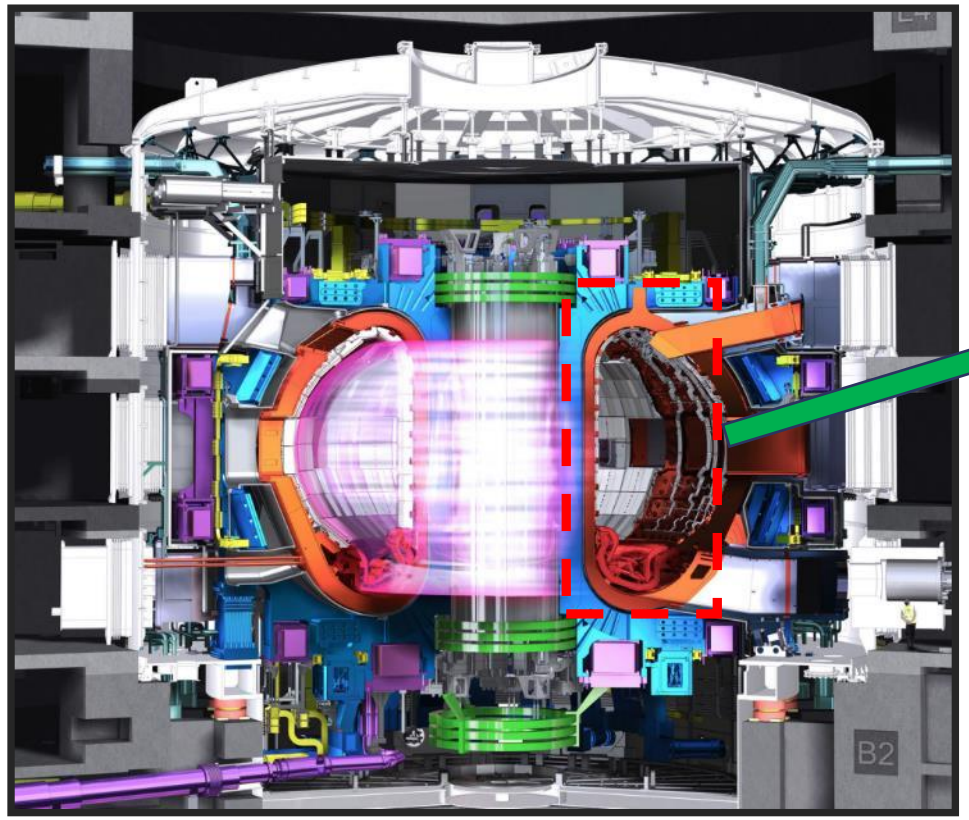


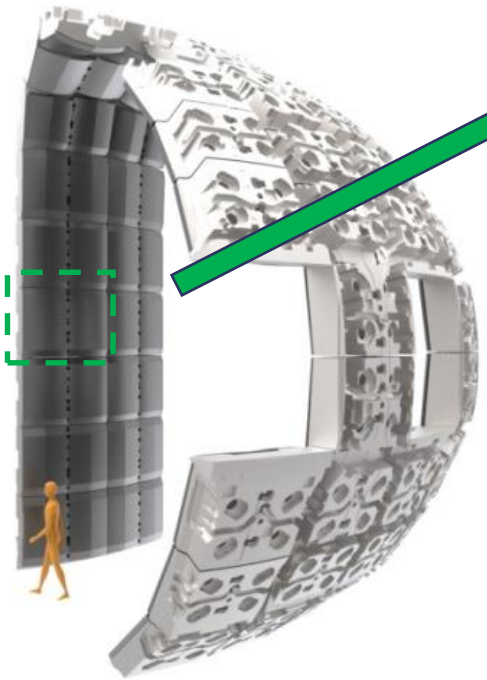
WEDNESDAY APRIL 23rd

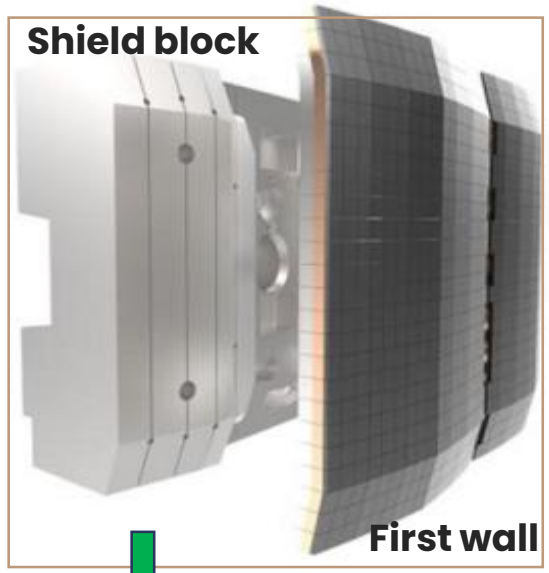
Procurement arrangement in NIKIET

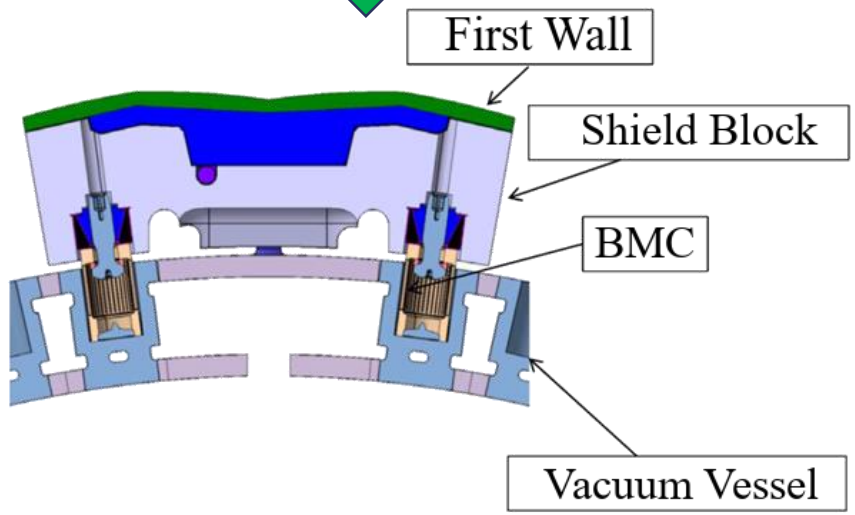
- Procurement arrangement for supplier the First Wall Panels with Enhanced Heat Flux - 1.6.P1A.RF.01 from 13.02.2014
  Start of serial production - 2021 y.;

- Procurement arrangement for supplier the Blanket Module Connections (BMC) - PA 1.6.P3.RF.01 from 19.12.2014
- Start of serial production - 2019 y.;





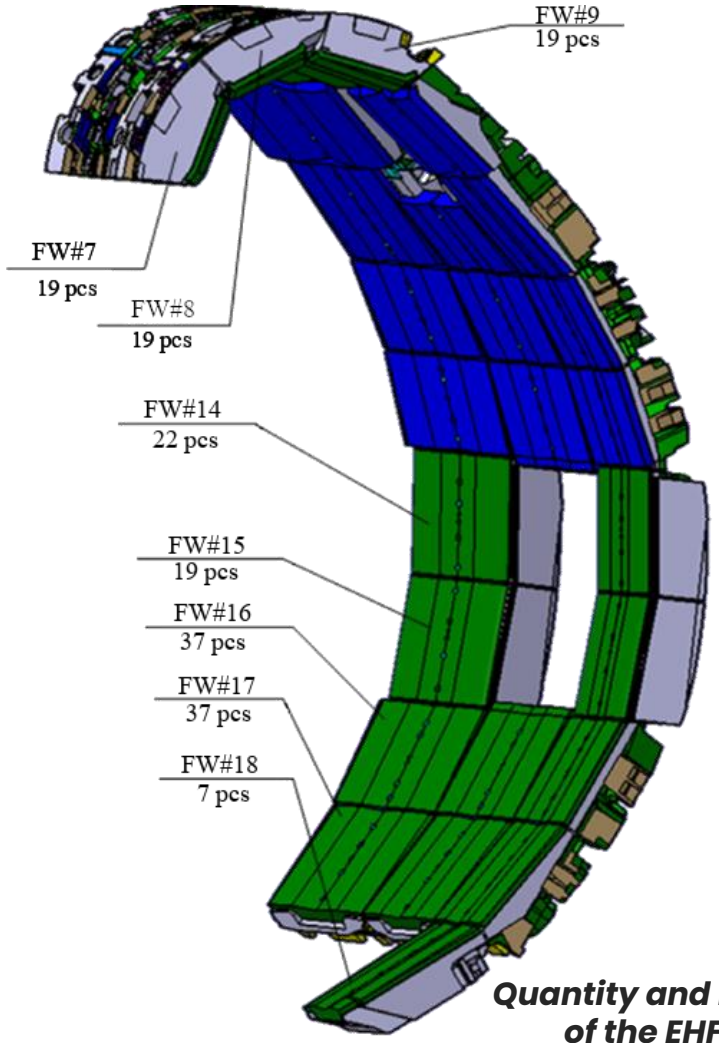




The NIKIET activity within the framework of the Agreement on the supply of First Wall. #1

The First Wall are a thermally stressed component of the blanket system facing the plasma and mechanically fixed to the shield block (SB) using a fastening system. A thermally stressed FW is capable of receiving a heat flux of up to 4.7 MW/m^2 acting from the plasma.

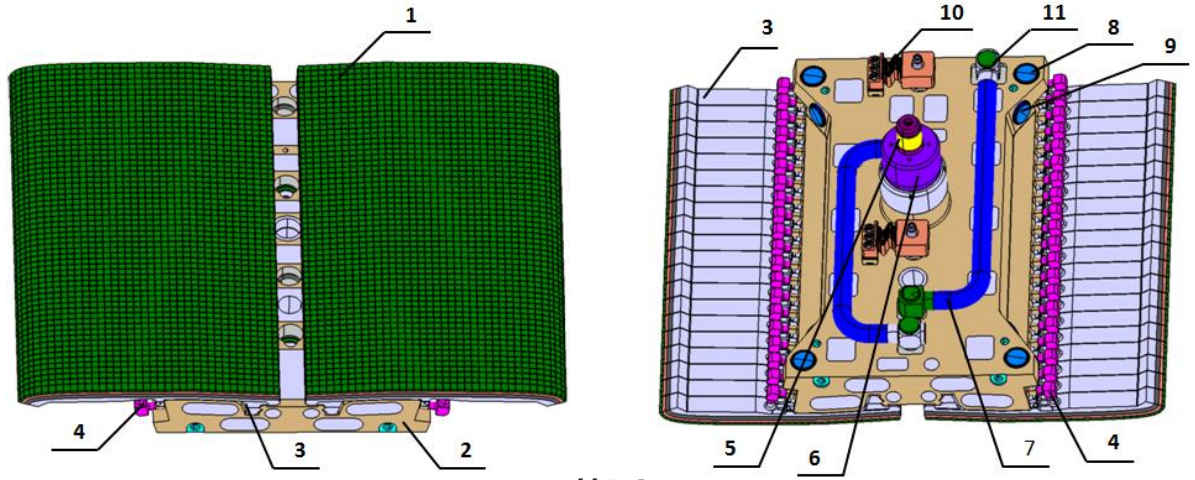
- Total number – 179 pcs
- Deferent design of the FW depending from the location
- Main supplier: NIKIET and NIIEFA



