Finanziato dall'Unione europea NextGenerationEU
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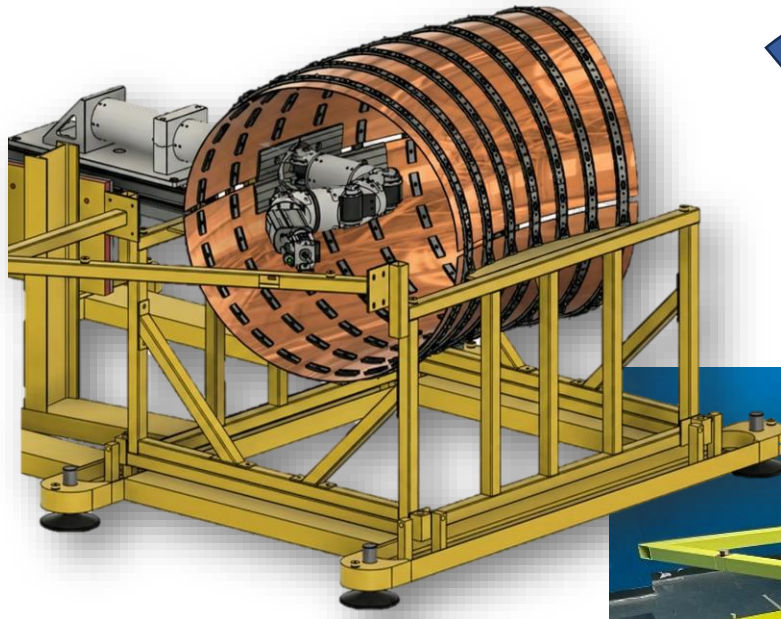
Consiglio Nazionale delle Ricerche
Università degli Studi di Padova
Università degli Studi di Napoli Federico II
Nefertari

WP-1-A3

Remote Handling: VR simulator and training



Giuseppe Di Gironimo

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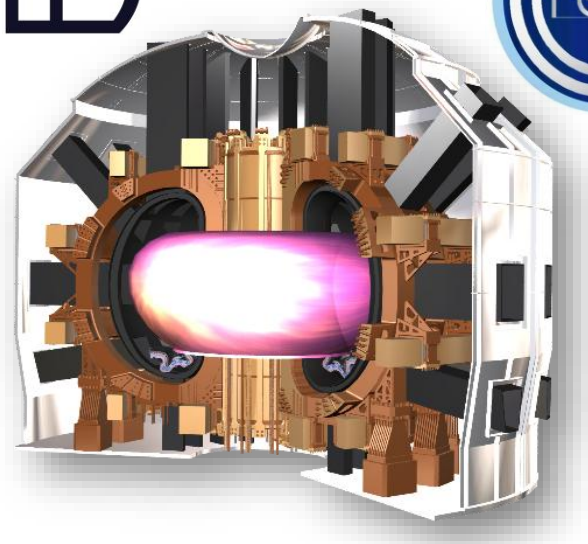
Università degli Studi di Napoli Federico II
Dipartimento di Ingegneria Industriale

DIPARTIMENTO DI INGEGNERIA INDUSTRIALE




ENEA
DTT
Divertor Tokamak Test facility
Project Proposal

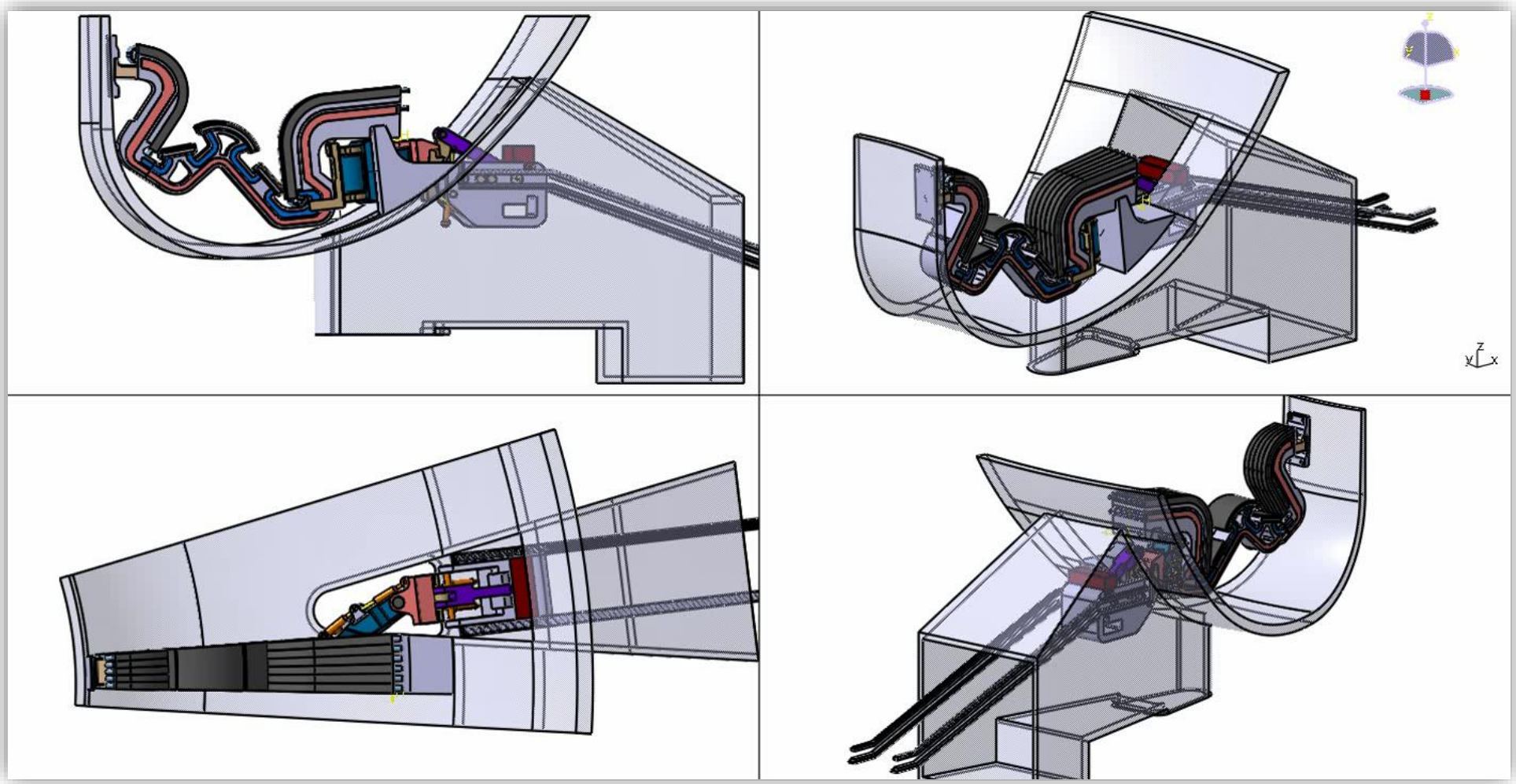

ENEA
DTT
Divertor Tokamak Test facility
Interim Design Report
A milestone along the roadmap to the realisation of fusion energy


