

THE DIVERTOR TOKAMAK TEST FACILITY: MACHINE DESIGN, CONSTRUCTION AND COMMISSIONING



G. M. Polli^{1,3}, G. Barone^{1,3}, A. Cucchiaro¹, M. Dalla Palma^{2,4}, L. Gabellieri¹, A. Lampasi^{1,3}, A. Pizzuto¹, G. Ramogida^{1,3}, A. Reale^{1,3}, B. Riccardi¹, S. Roccella³, and DTT Contributors

¹DTT S.C. a r.l., Via Enrico Fermi, 45 – 00044 Frascati, Italy; ²Consorzio RFX, corso Stati Uniti 4 – 35127 Padova, Italy; ³ENEA Via Enrico Fermi, 45 – 00044 Frascati, Italy; ⁴CNR-ISTP, corso Stati Uniti 4 – 35127 Padova, Italy

Corresponding author e-mail address: gianmario.polli@dt-project.it

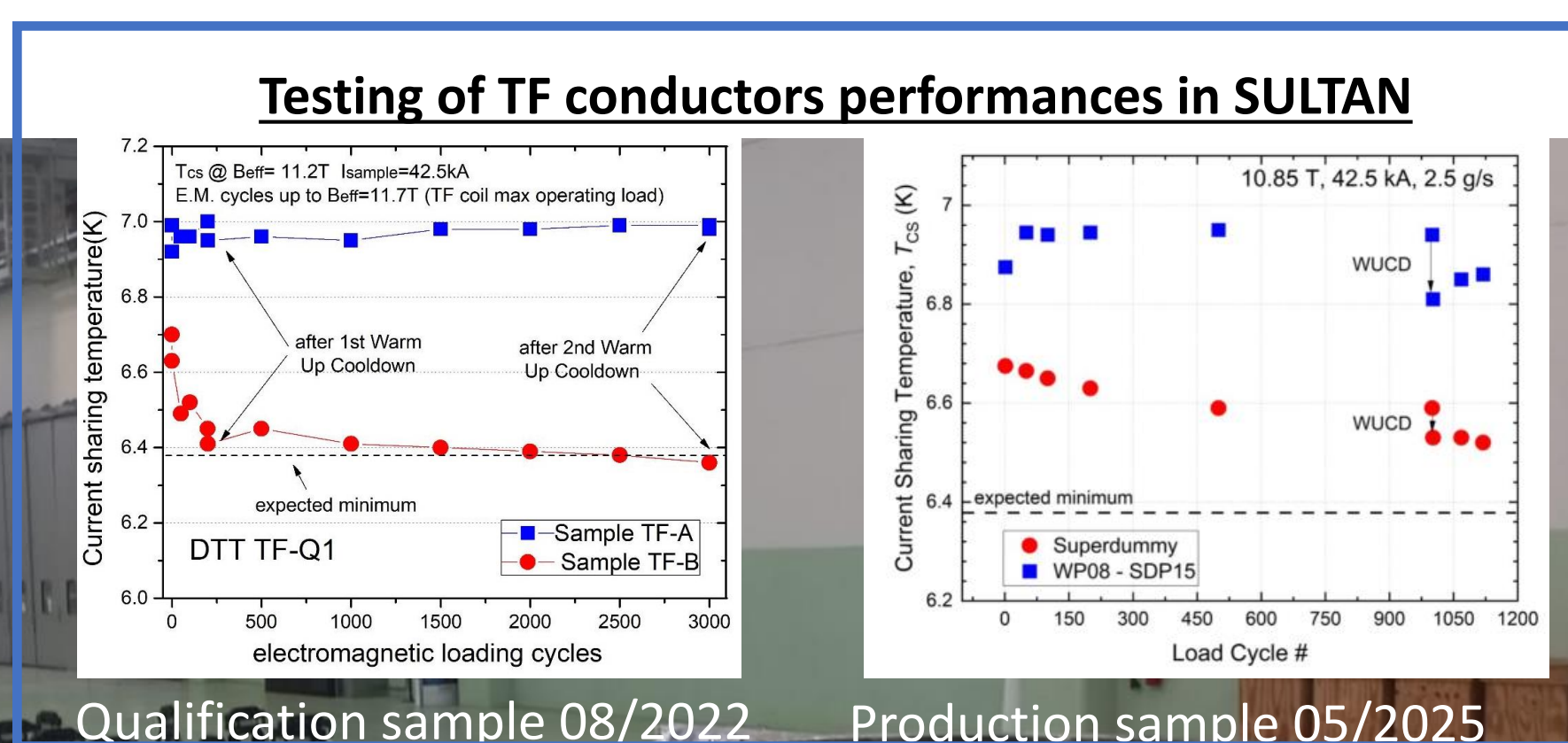
ABSTRACT

DTT (Divertor Tokamak Test) facility is an experimental facility under construction at ENEA Frascati, characterized by the following features:

- a breakeven-class tokamak
- fully superconducting to allow pulses of the order of 100s