Quantity and location of the EHF FW

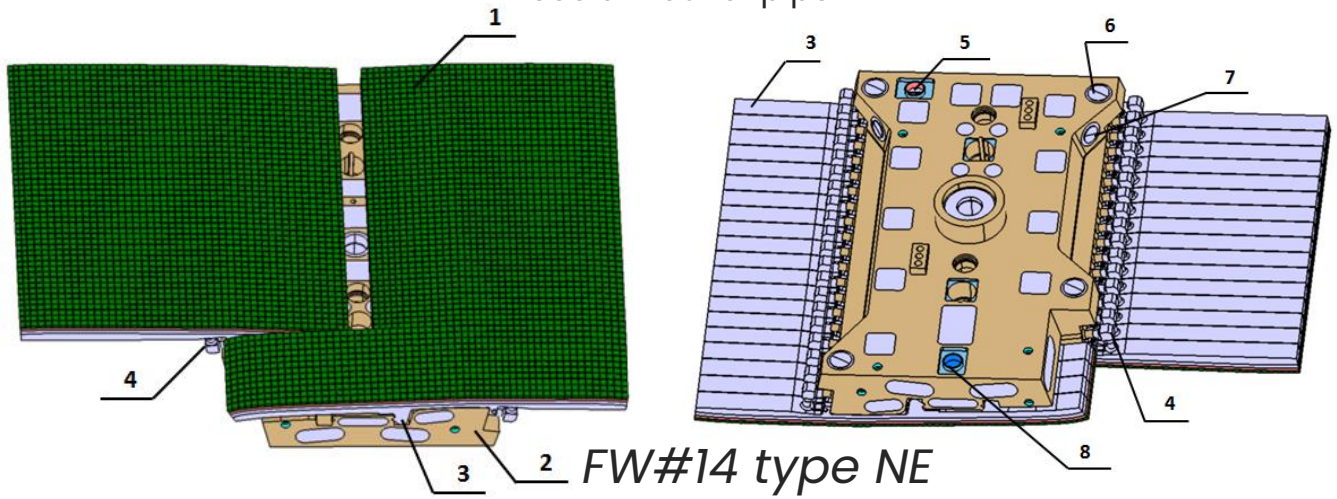
Row	Basic design variants	Additional design variants	Quantity
14	Type A (13 pcs) Type NDL (1 pcs) Type NE (1 pcs)	Type AND (1 pcs) Type ADL (1 pcs) Type ND (2 pcs) Type NC (3 pcs)	22
7	Type A (13 pcs)	Type AR (1 pcs) Type B (5 pcs)	19
8	Type A (15 pcs)	Type B (4 pcs)	19
9	Type A (19 pcs)	-	19
15	Type A (11 pcs) Type S (3 pcs) Type NE (1 pcs)	Type AND (1 pcs) Type ADL (1 pcs) Type NC (1 pcs) Type NCA (1 pcs)	19
16	Type AD (12 pcs) Type S (3 pcs)	Type A (20 pcs) Type AICH (2 pcs)	37
17	Type A (37 pcs)	-	37
18	Type E (4)	Type B (3)	7

The NIKIET activity within the framework of the Agreement on the supply of First Wall. #2

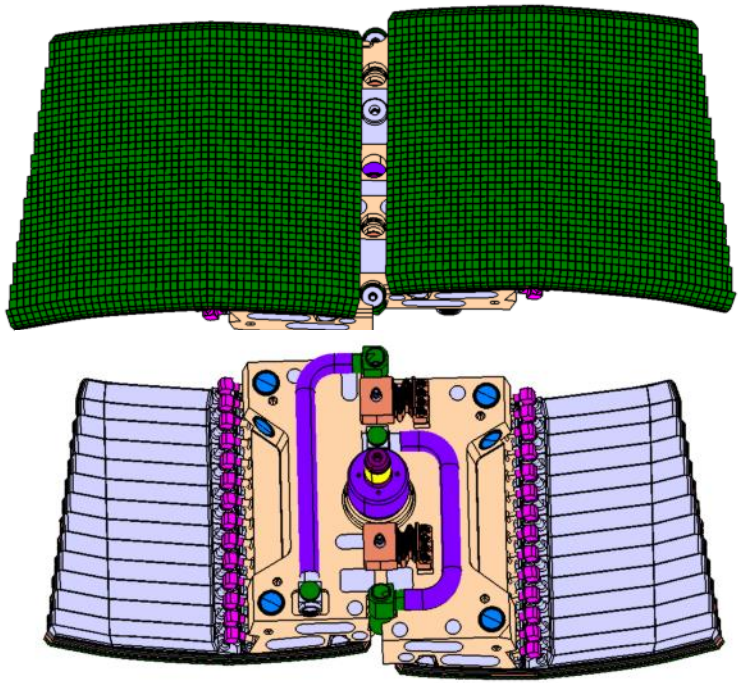


FW#14 type A

1 – Be (W); 2 – FW beam; 3 – FW fingers; 4 – pipe; 5 – bolt; 6 – threaded barrel; 7 – coolant supply pipe; 8 – radial Pad; 9 - poloidal Pad; 10 – Electrical strap; 11- coolant outlet pipe

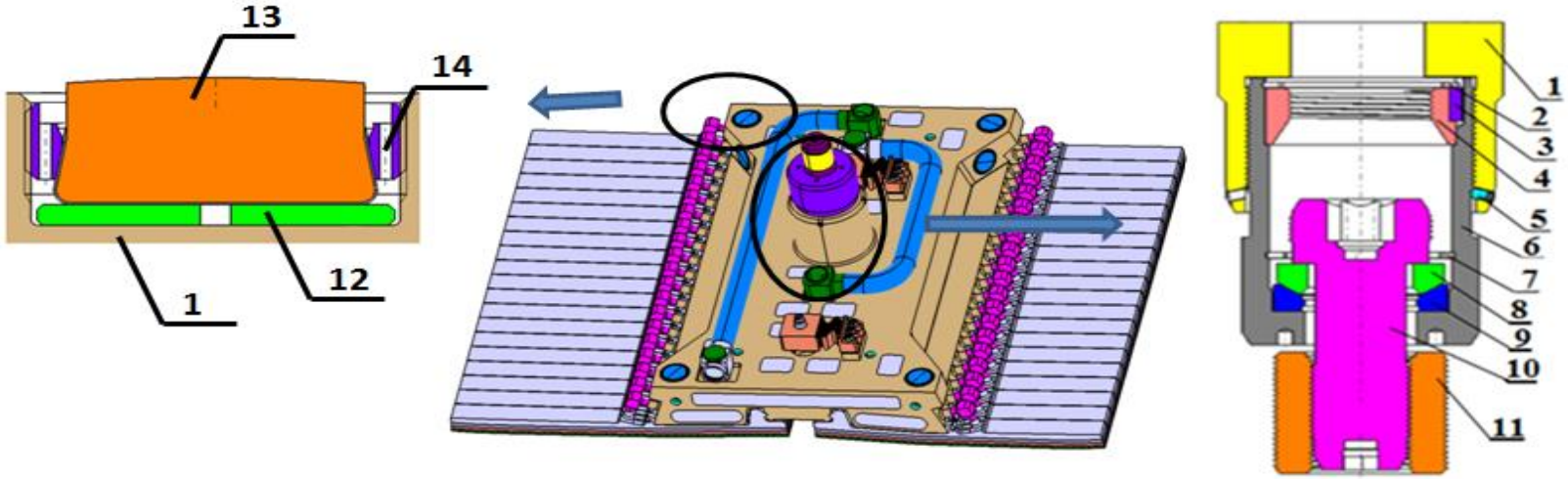


FW#14 type NE

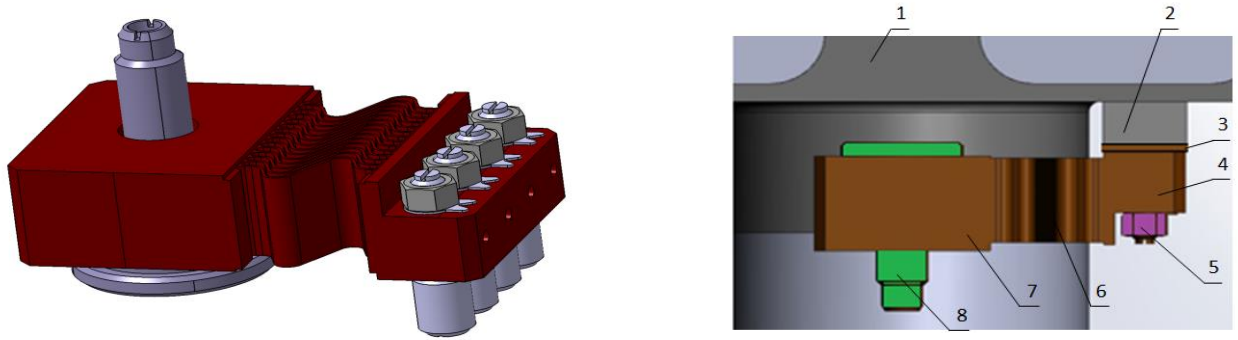


FW#8 type A

The NIKIET activity within the framework of the Agreement on the supply of First Wall. #3



1-FW beam; 2- locking ring; 3-key; 4-sleeve; 5-locking bolt; 6- barrel; 7- locking ring; 8-spherical washer; 9-conical washer with electrical insulation coating; 10-strength bolt, 11- threaded washer; 13- Pad; 14 - nut;



1- FW beam; 2- bimetallic pedestal; 3- bronze layer; 4- side flange of electrical strap; 5- nut and stud; 6 – current –carrying lamellas; 7- central flange of ES; 8 - strength bolt

The NIKIET activity within the framework of the Agreement on the supply of Blanket Module connections (1.6.P3.RF.01)

Blanket Module Connections are part of the ITER blanket system and perform the following functions:

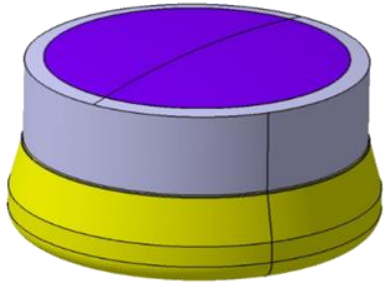
- Mounting of the blanket modules on the inner wall of the Vacuum Vessel;
- Electrical isolation of blanket modules from Vacuum Vessel in places of possible contact;
- Grounding of volumetric and surface currents induced in blanket modules on Vacuum Vessel

BMC delivery set consist of:

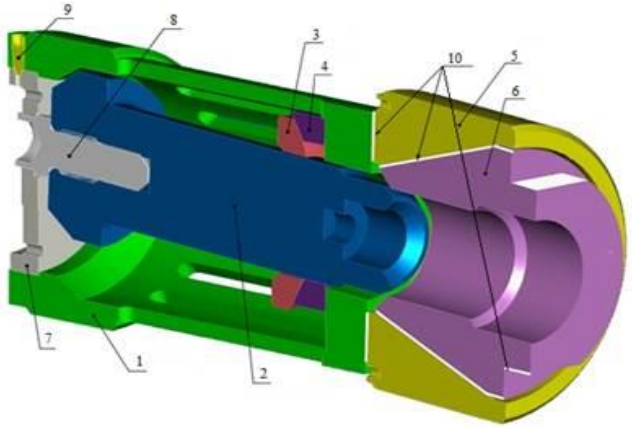
- Flexible cartridge assembly – 2109 pcs;
- Inter modular and Stub Key Pads – 866 and 1075 pcs;
- Electrical Strap Assemblies – 1052 pcs.
- Bimetallic Pedestals - 1052 pcs.