ENEA
To generate the energy of stars
FAST
Fusion Advanced Studies Torus

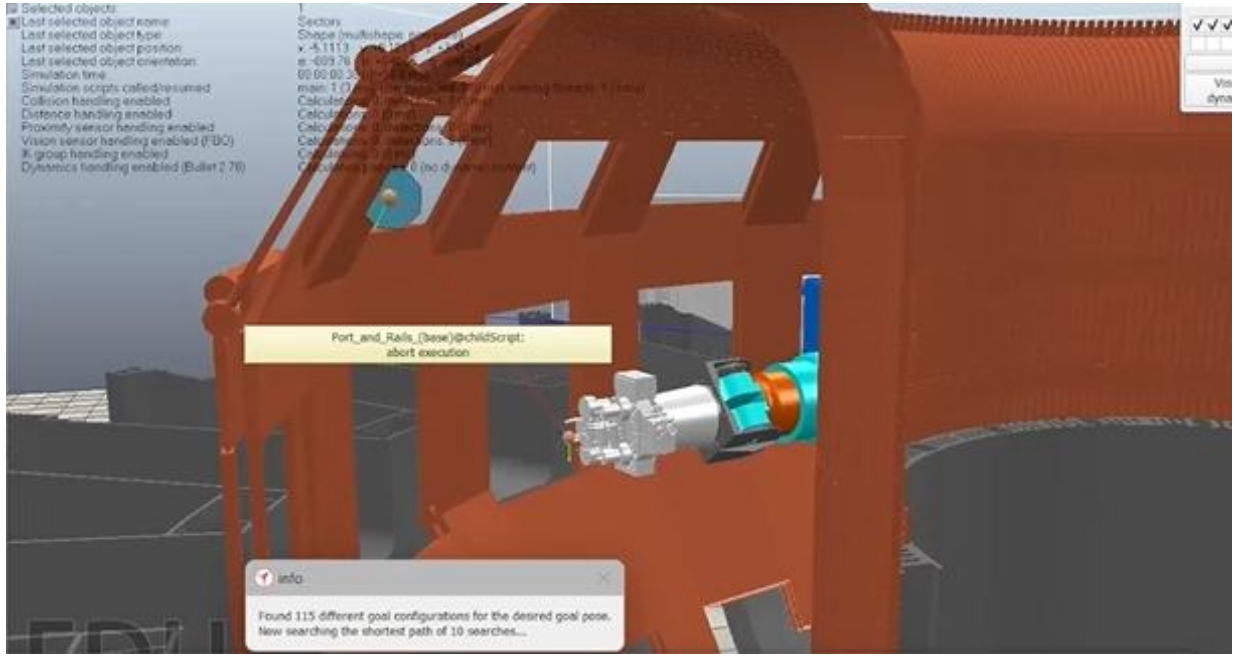
Remote Handling in CREATE - UNINA

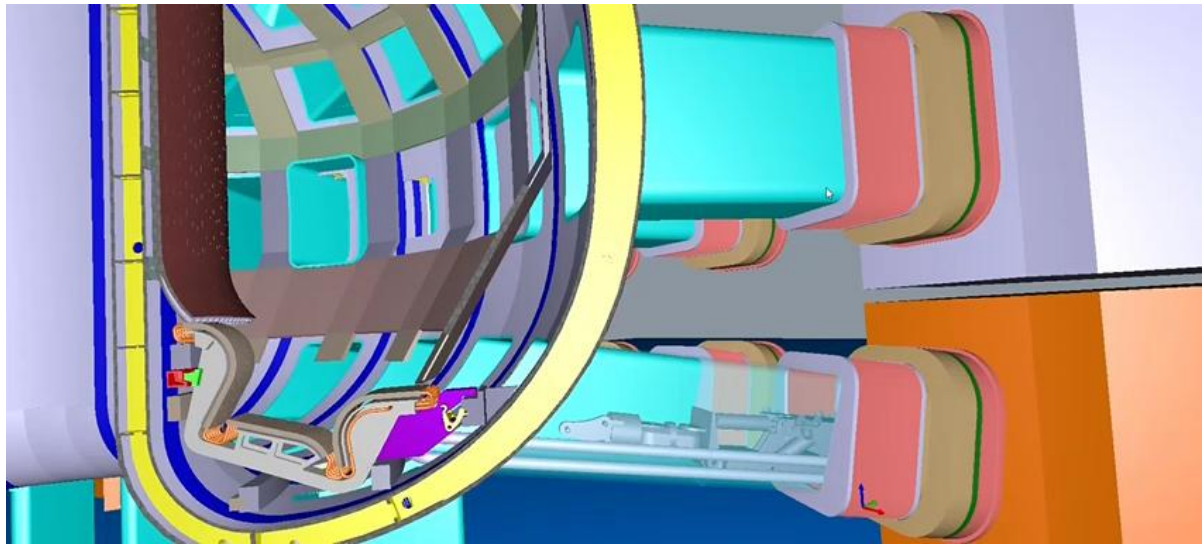
create

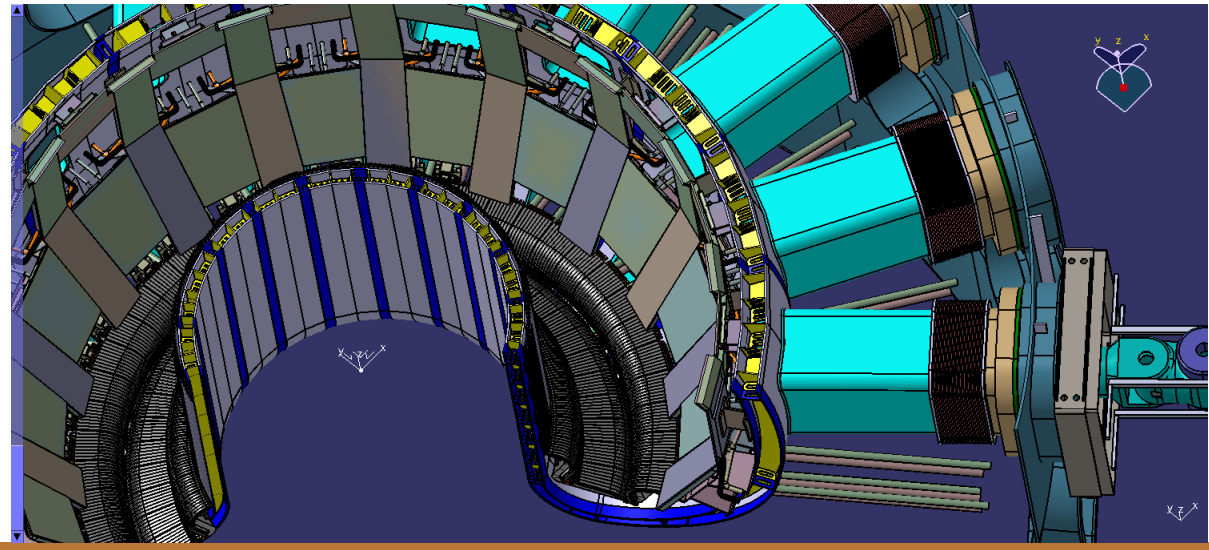
DIPARTIMENTO DI INGEGNERIA INDUSTRIALE



Remote Handling in CREATE - UNINA

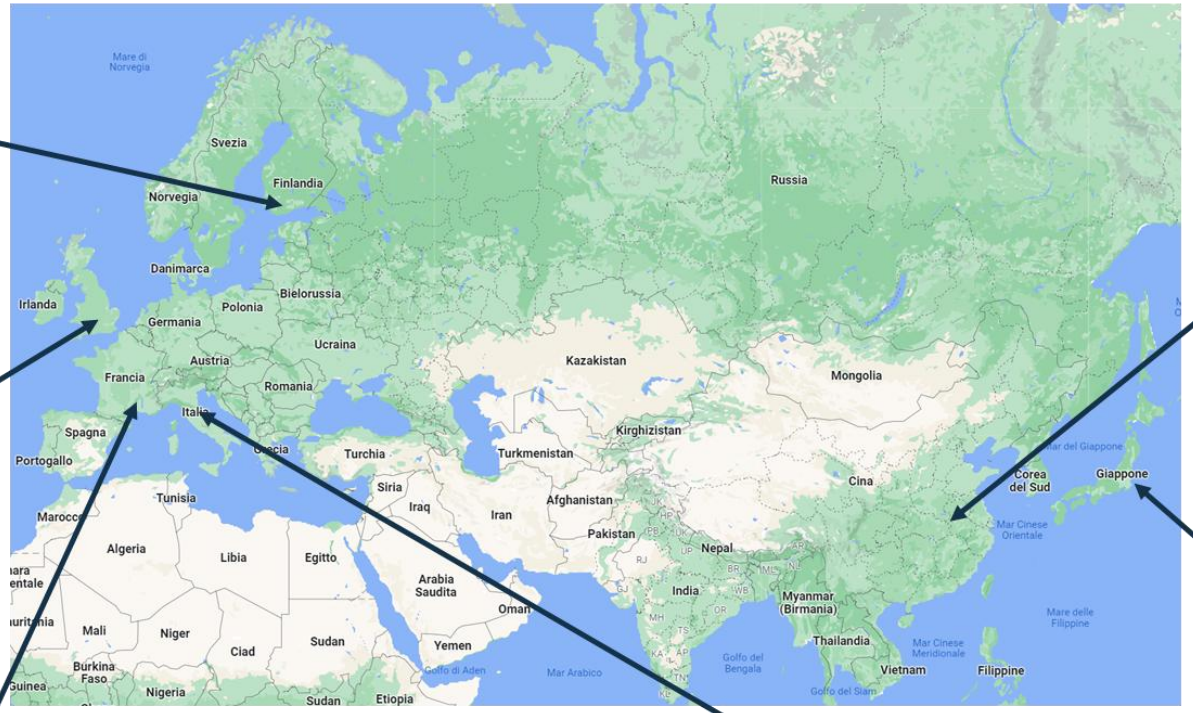




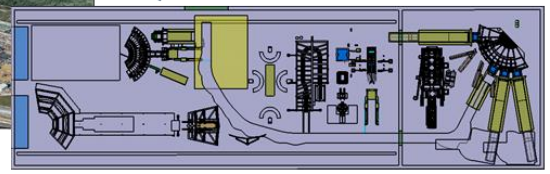


Remote Handling in Facilities in fusion world

Divertor Test Platform 2 (DTP2) @ VTT Technical Research Centre of Finland in Tampere



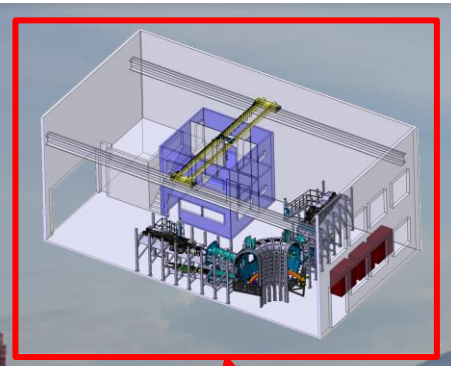
In Vessel Training Facility (IVTF) & **RACE facility** @ Culham Science Center (UK)



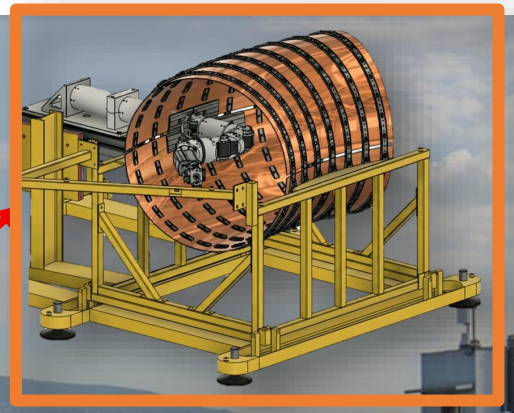
ITER Cold Test Facility @ ITER site in Cadarache, France

CRAFT RH Platform @ Institute of plasma physics of Chinese Academy of Sciences in Hefei, China

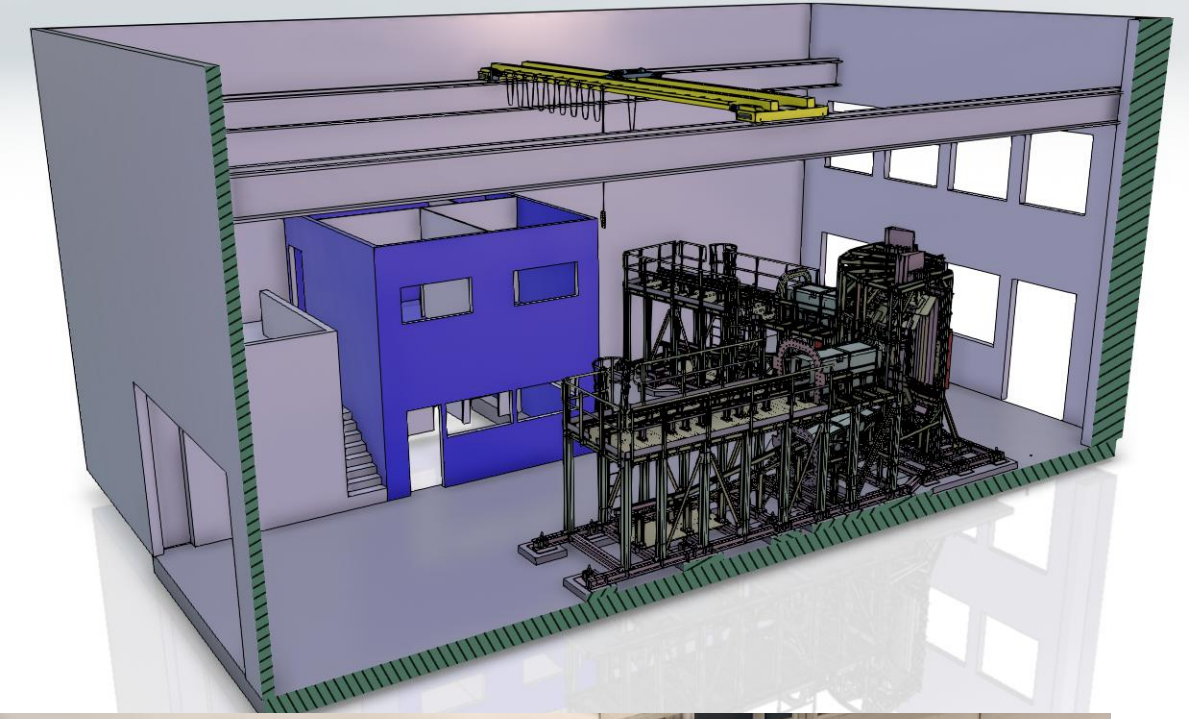
Blanket Test Platform (BTP) @ former Japan Atomic Energy Research Institute (JAERI)