- with water cooled, tungsten plasma facing components capable of confining deuterium plasmas

The status of design and construction of some of the main tokamak systems and components is here reported and the plan for the assembly and commissioning is illustrated

- ✓ WP-01 - WP-04 completed
- ✓ 6 WP within 2025
- ✓ 18 WP within 2026
- ✓ 1 TFC delivered in Q3/2027



Qualification sample 08/2022

Production sample 05/2025

FCCTF – Frascati Coil Cold Test Facility is a facility under preparation in ENEA to test the 27 Nb3Sn DTT coils (TF, PF1/6 and CS modules). The final DTT TF power supply is used to convey the nominal current (up to 45 kA) in cryogenic conditions

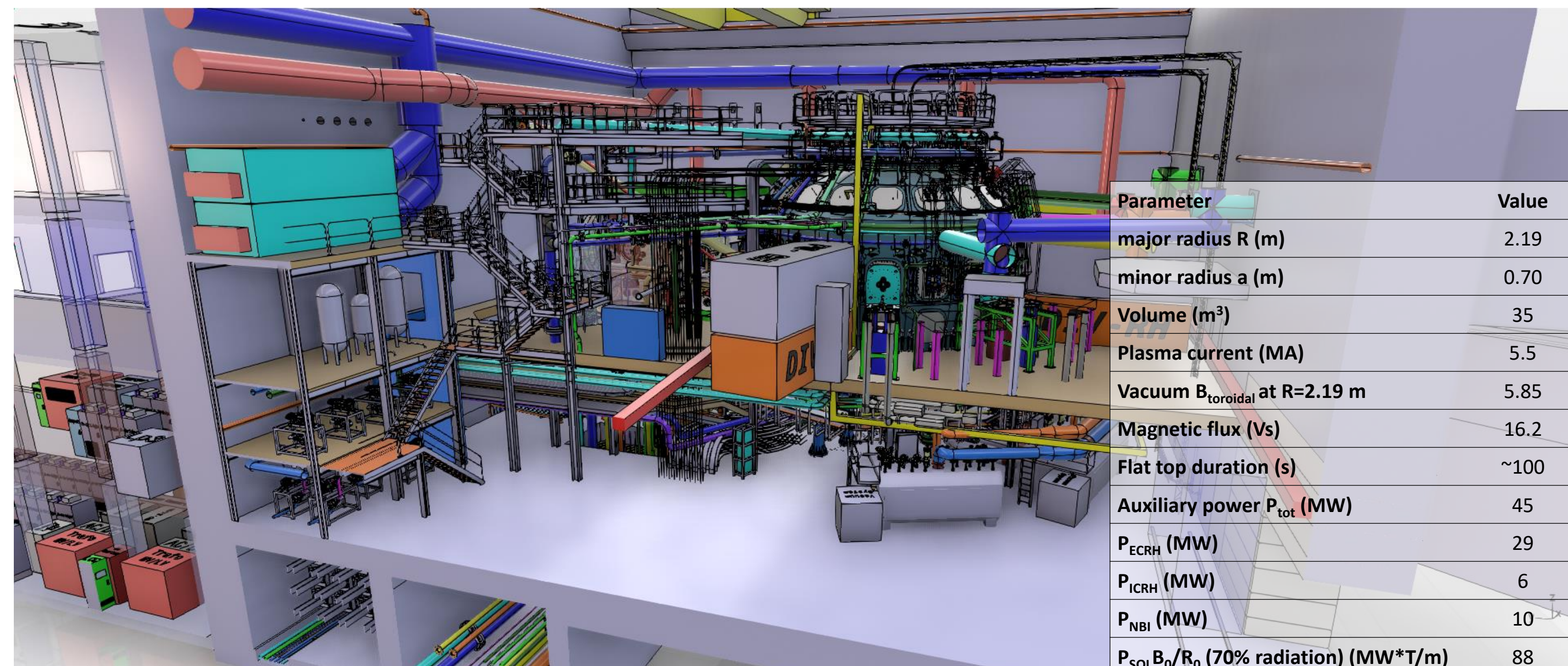
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- ✓ Every qualification process for the final integration completed
- ✓ Tooling for WP into casing integration installed