Critical manufacturing processes:

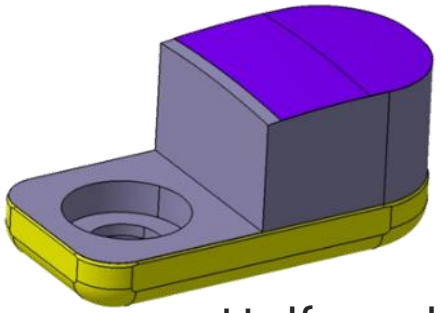
- Electrical coating deposition (Al2O3)
- Low-friction coating deposition(MoS2)
- Hot Isostatic Pressuring



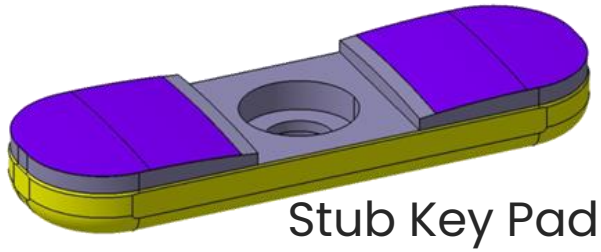
IMK



Flexible Cartridge Assembly

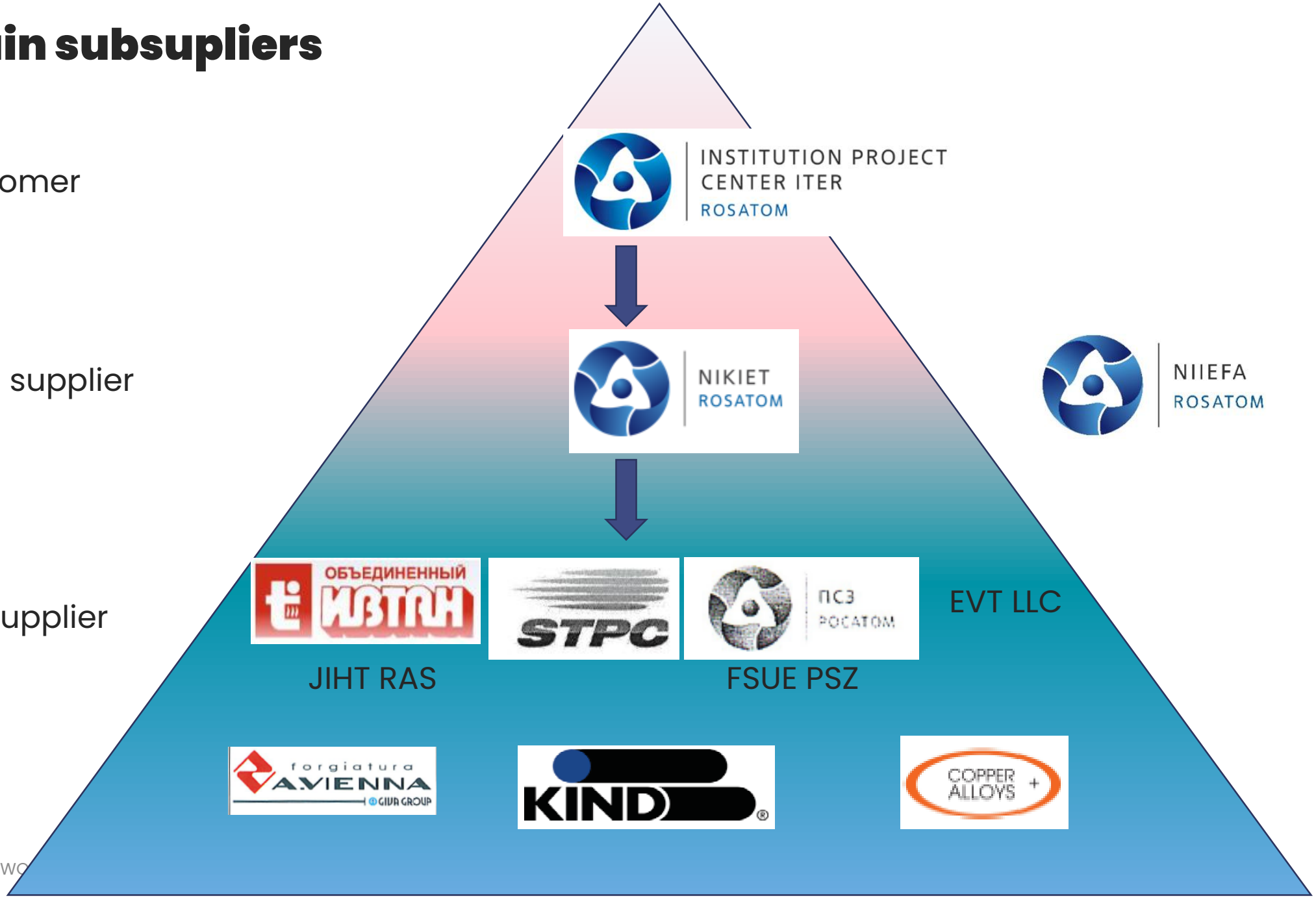


Half-pad



Stub Key Pad

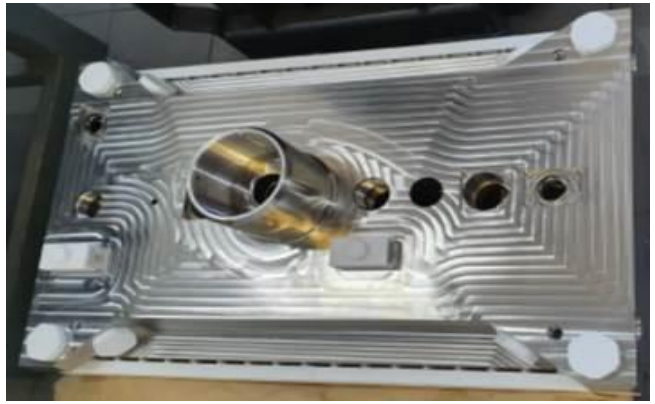
Main subsupliers



Manufacturing of Full Scale Prototypes

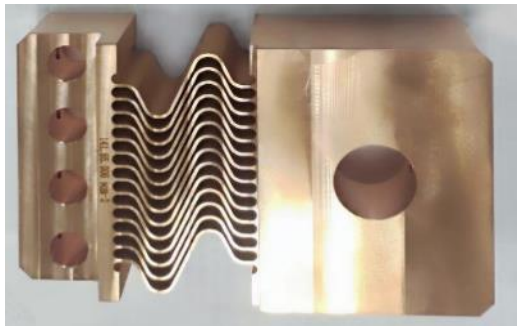
Bimetallic Pedestals

FW beam after laser welding of covers

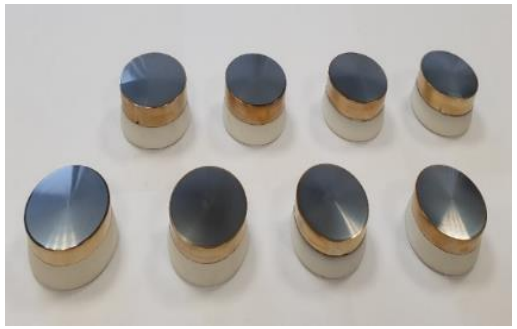


FW beam after laser welding of cover final machining

Finger cases after covers welding



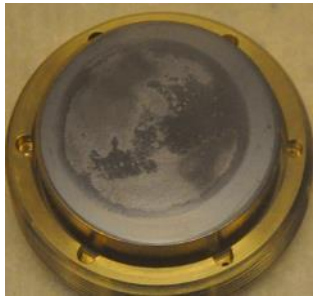
Electrical Strap



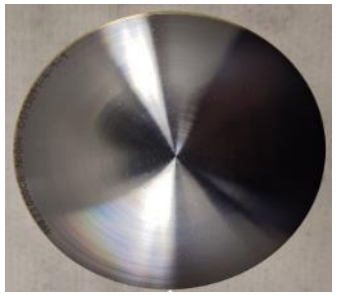
FW Pads

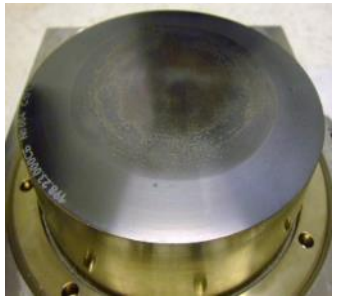
Fasteners

Qualification of Pad Assembly manufacturing process

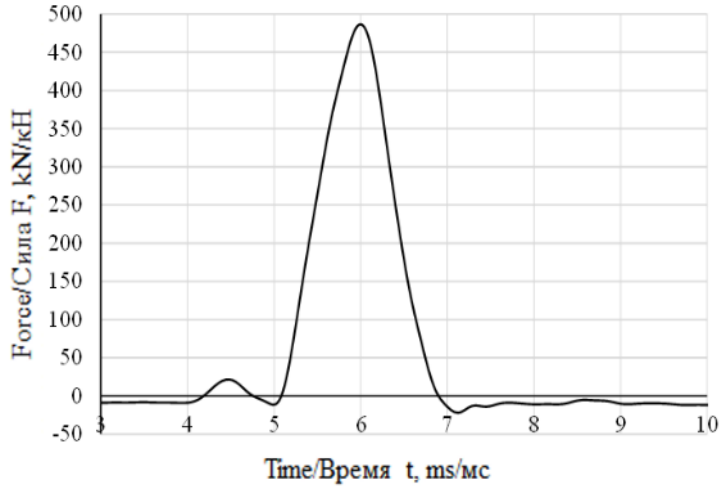


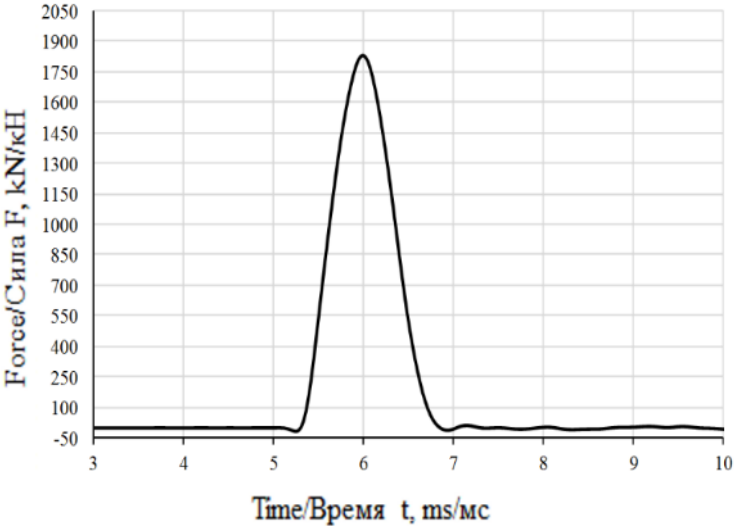
FW Pad





IMK Pad

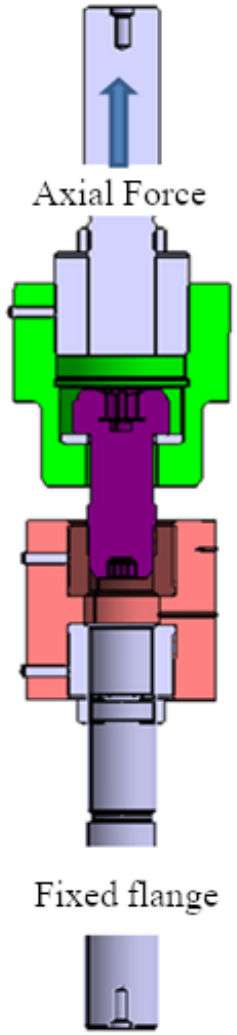




Main results:

- Full scale prototypes (50 sets) were manufacturing with fully agreement with ITER requirements;
- No electrical breakdown;
- Integrity of electrical insulation coating were confirmed under Impact and Static loads.