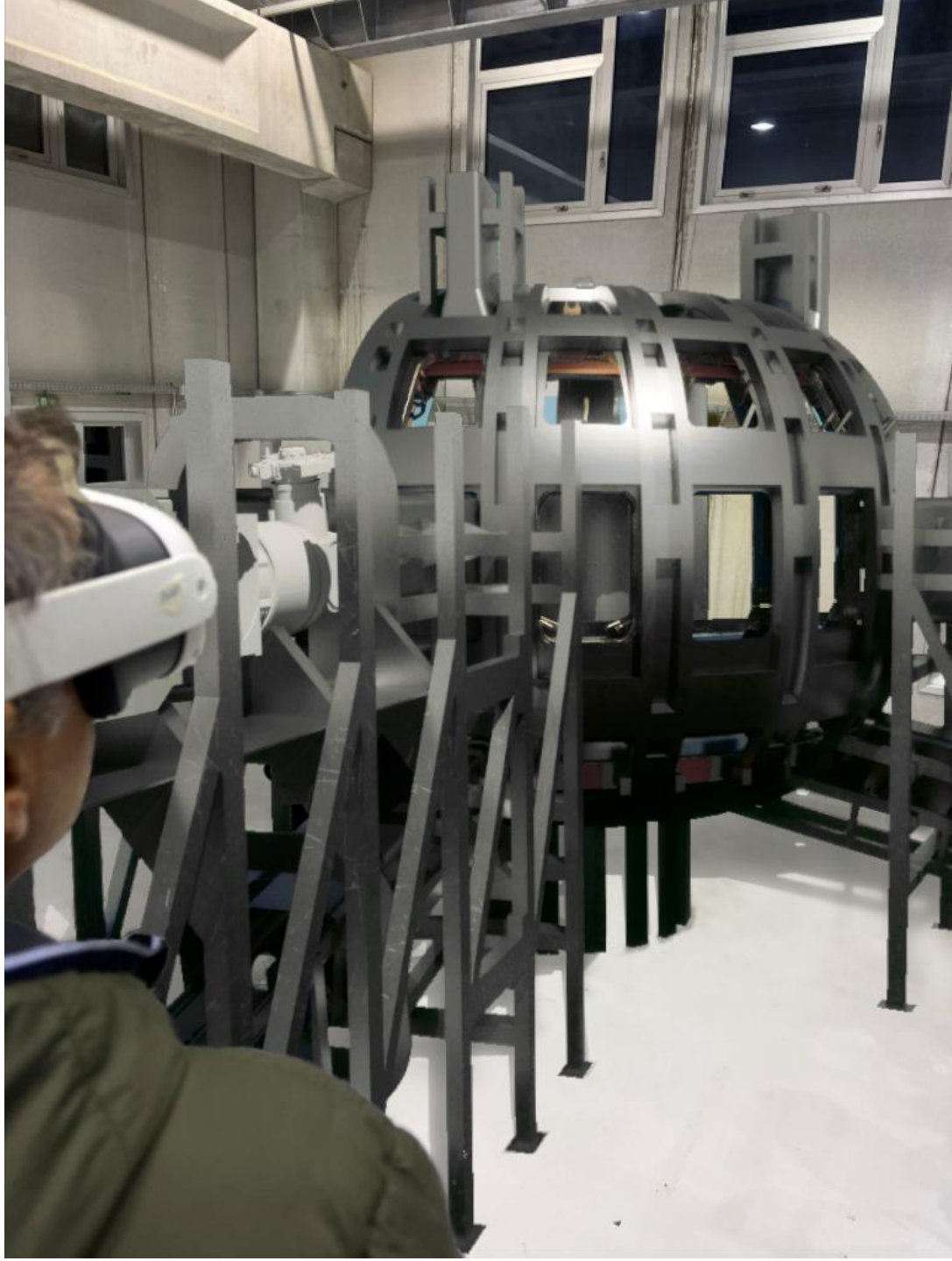


REMHAT x DTT



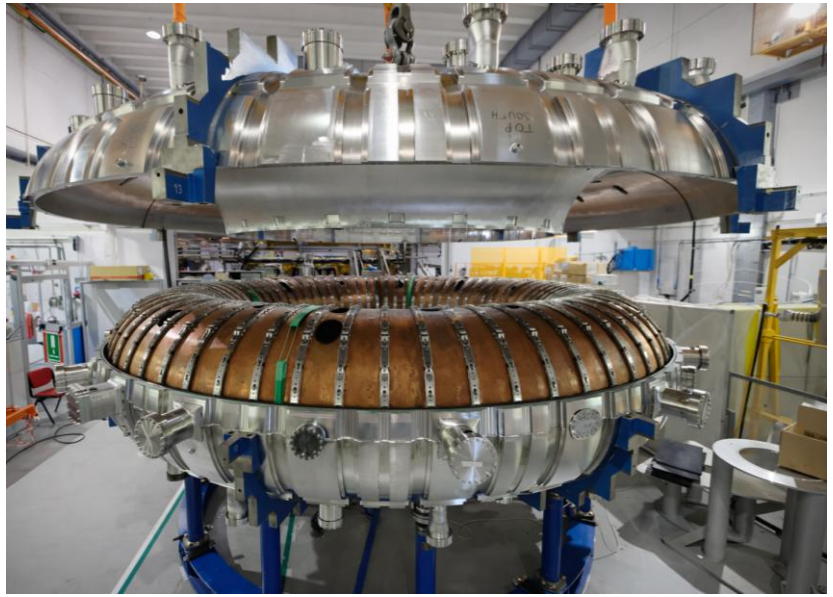
FARHA-ONE

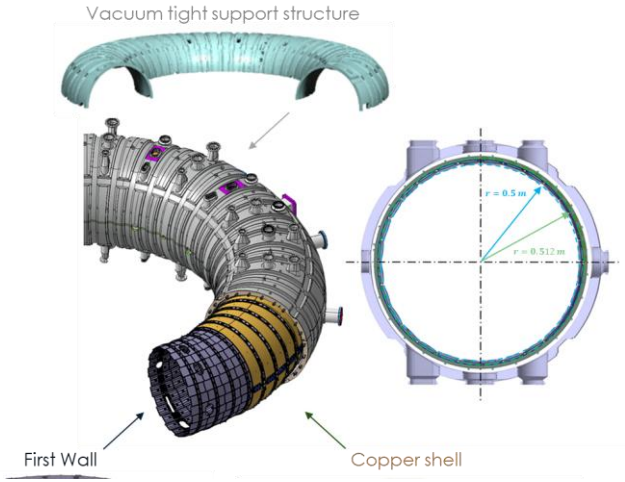


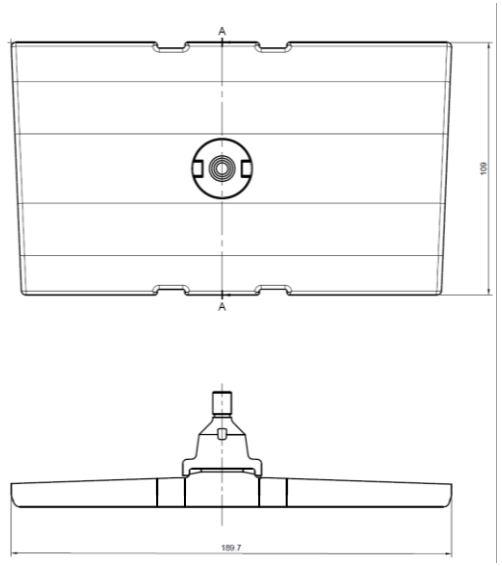


Remote Handling in RFX-mod2 – the need

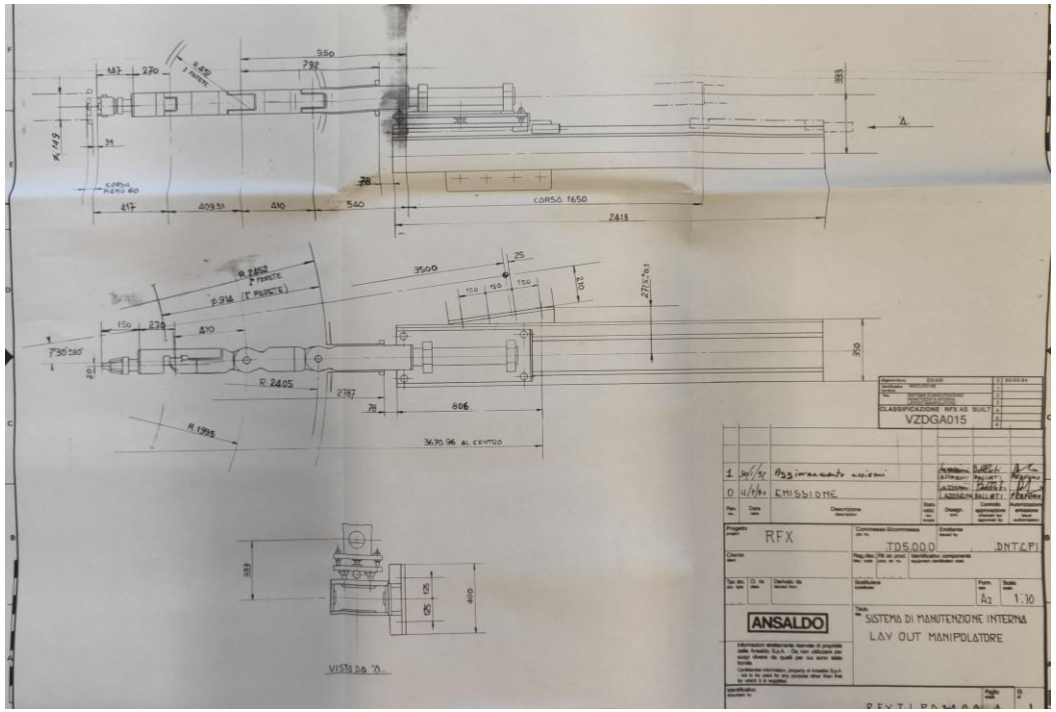
- RFX-mod2: requires periodic first-wall maintenance (graphite tile replacement)
- Internal access limited to **150 mm circular ports** — direct human intervention not feasible
- Tile engagement/disengagement requires ≥**150 N axial force** with millimeter-level positioning accuracy
- Operations demand a **high-dexterity**, remotely operated manipulator capable of operating through port constraints
- A dedicated training facility is essential to qualify operators and validate procedures before live interventions on the machine