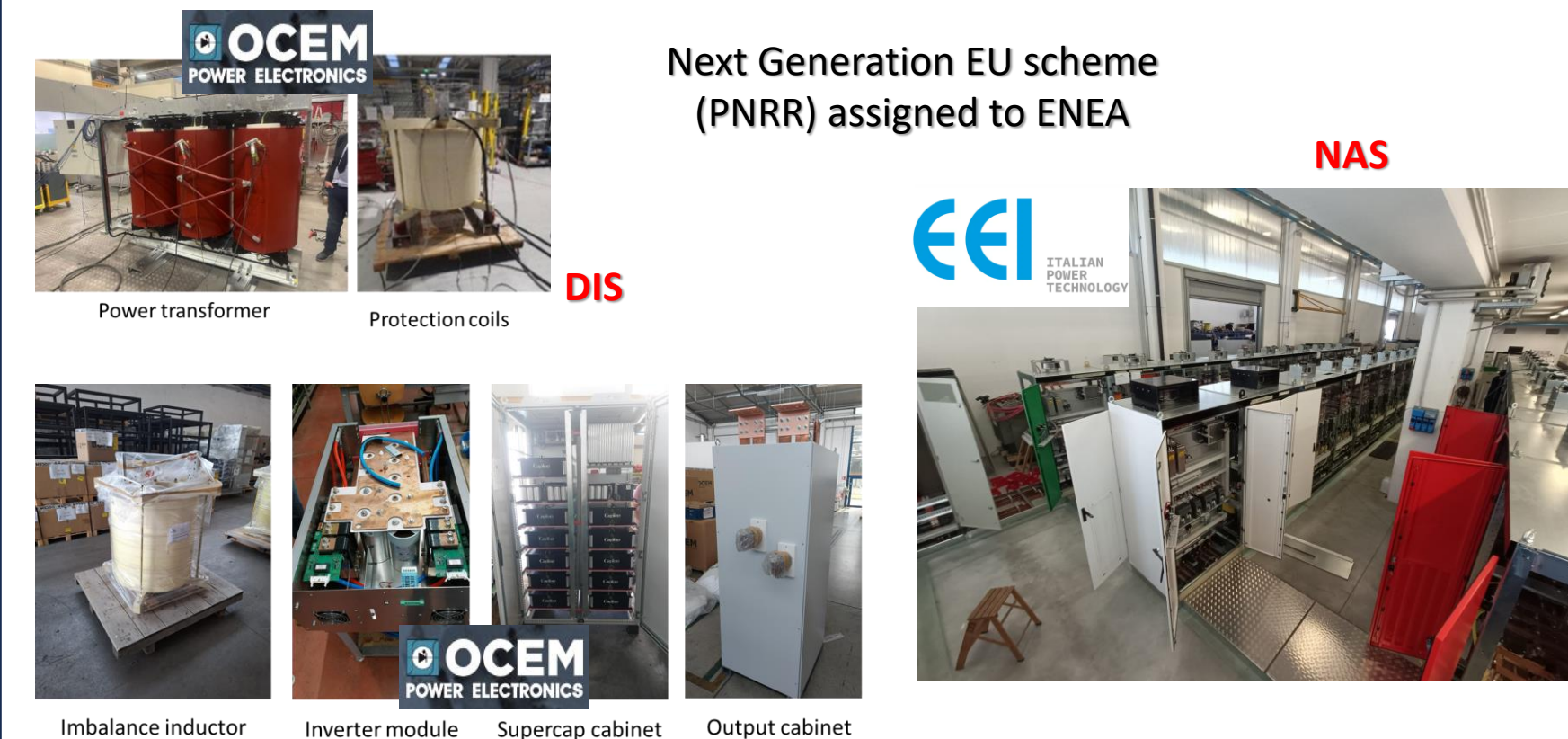
Integration mock-up subject to cryogenic cooling in liquid Nitrogen to qualify fiber optic sensors for strain and temperature measurements.