Qualification of Strength Bolt Design

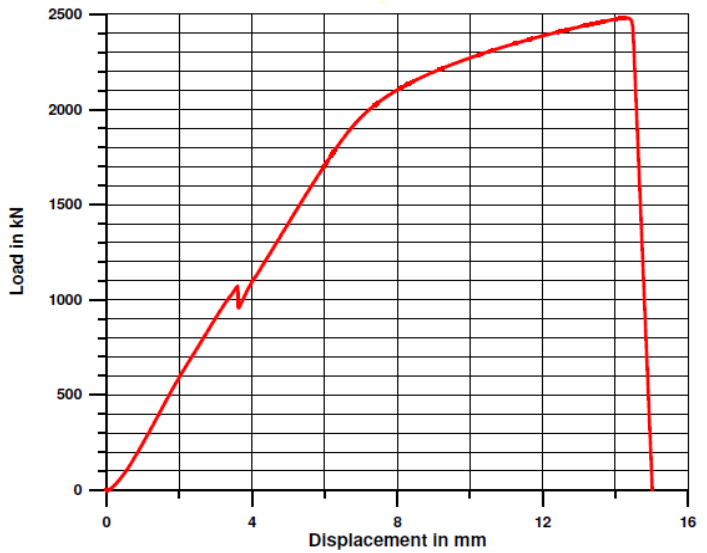


M64x4 FW

M64x4 BMC

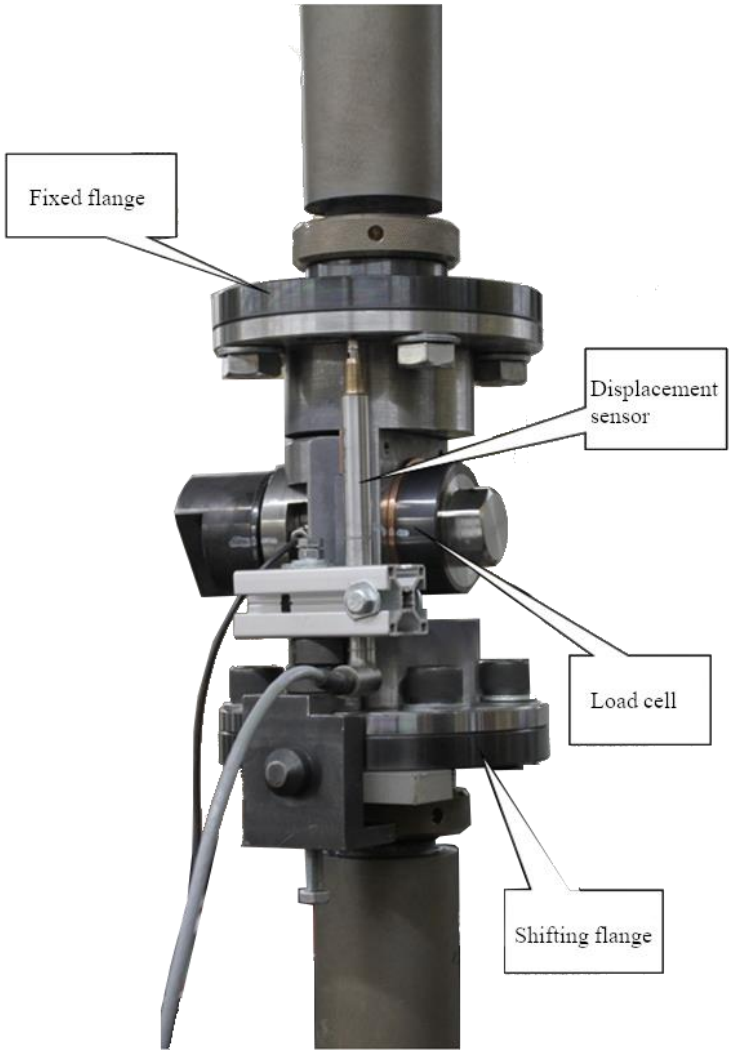
M52x4 BMC

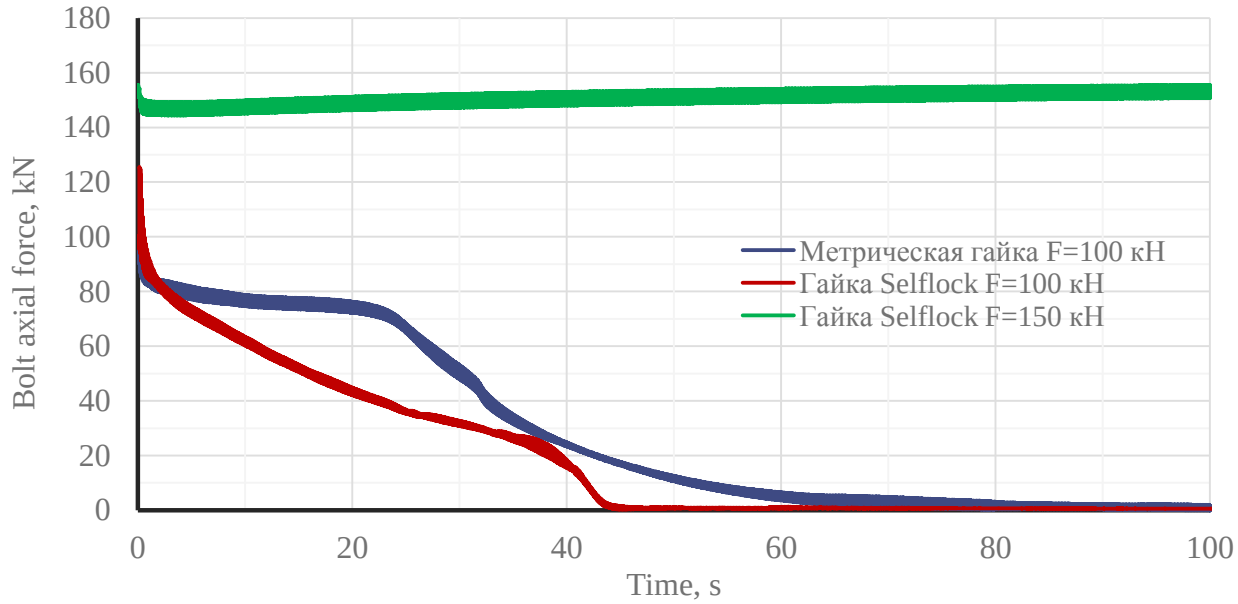
M64x4 FW



According to the test results, the strength of the bolts was confirmed in accordance with the ITER criteria, at the same time the bolt manufacturing process was certified, which will be used in the manufacture of fastening elements of the supplied sets of FW and BMC.

Qualification of Selflocking properties of Selflock Threads

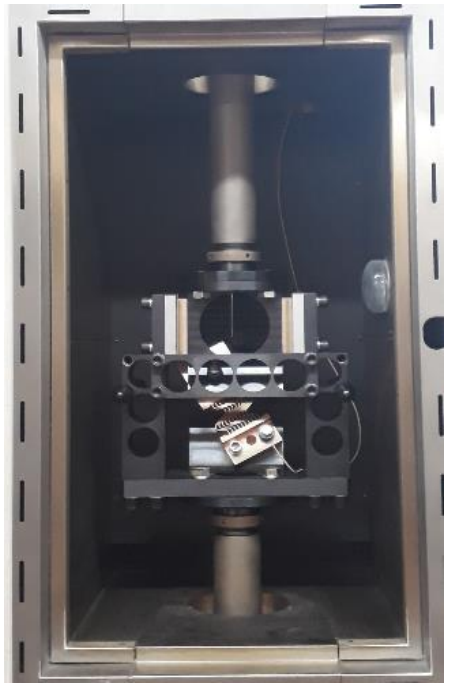




Based on the test results, the following conclusions and recommendations can be made:

1. the Selflock thread with an low-friction coating has satisfactory self-locking properties.
2. it is necessary to increase the bolt tightening force to (140±10) kN in threaded pairs with Selflock thread and low-friction coating in order to avoid unwinding during operation in ITER.

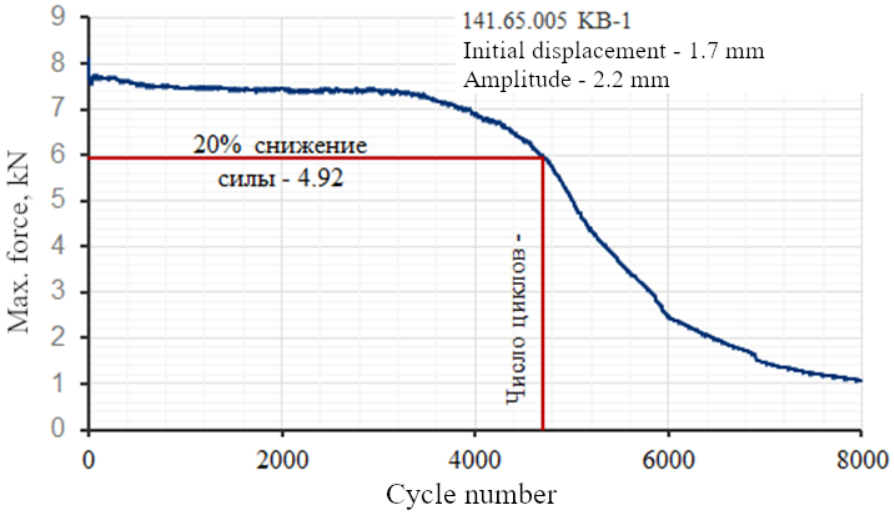
Qualification of Electrical Strap Design

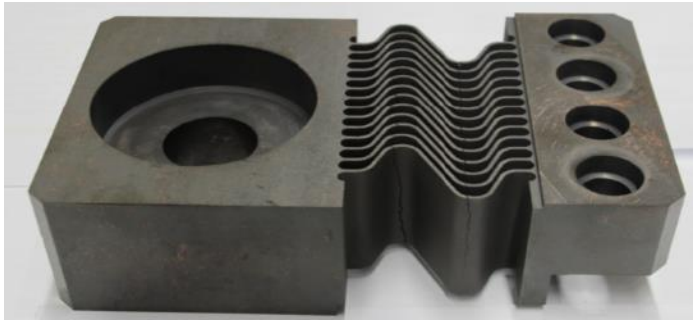


Test jig

Stage of the test	Displacement, mm	Number of cycles
Stage I	± 0.8	22000
Stage II	± 1.1	8000
Stage III	± 2.2	8000

Test was performed at 290 ^{0}C





Electrical strap after test

According to the test results, the cyclic strength of the ES was confirmed at stages 1 and 2.

The minimum margin relative to the required 400 cycles are in the ranges from 2 to a maximum of 19.

Main results

1. The delivery of 1052 sets of bimetallic pedestals to the ITER site has been completed.
2. The qualification of the manufacturing process of high-strength FW and BMC bolts has been completed.
3. The technology of manufacturing the main components of the FW and BMC has been tested.
4. Experimental models of the main nodes of the FW and BMC were made.
5. An experimental study of threaded pairs made using EMUGE Self-lock technology has been performed, which confirmed the self-locking properties for M24 threaded pairs used for the ES Assembly.
6. Manufacturing and testing have been completed, which confirmed the efficiency of the ES under ITER loading conditions.
7. Pilot production of FW and BMC components has begun.