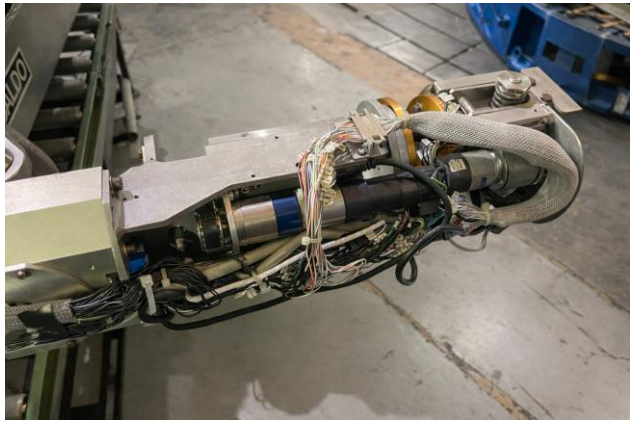
Remote Handling in RFX-mod: the history



Ansaldo Luglio 1990

Remote Handling in RFX-mod: limitations and criticalities

- **Mechanical backlash** in joints reduces the positioning accuracy
- Complex, wiring harness due to **external power and control electronic**s reflects in poor maintainability
- Not redundant **6-DOF** kinematics does not permitt reconfiguration to reduce joints torque
- Mock-up not representative of the updated first-wall geometry
- **Complex conichal gears** transmission mechanism
- **Reduced stiffness for the joint 5**



Main Objectives

1. Realization of an **improved mechanical structure of the robotic arm**

   *starting from the **revision of the original kinematics**, it will be released an **upgrade of the mechanical structure** of the manipulator and will be developed a **new multi-purpose end-effector***

2. Development of a **Virtual Reality Simulator** whose main functions are:

   ***kinematic and flexibility modeling** of robotic manipulators; **collision detection**; **VR visualization,** real-time alignment of virtual arm with the real one (**Digital Twin**).*

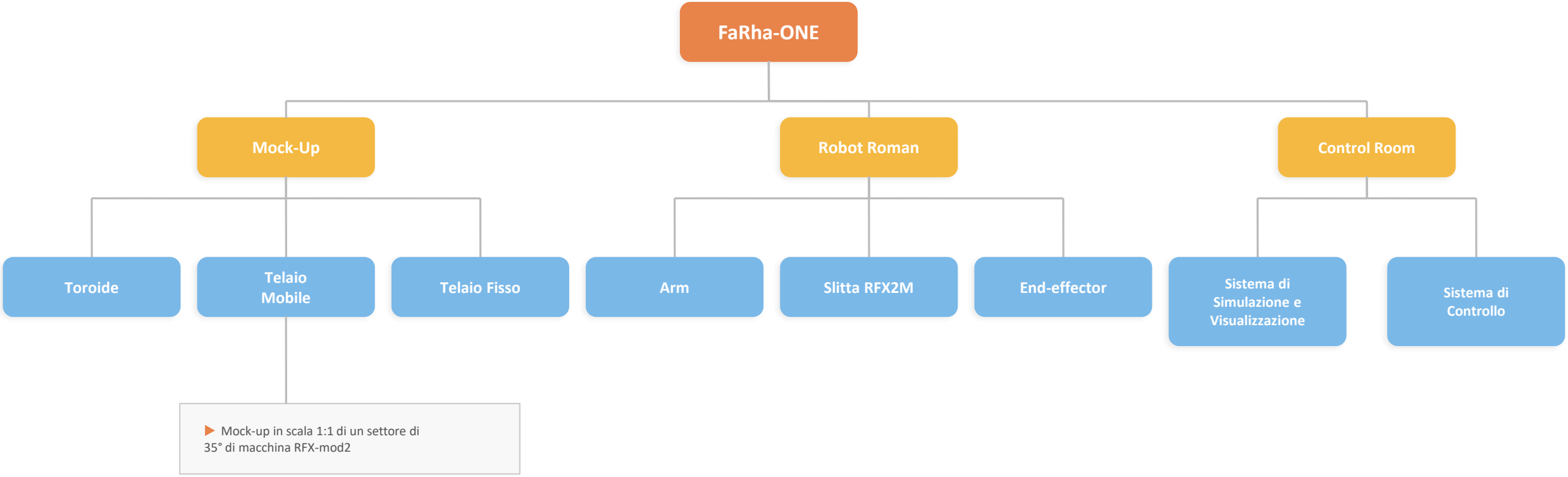
3. Realization of a **RH Test and Training Facility** whose main function are:

   Testing and validation of the RH maintenance procedures,

   Qualification and acceptance testing of RH equipment and tooling.

   Training and certification to the RH maintenance operators, by making available to operators the knowledge, instructions and experiencing of the Virtual Simulator platform, the control room devices, the robots and tooling to be used for RH tasks.

FaRha-ONE Training Facility: System Architecture

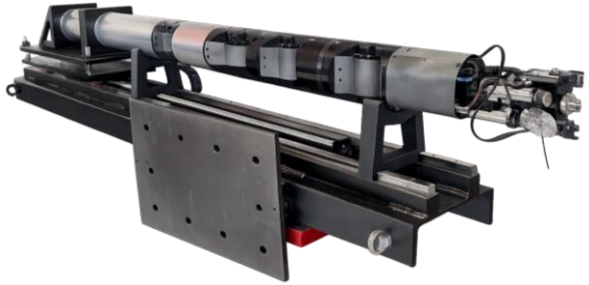


Tenders

- Completion of Technical specification in Oct/Nov 2023
- Tenders published in May 2025
- Tenders awarded in July 2025
- Contracts signed in December 2024

Mechanical & electrical executive design, manufacturing of the ROMAN manipulators

SOPHIA HIGH TECH



Structural executive design, precision machining of the Mock-up

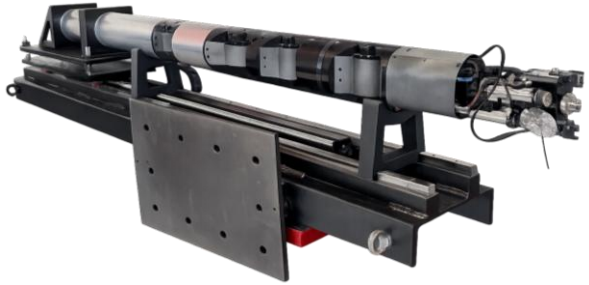
B&R BREMBANA&ROLLE

Executive Design: Industrial Partners

- Technical specifications developed internally from project requirements
- Continuous technical supervision throughout executive design phase

Mechanical & electrical executive design, manufacturing of the ROMAN manipulators