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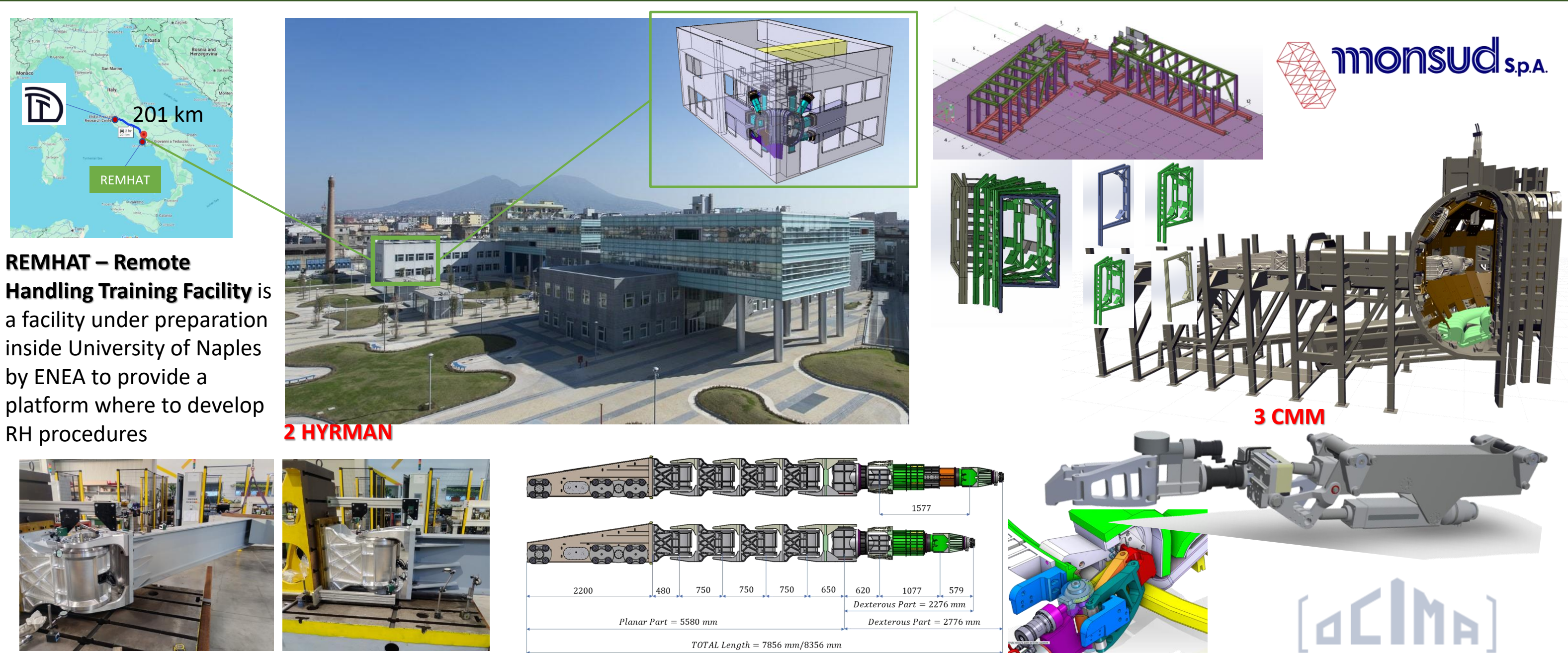
- The **Toroidal Field (TF) Magnets Production**: The Nb3Sn TF magnets, designed for steady-state operation, are in advanced manufacturing, with conductor production in Italy and winding assemblies at ASG Superconductors. The first TF module delivery is expected in the second half of **2027**, and the final one by early **2029**, ahead of the planned tokamak assembly.
- **Poloidal Field (PF) and Central Solenoid (CS) Coils**: The six PF coils are being manufactured (two in Nb3Sn, four in NbTi).
- The **Central Solenoid CS** design has adopted the **pancake winding** scheme, and an **High-Temperature Superconductor (HTS) insert** project has been launched to generate surplus magnetic flux larger than the target 16.2 Vs.
- **Magnet Testing and Qualification**: All Nb3Sn magnets (TF and PF) will undergo full-current testing at the **Frascati Coil Cold Test Facility (FCCTF)**, currently under construction, to assess superconducting performance and allow for potential repairs before final integration.
- **Cryogenic Plant Status**: The final design was completed in 2025. The plant, comparable in class to those of JT-60SA and KSTAR, will be housed in modified existing buildings. The first components are not expected until 24 months after the supply contract signing, which is scheduled for **2026**.