IBF/25
INTERNATIONAL ITER BUSINESS FORUM

THANKS

TO BE PART OF THE WORLDWIDE **FUSION** NETWORK

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amentum — SILVER SPONSOR
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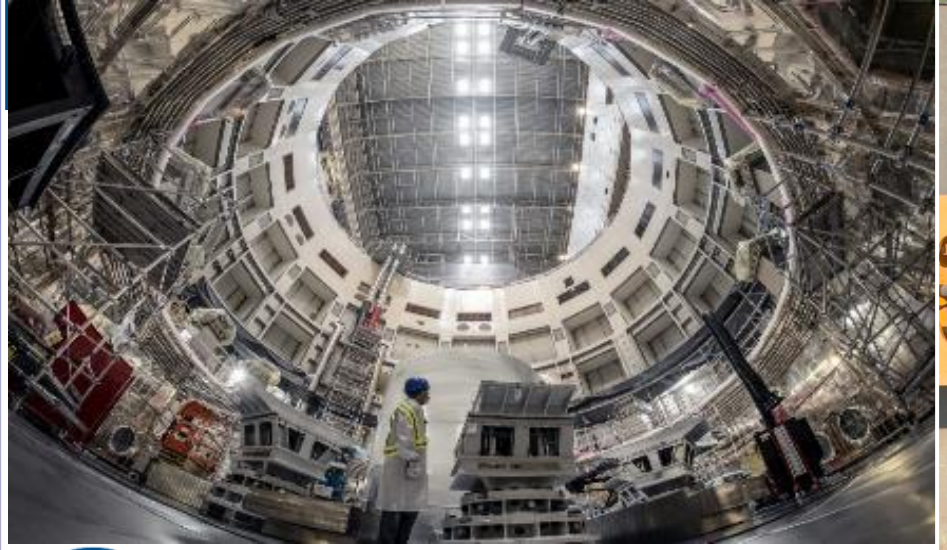
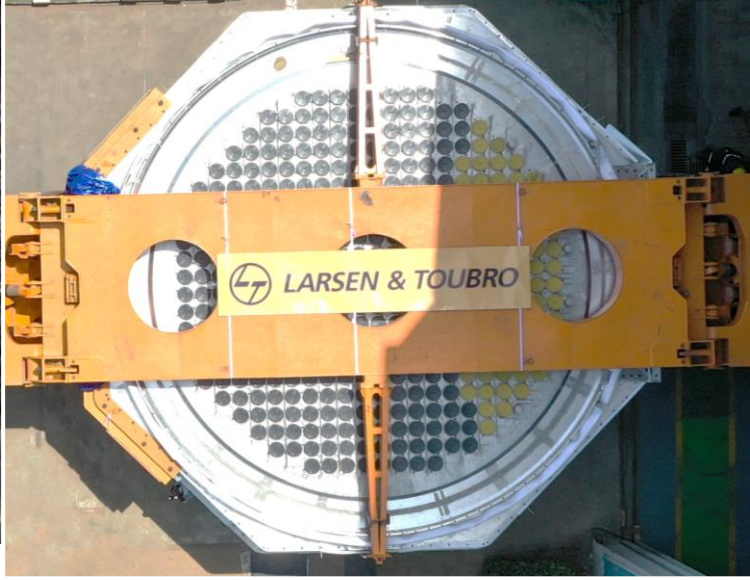
Journal of FUSION ENERGY — BRONZE SPONSOR





LARSEN & TOUBRO

L&T Group

Larsen & Toubro

founded in 1938 by Danish engineers

85
Years
of redefining possibilities

- **52+** Countries
- **120,000+** Employees
- **$ 27Bn** Annual Revenue
- **$ 60 Bn** Market Cap

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17th July 24

A M Naik Heavy Engineering Complex, Hazira, Surat, India

Hazira

Area (m2): 3,600,000

Covered Area (m2): 100,000

Annual Cap. (MT) : 200,000

No Size & Weight limitation

A M Naik Heavy Engineering Complex, Hazira, Surat, India

Hazira

Area (m2): 3,600,000

Covered Area (m2): 600,000

Annual Cap. (MT) : 70,000

No Size & Weight limitation

DAE's most reliable and trusted partner for over 6 decades

L&T Heavy Engineering

Contributed to all the 23 Nuclear reactors

PHWR

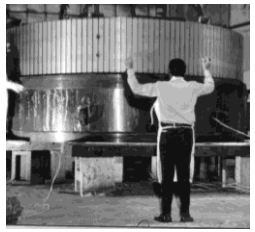
PFBR

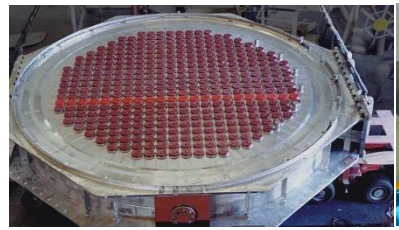
60 Yrs

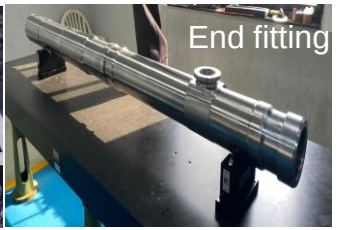
AHWR

ITER

220 MWe → 540 MWe → 700 MWe







1960 → 1980 → 2000 → 2020

Global Footprints

- 50+ Countries
- 4000+ Equipment

Sasol, USA

Valero, USA

MEGlobal, USA

Pemex, Mexico

ITER, France

Worley, NL

PKN,

International Thermonuclear Experimental Reactor (ITER)

Installation @ Tokamak Pit - Cadarache, France

The Cryostat

World's largest Vacuum application SS vessel

Fully welded cylindrical vacuum/pressure chamber

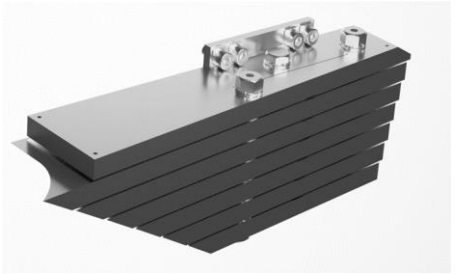
30m diameter, 30m height

Finished Wt. > 3500 MT

Thk. 80-900 mm

- ❑ Factory scope in India completed and components delivered to France
- ❑ Integration in pit is in progress, ahead of IO schedule.
- ❑ Manufactured as per European codes

- ❑ Inwall Shielding blocks for 03 Vacuum Vessels Sectors and Field joints (Precision machining of ~ 33,000nos SS plates & 01 lac fasteners)



IWS Blocks

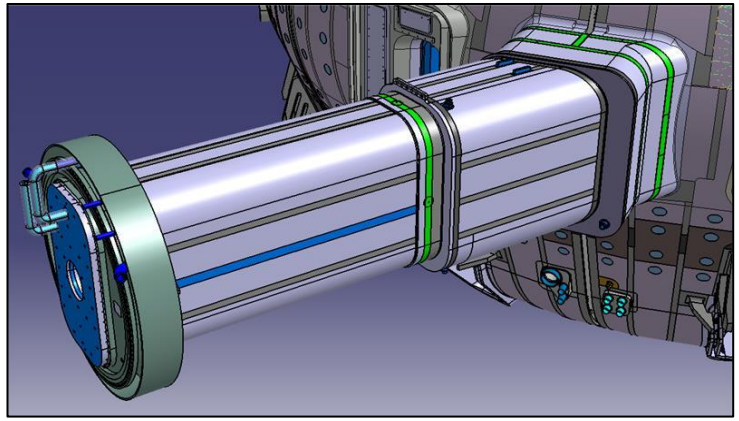
Cryostat Assembly 3D Model

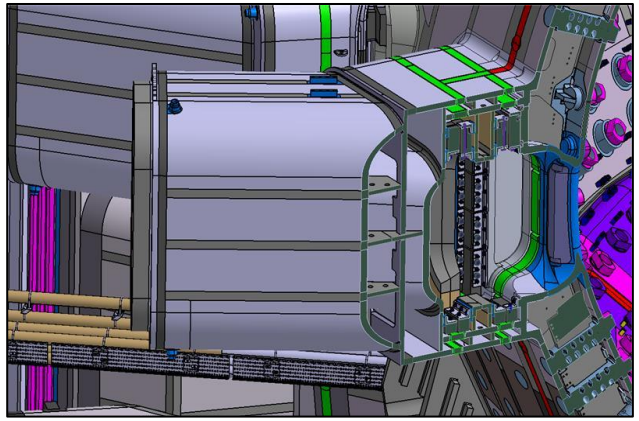
ITER – Execution Highlights & International Expertise

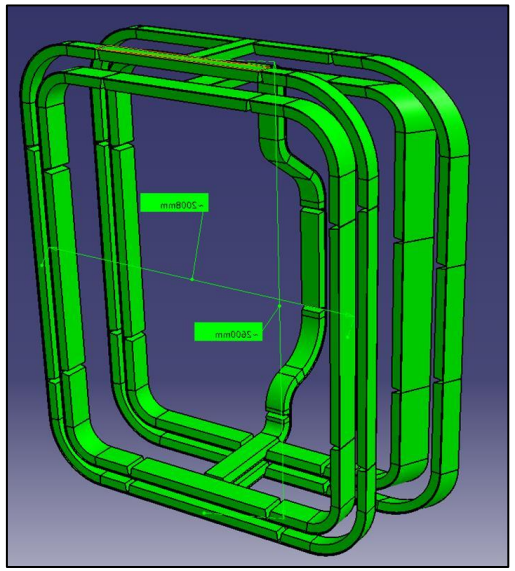
- Implementation of "First Article" (Mock-up) for critical sub-assemblies before the actual job
- Extensive state of the art metrology and virtual assemblies to prevent assembly surprises.
- Custom-designed fixtures & Tools for seamless handling & assembly.
- Construction of Dedicated Workshops @ L&T, Surat & ITER Site(B56)

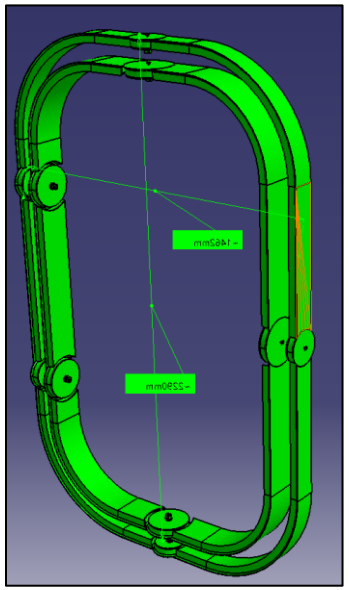
- Mobilization of Skilled Manpower
- Strong PMG and Project Monitoring
- Adaptability to international standards and culture