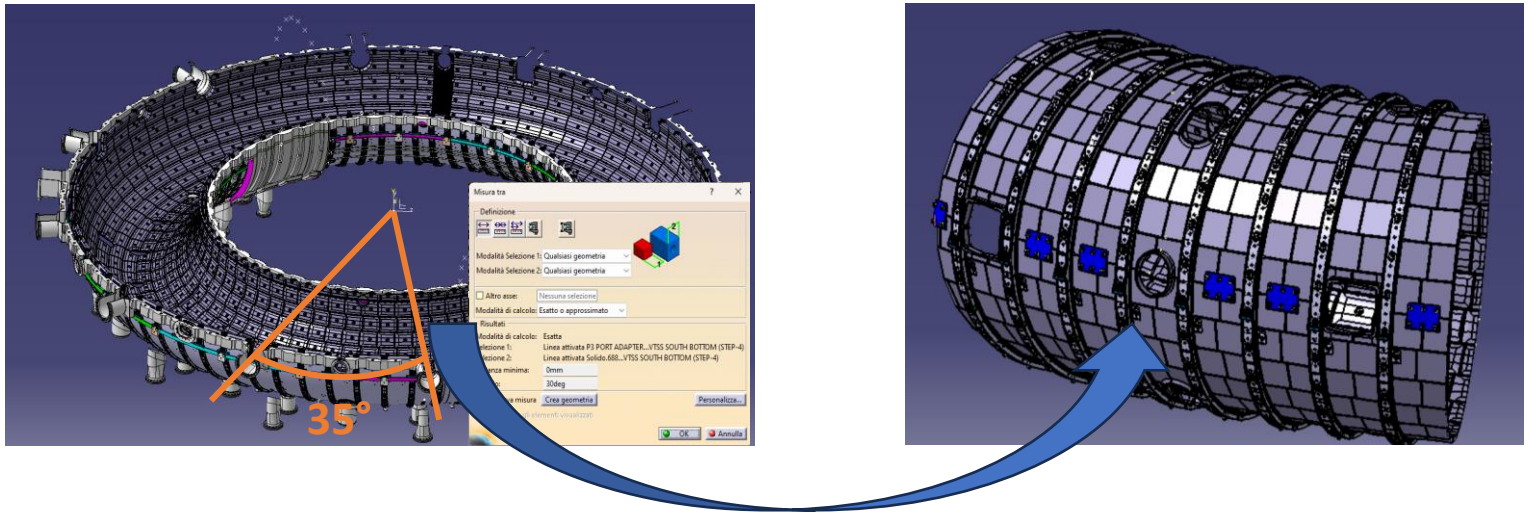
SOPHIA HIGH TECH



Structural executive design, precision machining of the Mock-up

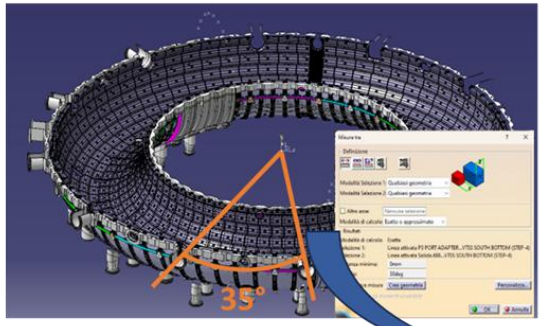
B&R BREMBANA&ROLLE

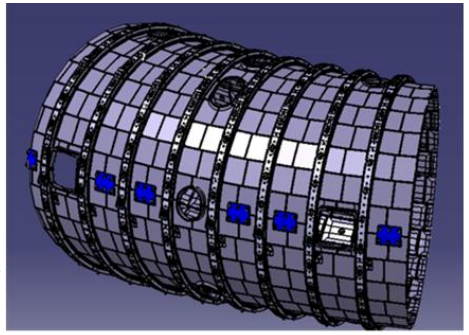
MOCK-UP – first idea

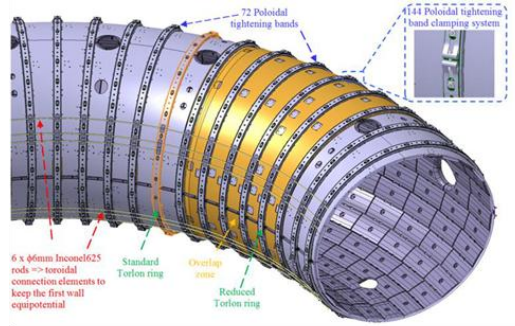


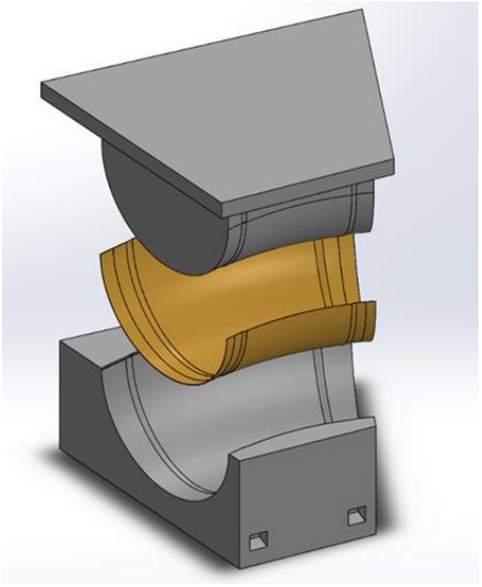
- Creation of a 35° sector with a central door.
- Use of a subset of circular sheet metal elements containing the tile supports and supported by a load-bearing structure.
- Possible use of plexiglass elements to join the structural elements.

MOCK-UP

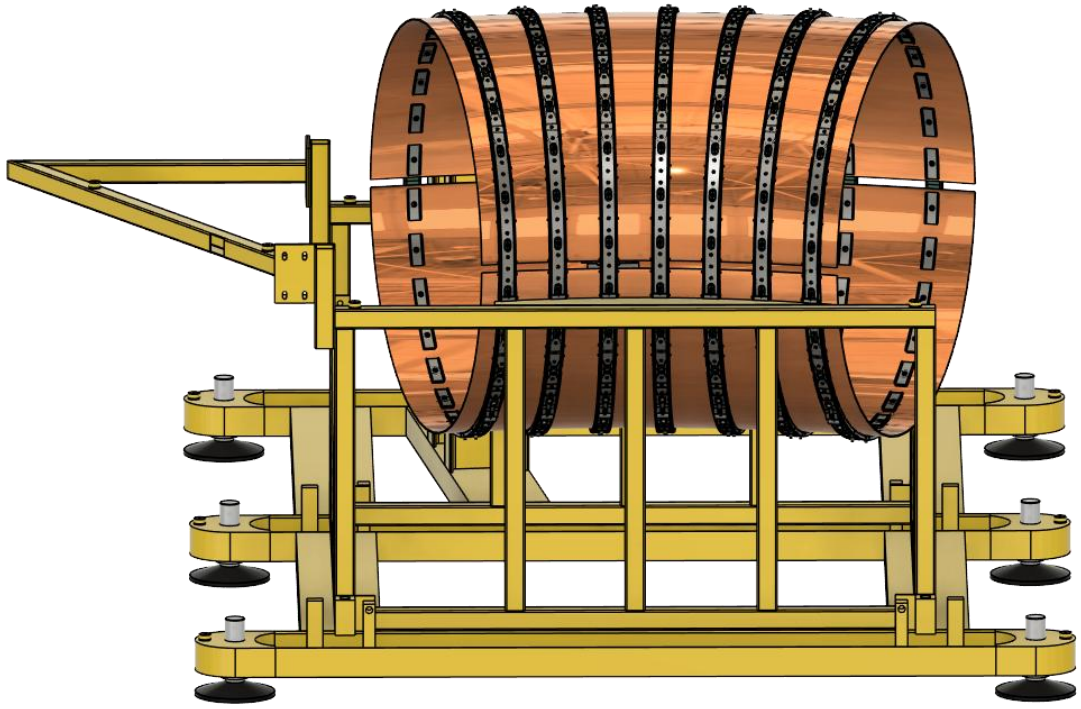

35°




72 Poloidal tightening bands
144 Poloidal tightening band clamping system
6 x ϕ6mm Inconel625 rods => toroidal connection elements to keep the first wall equipotential
Standard Torlon ring
Overlap zone
Reduced Torlon ring