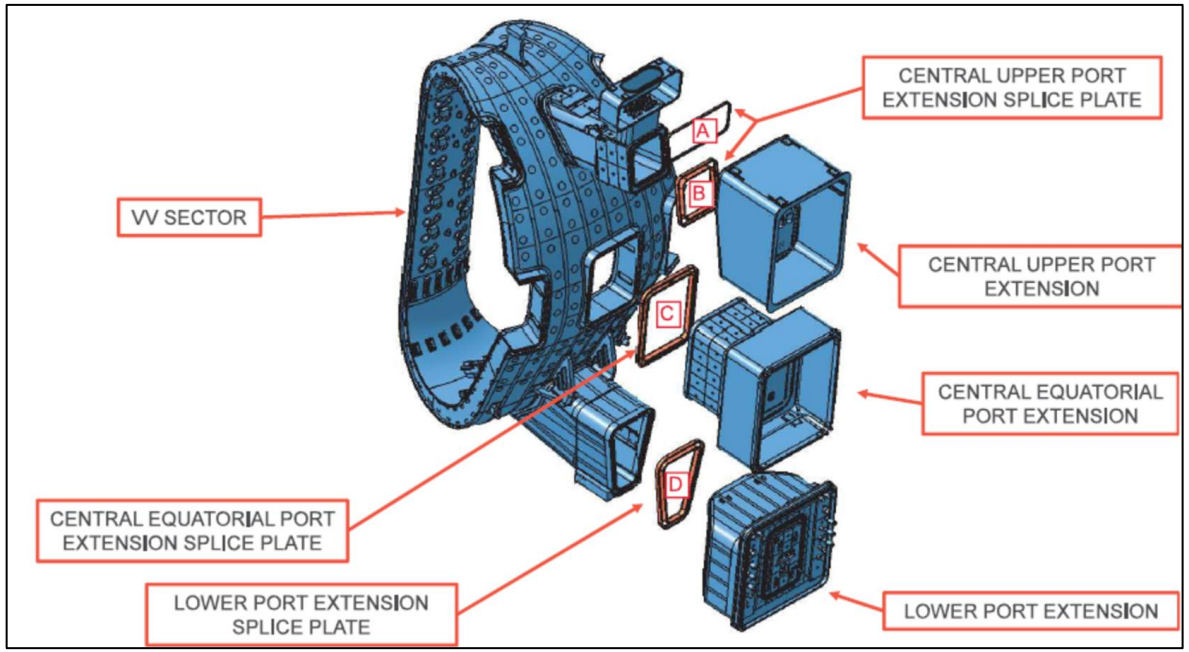
Port Positioning, Alignment and Welding (PPAW)





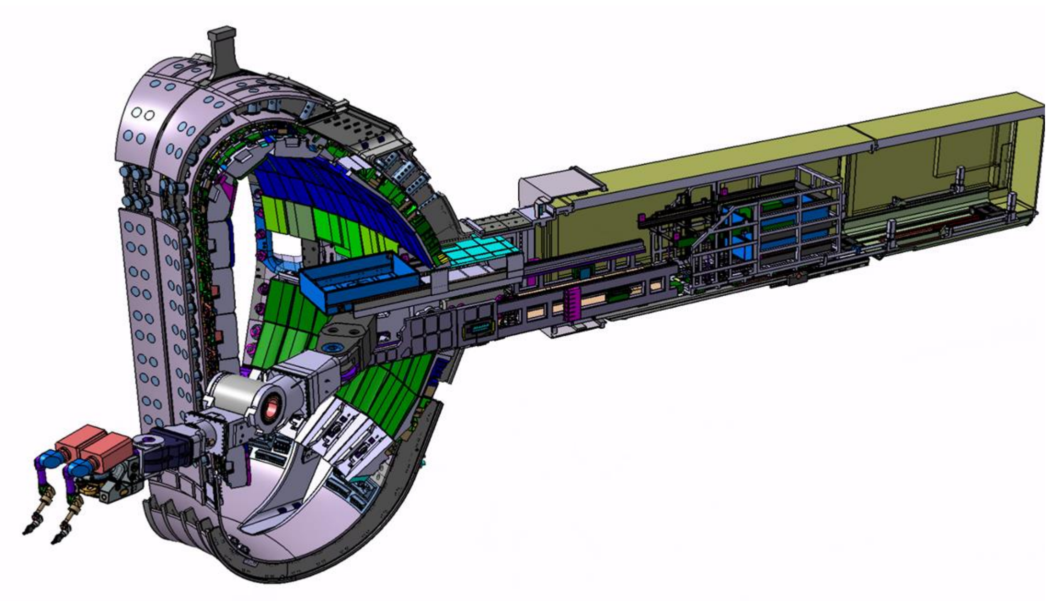






Parameters	Vacuum Vessel Port Welding (Current scope)
Welding Length at Site	7.5 km
Weld Deposition (incl. site)	40 Ton
No. of Ports & Bellows	148 nos

Blanket Assembly Transporter to assemble SB & TFW onto VV



Articulated Transporter (10 DOF)

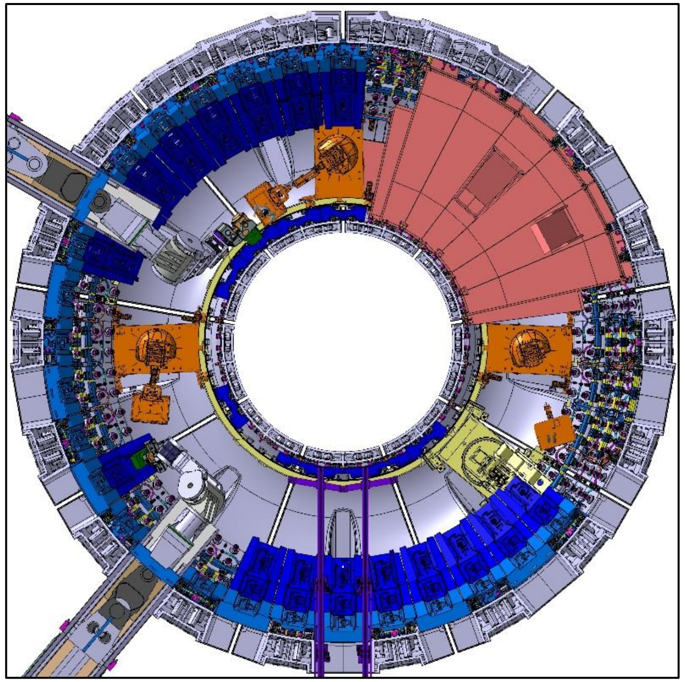
Kinematic motion

- Translation (J1)
- Horizontal Rotation (J2 & J3)
- Rolling (J4 & J6)
- Pitching (J5 & J7)

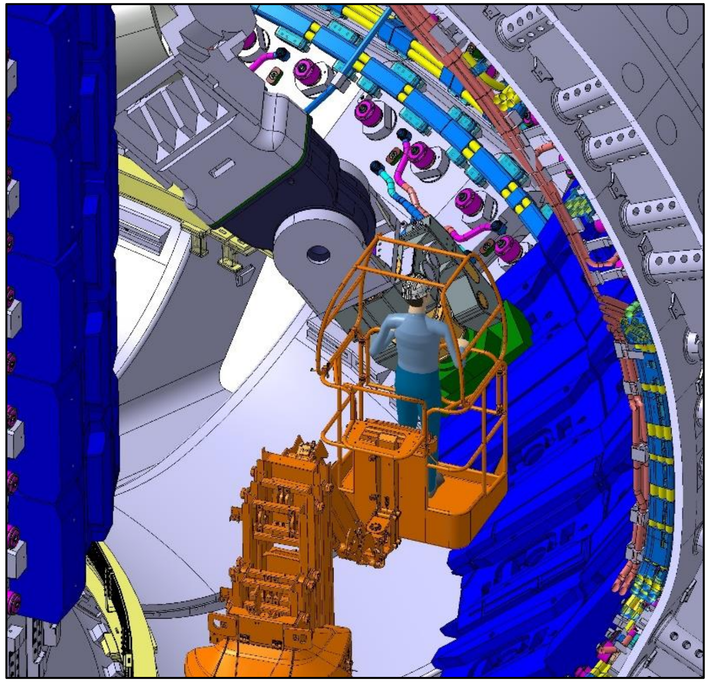
MOC
Duplex SS / Al 6061-T6
AISI 630 H900

Approx. Weight
AT with long – 42t
AT – 23.8 t
LME – 18 t
SME – 15 t

Scope of Work
1. Detail Design
2. Manufacturing Design
3. Manufacturing and Assembly
4. FAT & SAT

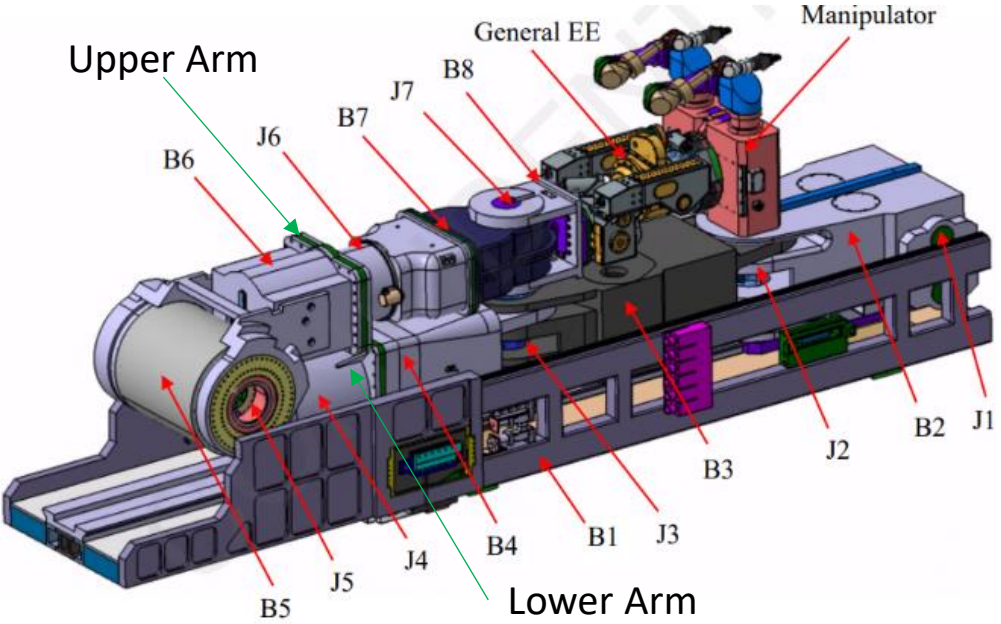


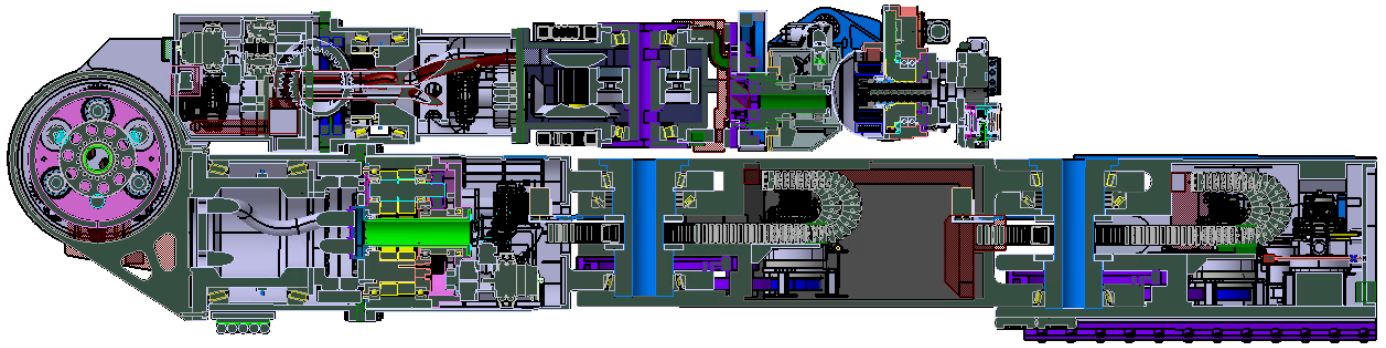
Two BATs and the IVTC installing Shield Blocks during assembly



BAT installing a Shield Block with Hands-on assistance

Blanket Assembly Transporter (BAT)

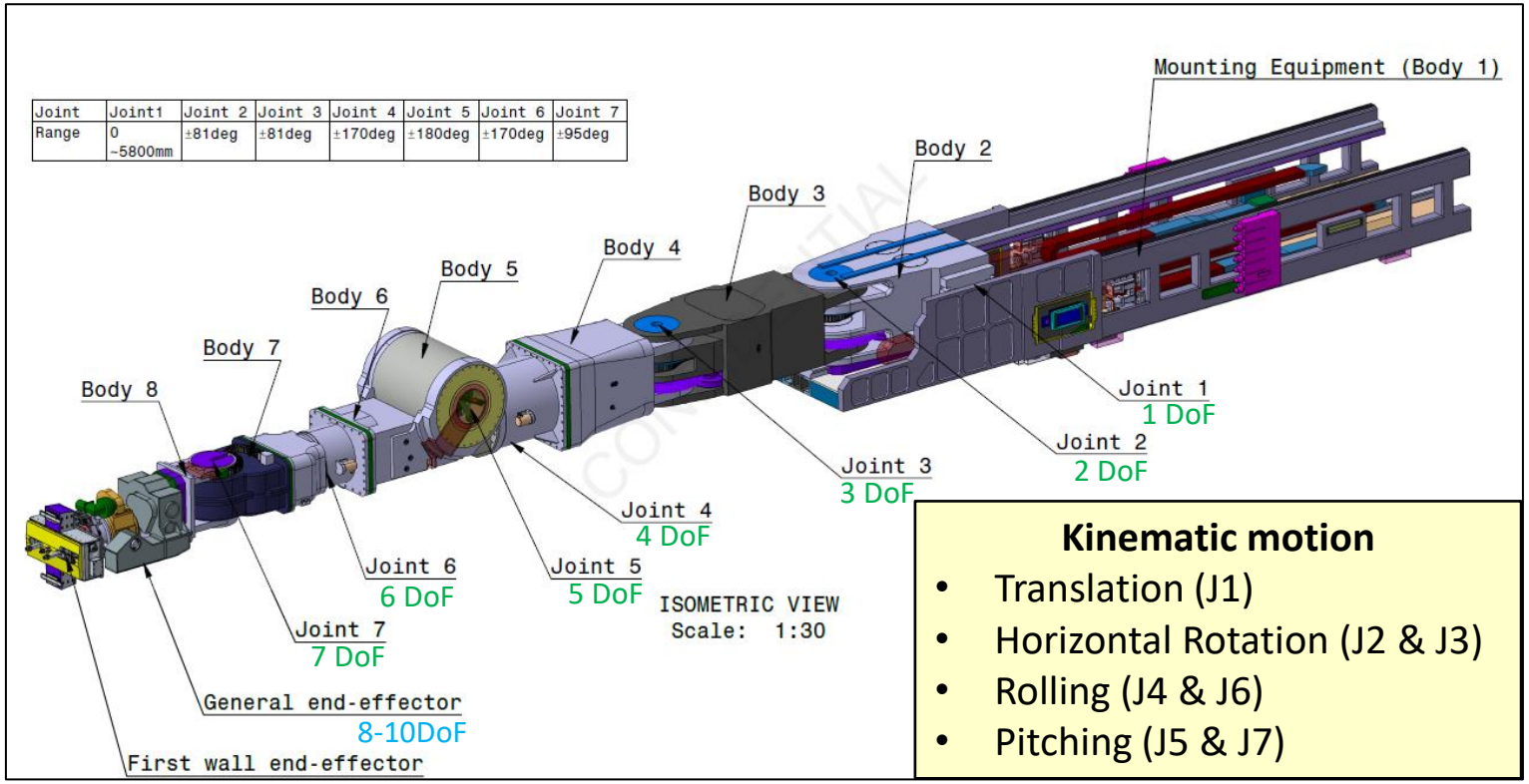




Blanket Assembly Transporter (BAT) (7 DoF)

- Blanket Assembly Transporter (BAT) is ***7 DoF*** *Articulated Robotic arm with General End Effector (3DoF) -* ***10 DoF.***
- It performs *assembly operations* inside Vacuum Vessel during *non-nuclear phase*.

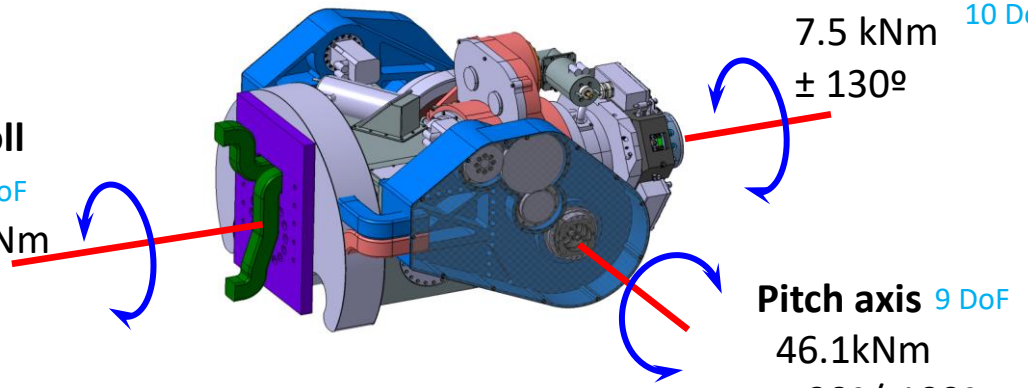
Joint	Joint1	Joint 2	Joint 3	Joint 4	Joint 5	Joint 6	Joint 7
Range	0 ~5800mm	±81deg	±81deg	±170deg	±180deg	±170deg	±95deg



Kinematic motion

- Translation (J1)
- Horizontal Rotation (J2 & J3)
- Rolling (J4 & J6)
- Pitching (J5 & J7)

General End Effector (GEE) (3DoF)

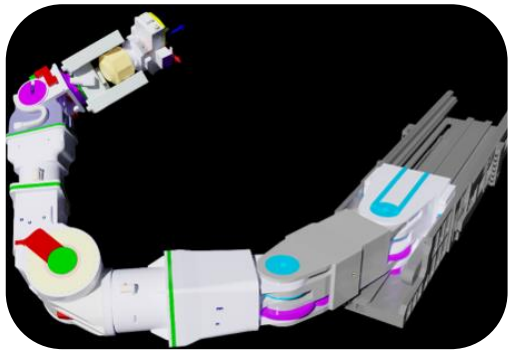


- GEE is a intricated articulated arm acts as *wrist of BAT* with 3 DoF
- Compact electrical mechanical drive system.

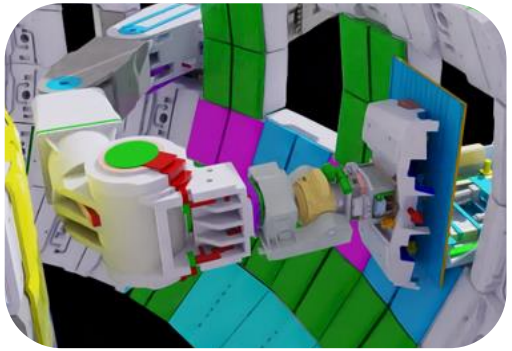
Robot Controller

- Robot control by ITER special developed control system software along with F4E.
- Robot can simultaneously operate 17 nos. motor in synchronous manner.

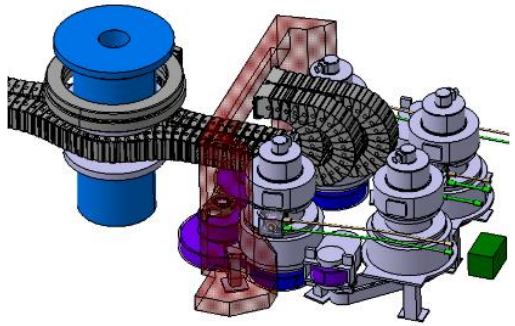
Salient Feature of BAT



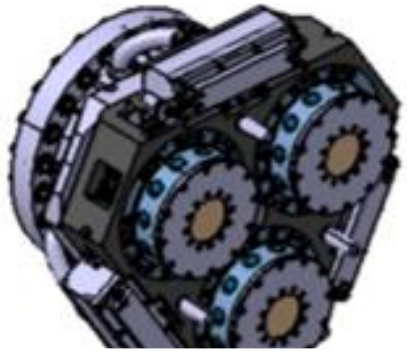
First of a Kind largest Articulated Industrial scale Robot