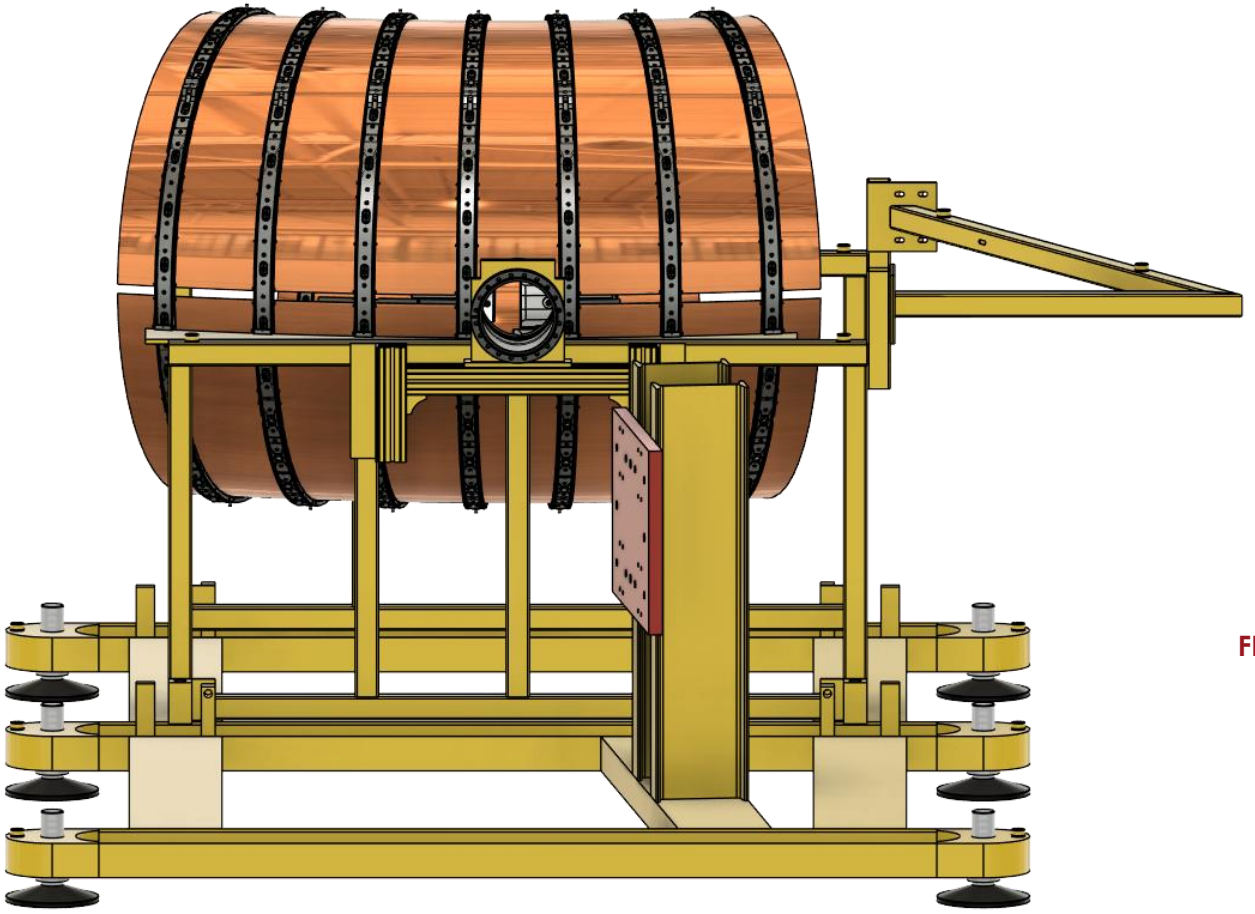
MOCK-UP



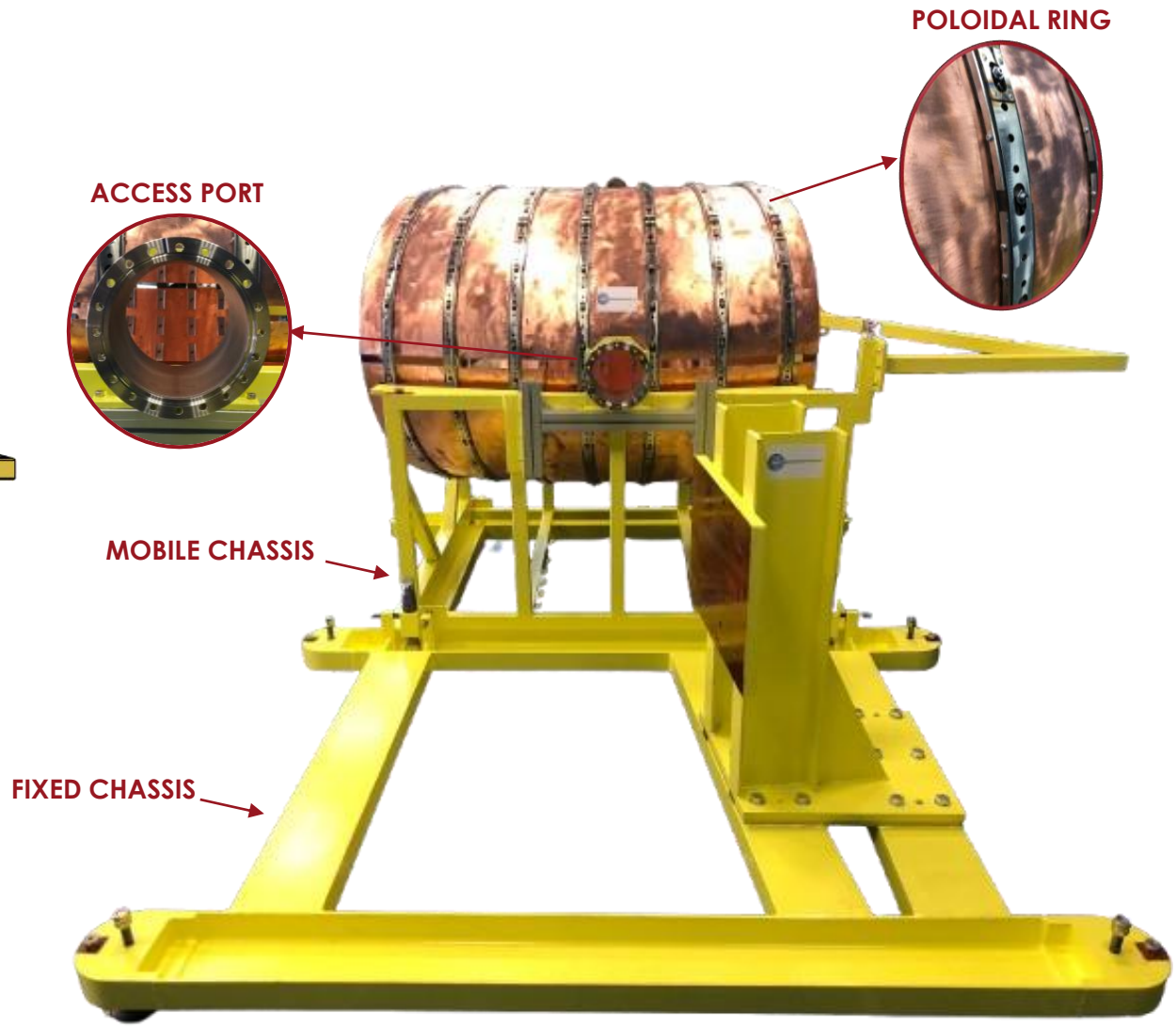
CAD VERSION

REAL VERSION

MOCK-UP

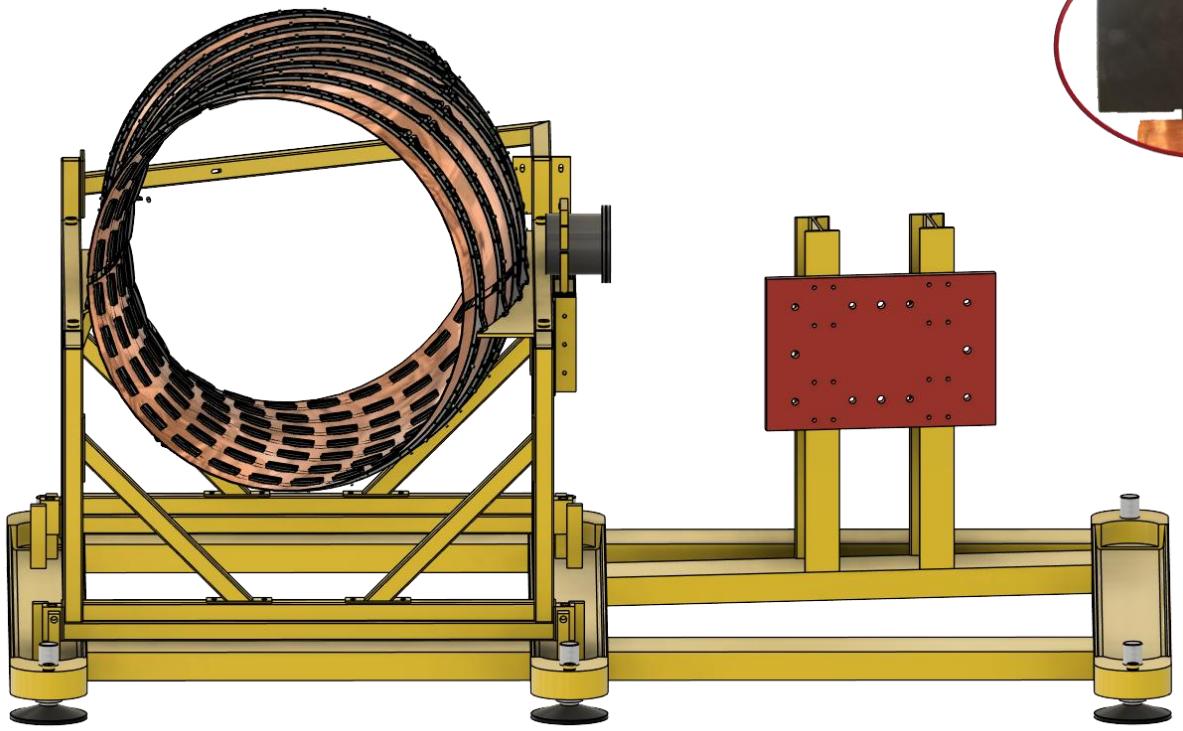


CAD VERSION

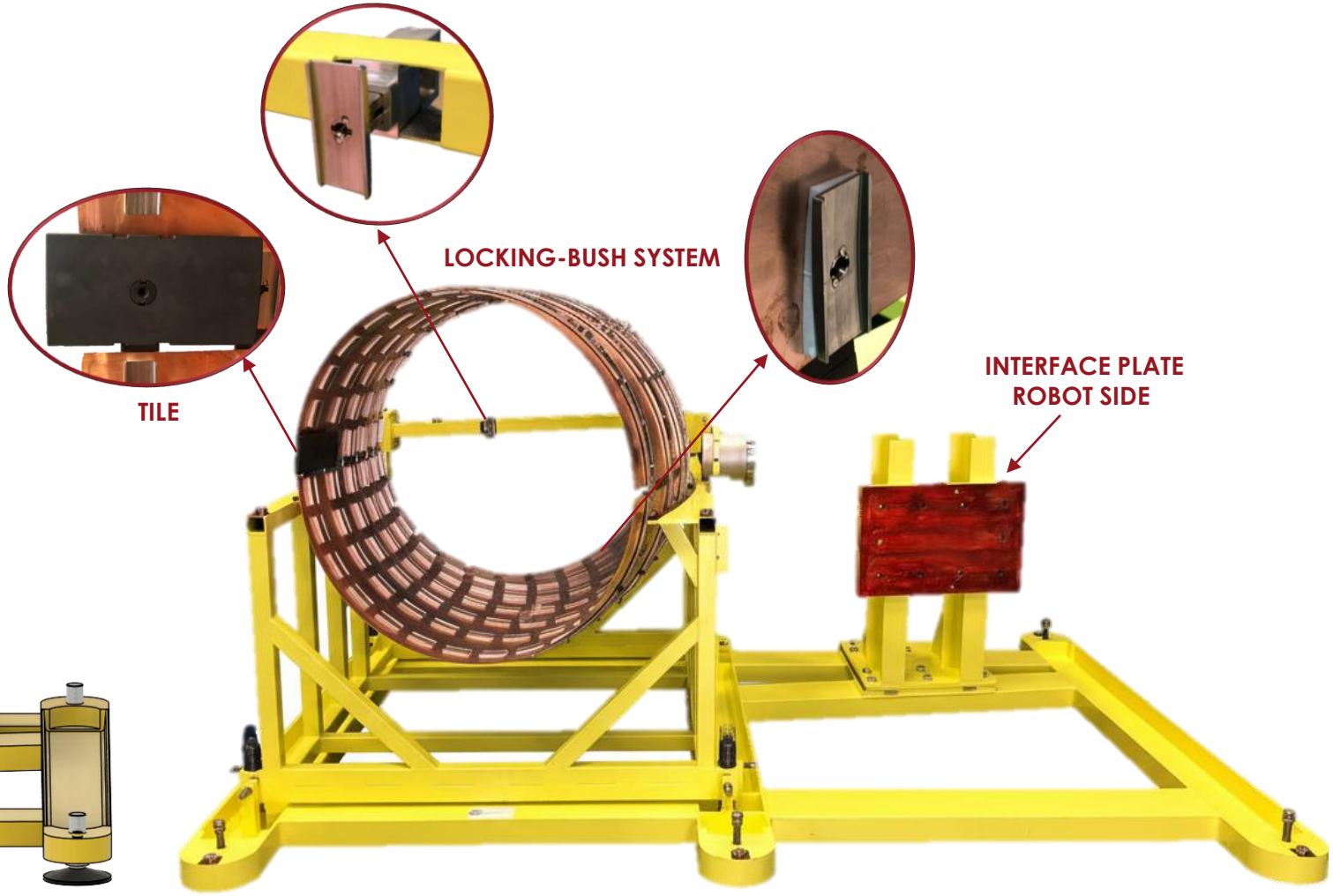


REAL VERSION

MOCK-UP



CAD VERSION

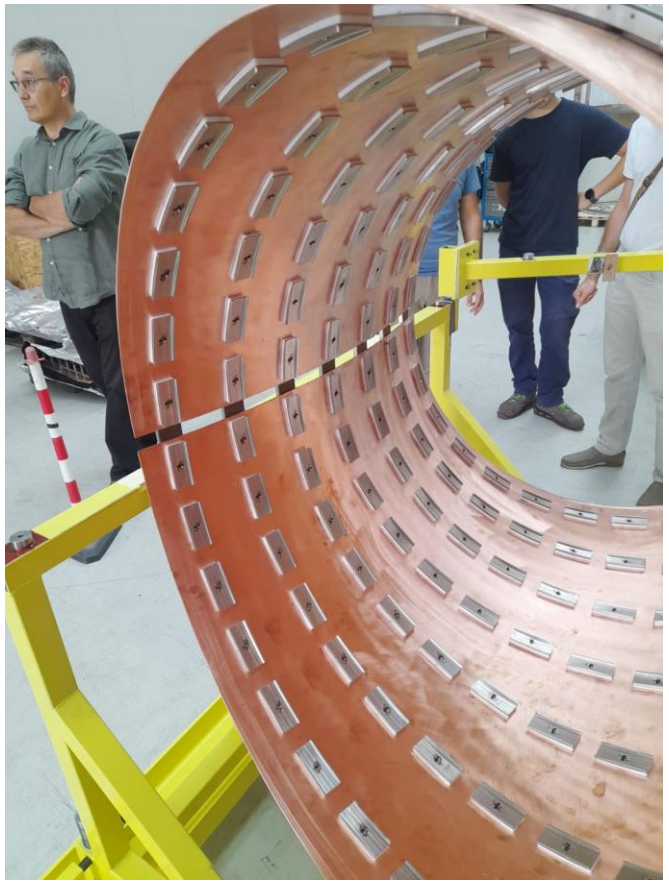


REAL VERSION

MOCK-UP: FAT

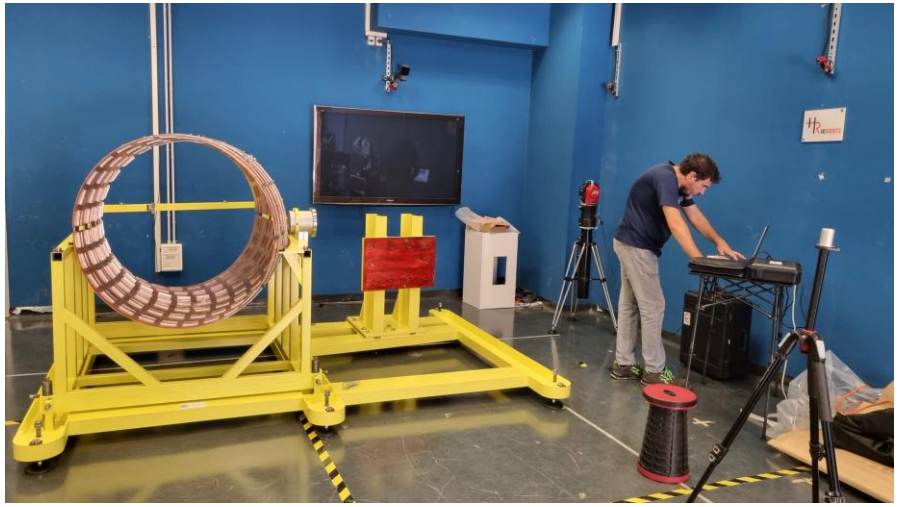
FAT completed in August 2025

BREMBANA&ROLLE

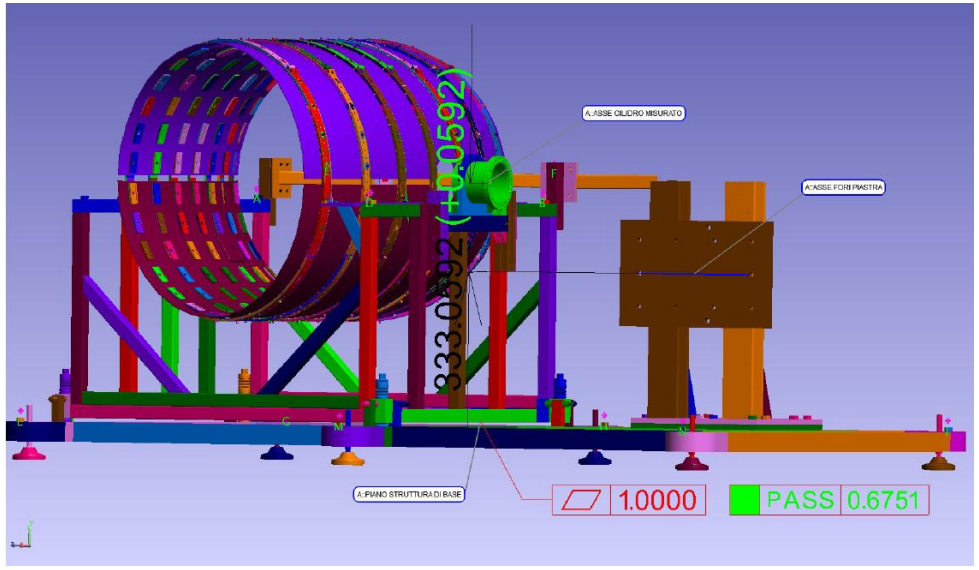


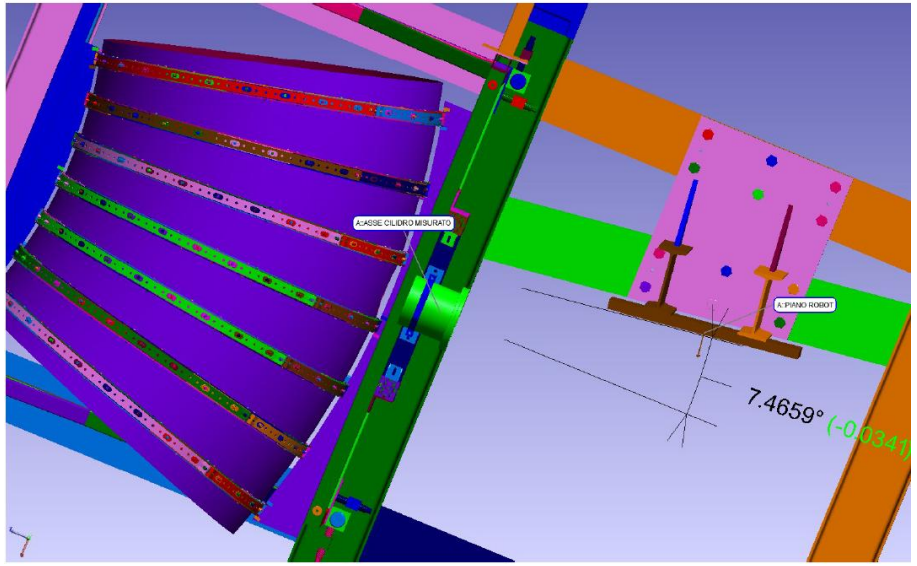
MOCK-UP: SAT

SAT completed in September 2025

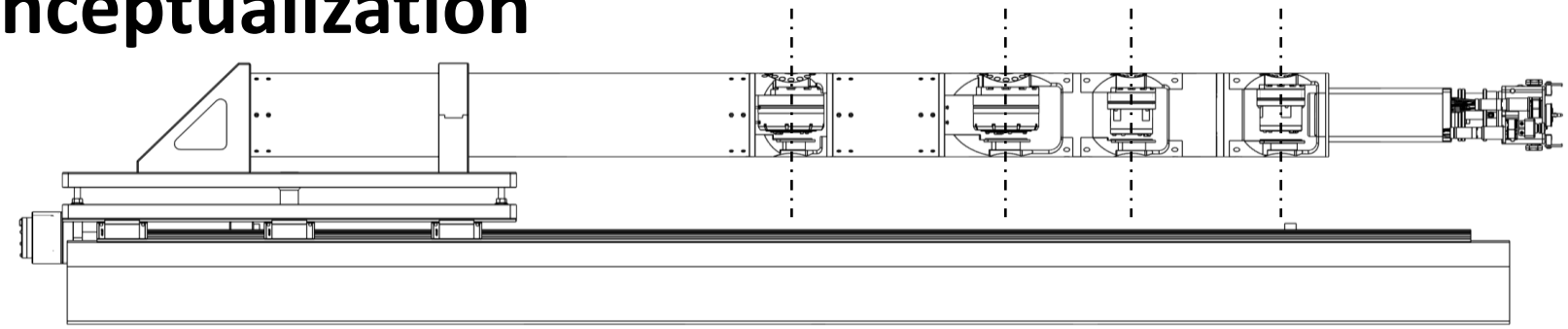


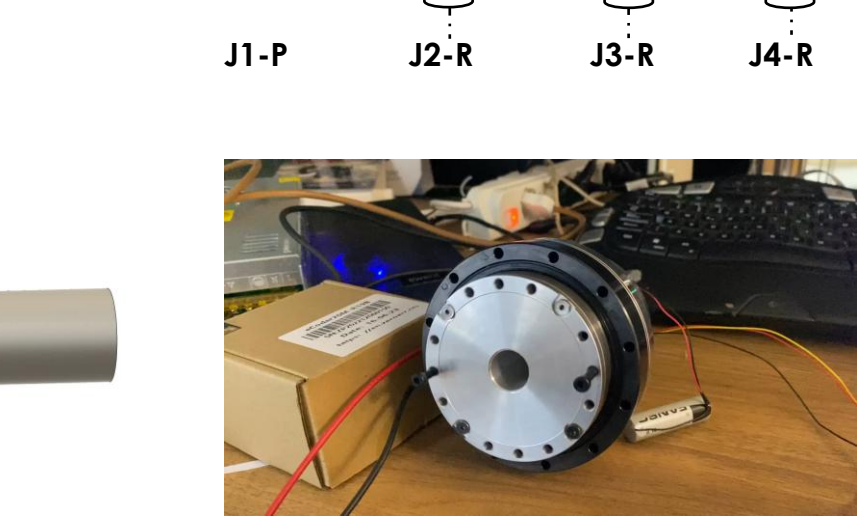
BREMBANA&ROLLE





ROMAN: conceptualization

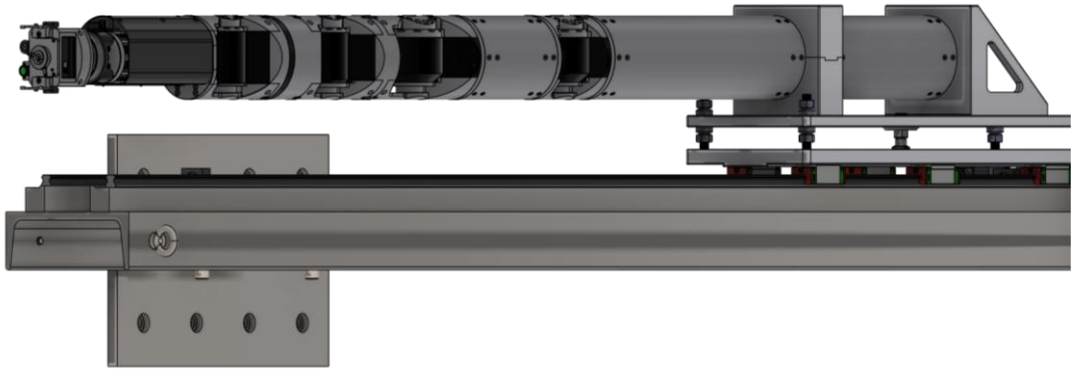


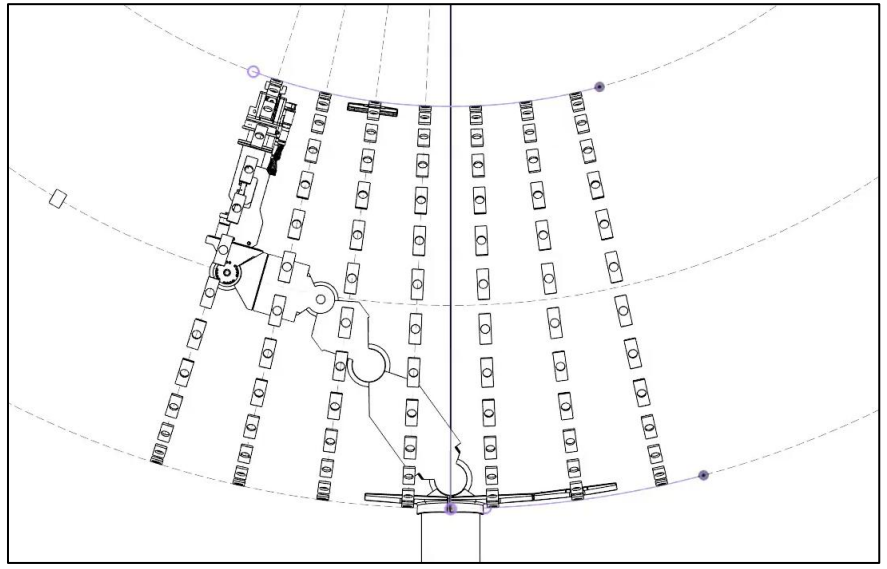


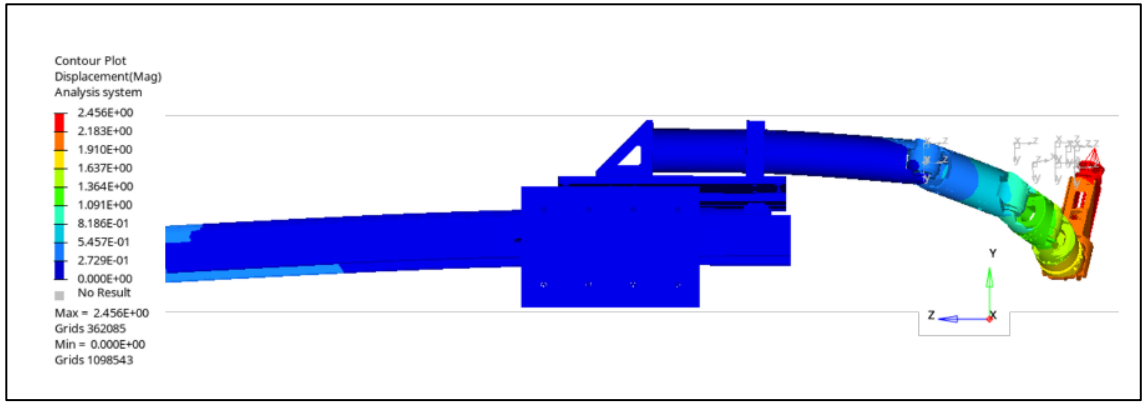
FDM

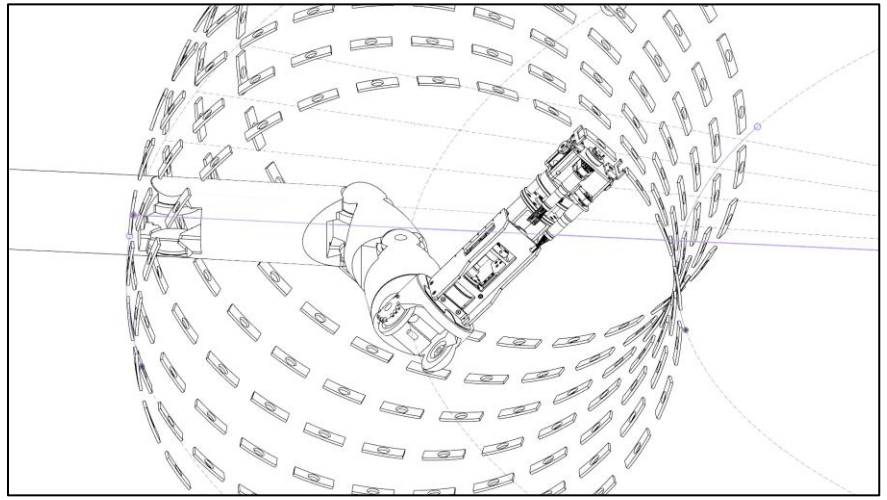
CNC

ROMAN: design verification









ROMAN: FAT

FAT completed in November 2025