Maximum Pay load capacity to handle is 4 tonnes

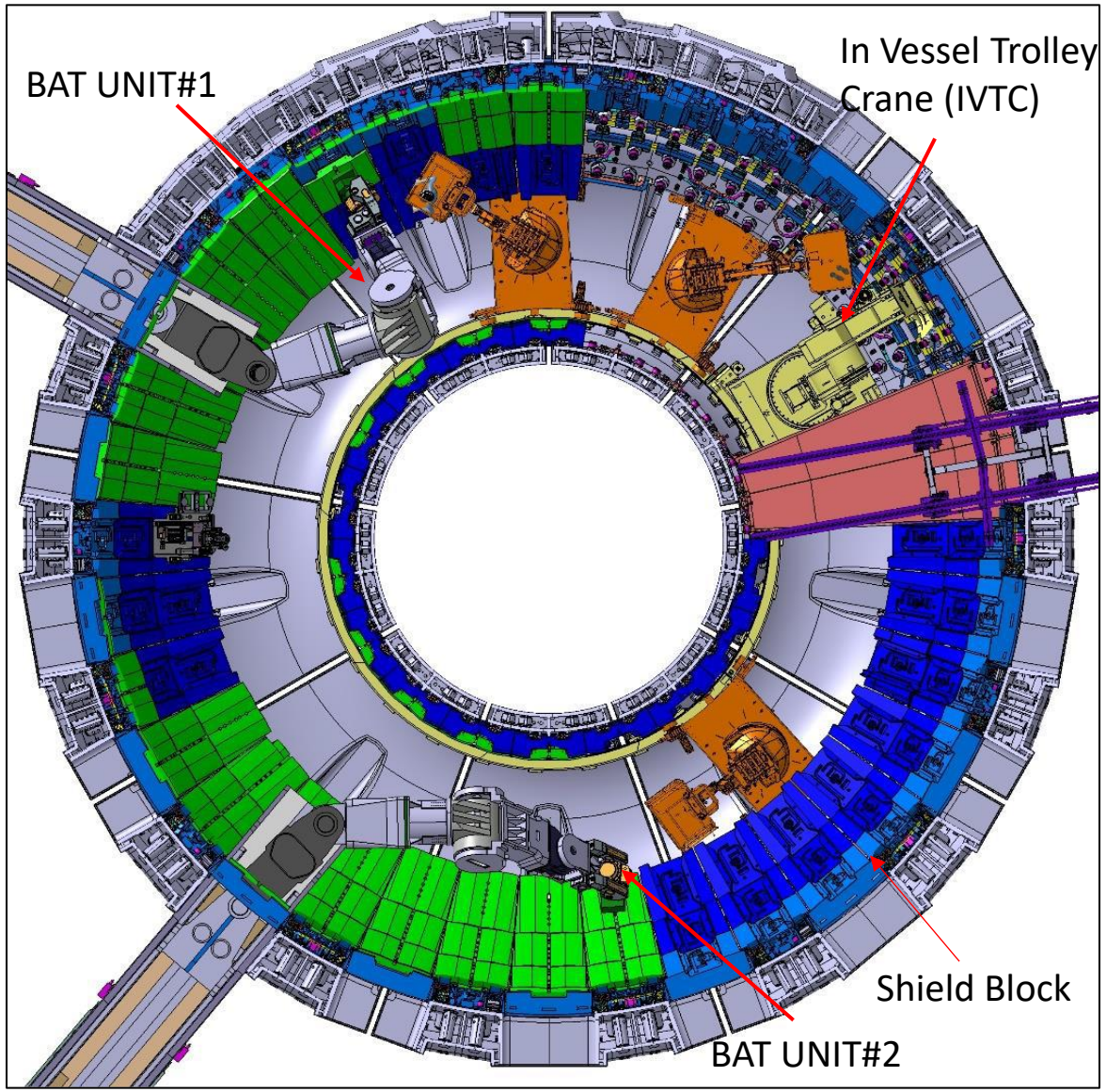


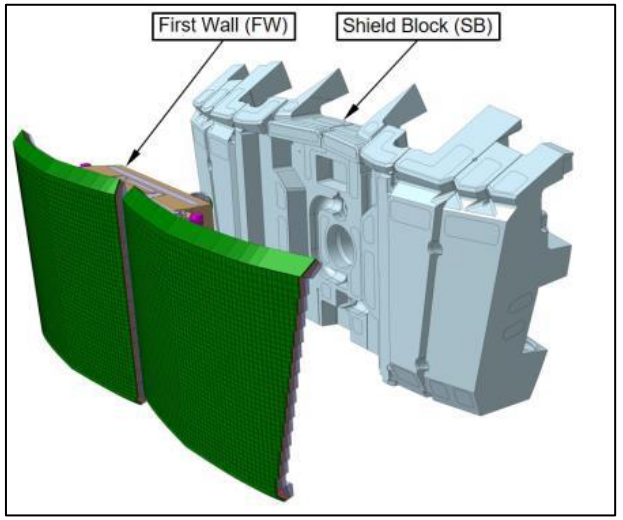
Completely electro – mechanical driven system



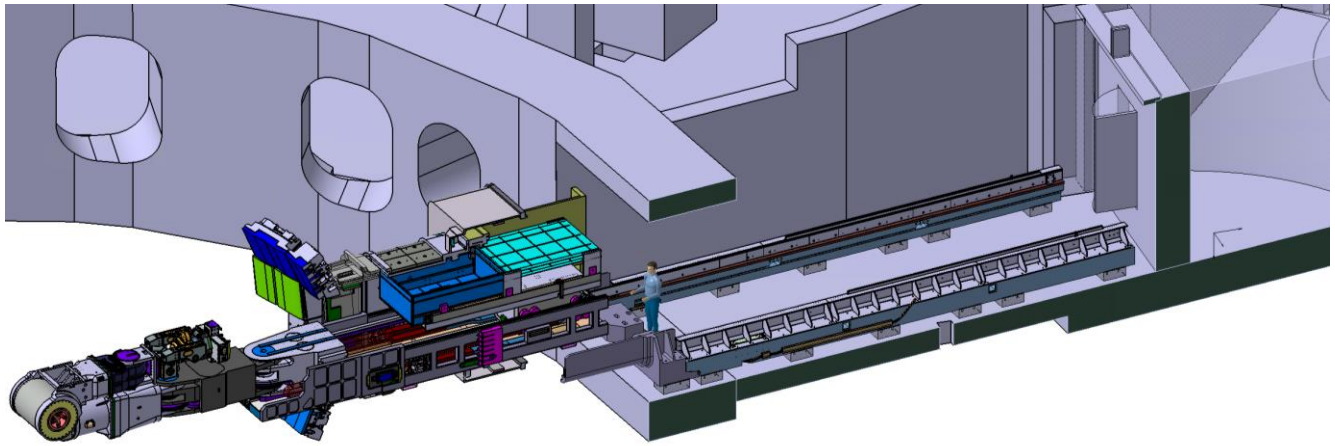
Hypersensitive to detect the even 10 gms of force at end connection

Role of BAT in Vacuum Vessel Blanket Assembly



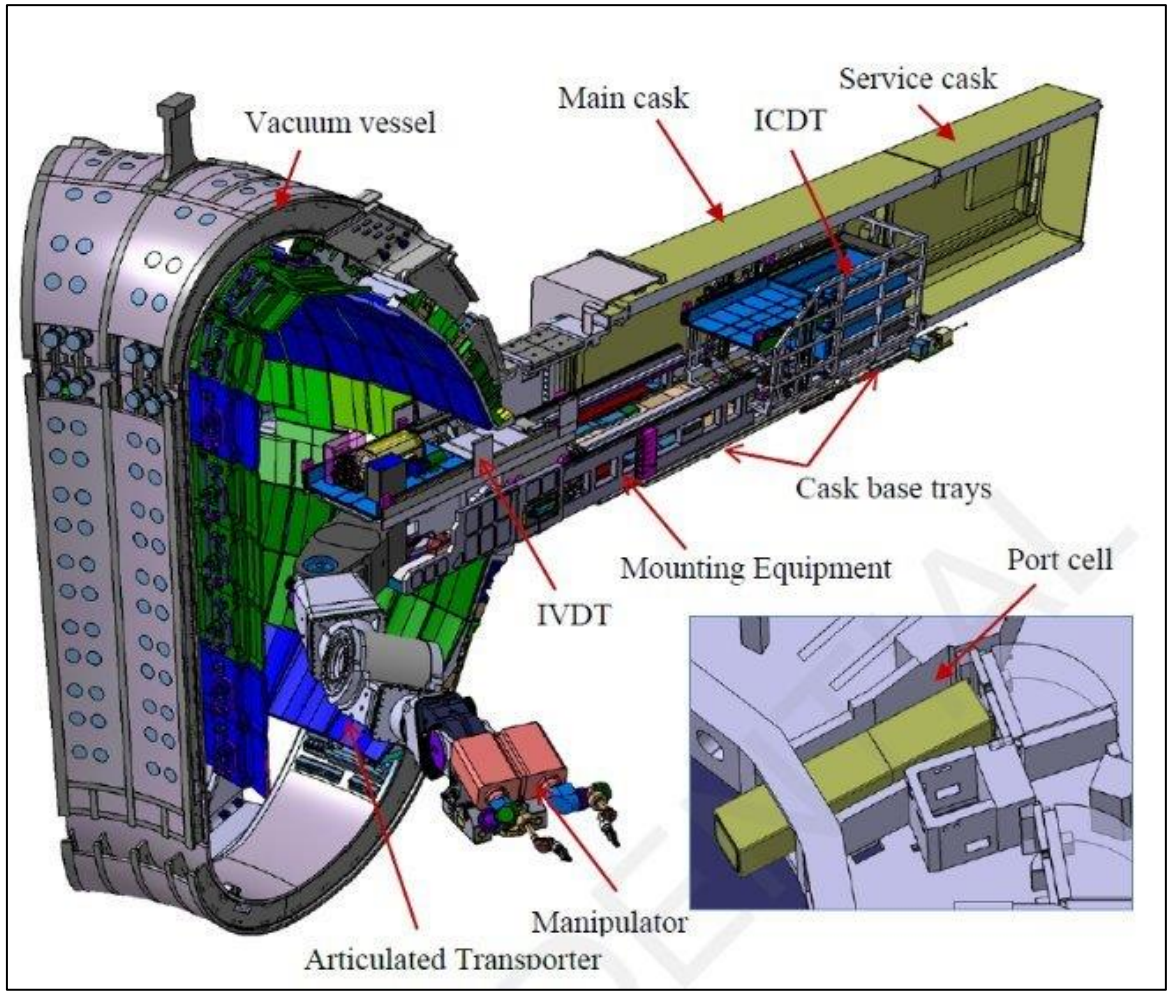


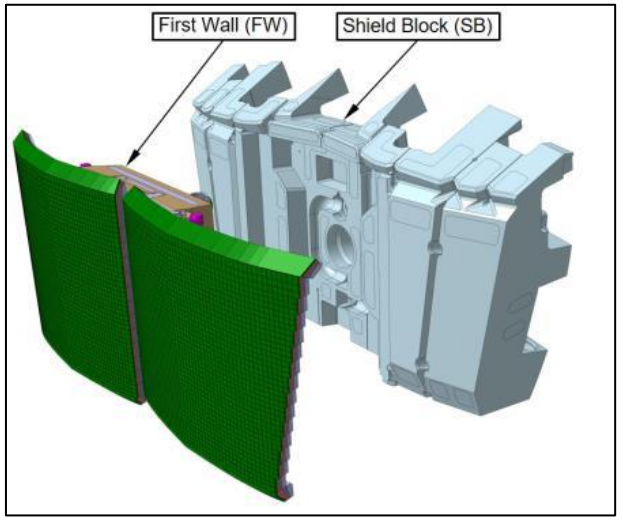
- BAT along with IVTC and Cherry Picker will be used for assembly.
- 2 nos. of BAT will be used in VV for Blanket assembly (Shield block & First wall)
- BAT collects blanket assembly from In Vessel Deployment Trolley (IVDT)



- BAT has several vision system for viewing and position of arm to final intended location

Role of BAT in Vacuum Vessel Blanket Assembly





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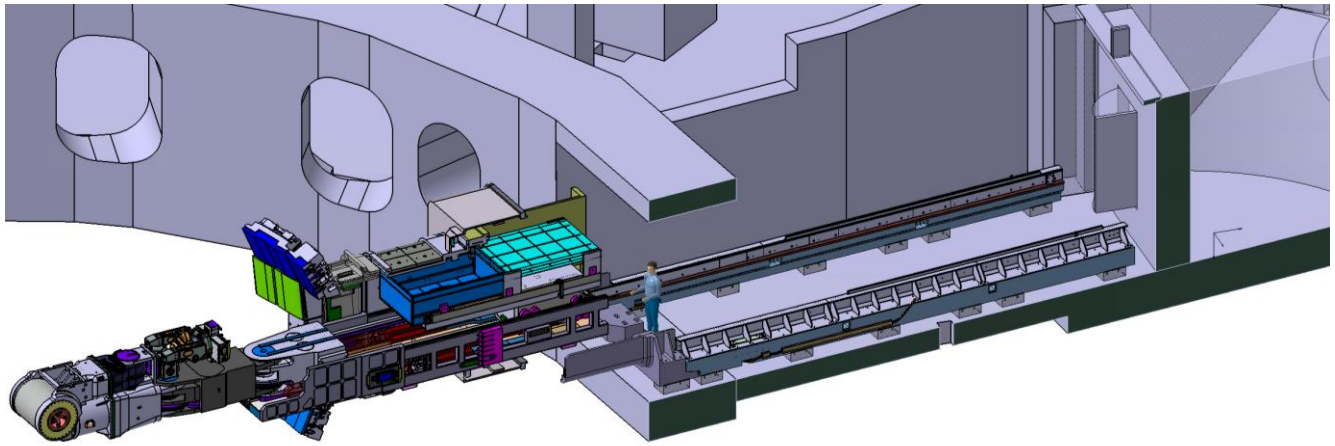

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L&T Special Steels and Heavy Forgings (LTSSHF)

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100% Technology Developed Indigenously

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9000 MT Open Die Press
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Differentiating Capabilities

Culture of Complex fabrication

First Time Right Approach Early Delivery

Best in class talent Pool

Industry Trendsetter

State of art Facility

Merci