SOPHIA HIGH TECH

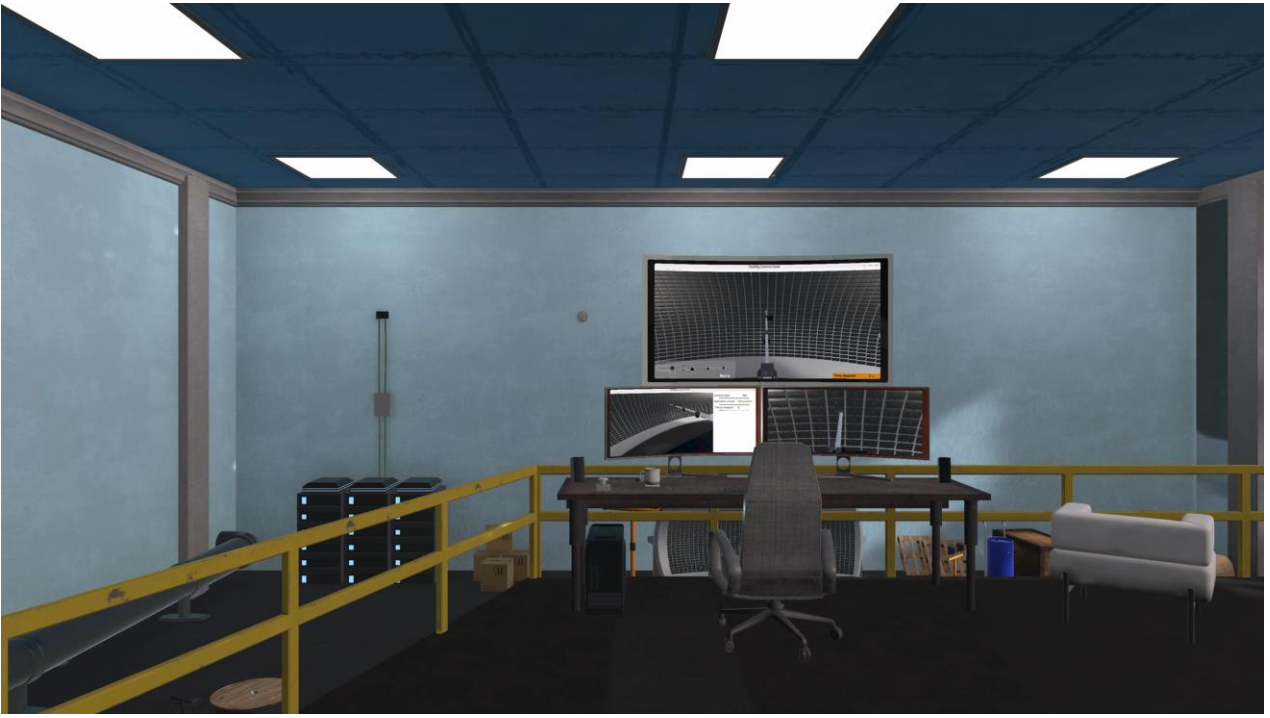
ROMAN: SAT

SAT completed in January 2026

SOPHIA HIGH TECH

Virtual Reality Simulator and Digital Twin

Interconnecting the virtual and real worlds…



CONCLUSIONS

Giuseppe Di Gironimo

Andrea Fontanelli

Salvatore Fusco

Alessandro Sofia

Students and young researchers are stimulated by the infrastructure and the **multidisciplinary** knowledge it requires.
They learn to work in teams, **without boundaries** between disciplines,
and we do the same for them.

PUBLICATIONS

[1] Fusco, S., Sofia, A., Fontanelli, G.A., Grazioso, S., Di Gironimo, G. (2025). Preliminary Concept Design of an Innovative Under-Actuated Gripper for the Remote Handling Operations in the RFX-Mod2 Fusion Machine. In: Di Stefano, P., Gherardini, F., Nigrelli, V., Rizzi, C., Sequenzia, G., Tumino, D. (eds) Design Tools and Methods in Industrial Engineering IV. ADM 2024. Lecture Notes in Mechanical Engineering. Springer, Cham. https://doi.org/10.1007/978-3-031-76597-1_17

[2] Giuseppe Andrea Fontanelli, Alessandro Sofia, Salvatore Fusco, Stanislao Grazioso, Giuseppe Di Gironimo, Preliminary architecture design for human-in-the-loop control of robotic equipment in remote handling tasks: Case study on the NEFERTARI project, Fusion Engineering and Design, Volume 206, 2024, 114586, ISSN 0920-3796, https://doi.org/10.1016/j.fusengdes.2024.114586.

[3] Fusco, S., Sofia, A., Grazioso, S., Fontanelli, G.A., Di Gironimo, G. (2024). Brief Overview of Long Reach Manipulators for Remote Maintenance in Fusion Reactors. In: Carfagni, M., Furferi, R., Di Stefano, P., Governi, L., Gherardini, F. (eds) Design Tools and Methods in Industrial Engineering III. ADM 2023. Lecture Notes in Mechanical Engineering. Springer, Cham. https://doi.org/10.1007/978-3-031-58094-9_31

Thank You!

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