Parameter	Value
major radius R (m)	2.19
minor radius a (m)	0.70
Volume (m ³)	35
Plasma current (MA)	5.5
Vacuum B _{toroidal} at R=2.19 m	5.85
Magnetic flux (Vs)	16.2
Flat top duration (s)	~100
Auxiliary power P _{tot} (MW)	45
P _{ECRH} (MW)	29
P _{CRH} (MW)	6
P _{NBI} (MW)	10
P _{SOL} B ₀ /R ₀ (70% radiation) (MW*/T/m)	88



- ✓ **TF Power Supply Procurement**: The procurement for the TF system, initiated in 2022, was split into two parts: the **AC/DC converter** (42.5 kA at 100 V, manufactured by JEMA) and the **Fast Discharge Units (FDUs)**. The converter procurement has been completed and provisionally installed at the Frascati Coil Cold Test Facility (FCCTF).
- ✓ **Fast Discharge Units (FDUs)**: The FDUs, which use **SIC varistors** for a 10-second linear current reduction, manufactured by OCEM Power Electronics. The first of three identical units has been finalized, shipped, and is scheduled for setup at the FCCTF by late **2025**.
- ✓ **PF and CS Power Supplies**: Specifications are finalized, and the bidding process is scheduled to start shortly in **2025**.
- ✓ **In-Vessel Coils Power Supplies**: the delivery of 27 units for the non-axisymmetric coils is expected by the end of **2025**, while the units for the axisymmetric divertor and vertical stabilization coils will be delivered in early **2026**.



- ✓ **Remote Maintenance is Essential**: DTT's long-term availability relies on **Remote Handling (RH)** systems to perform crucial maintenance, particularly the rapid, multiple replacement of **divertor modules** (a key design requirement) and the maintenance of the first wall and Ion Cyclotron Heating (ICH).
- ✓ **Training and Validation Facility (REMHA)**: A dedicated **Remote Handling Training Facility (REMHA)** is being constructed at the University of Naples Federico II by ENEA. This facility, featuring a **full-scale replica of a 110° DTT vacuum vessel sector** and mock-ups, will be central to validating RH tools, procedures, and equipment compatibility, as well as training personnel before deployment.
- ✓ **Specialized RH Systems**: The facility will use dedicated robotic systems: **two HYRMAN** robotic arms for the first wall and ICH antennas, and **three Cassette Multifunctional Movers (CMM)** for handling the divertor. Both the HYRMAN and CMM systems are progressing in their manufacturing phase in Italy.

- ✓ **Assembly and Commissioning Contract**: The call for tender for the machine's assembly and commissioning will be launched by the end of **2025**. The contract is divided into four main phases: **engineering design of tooling**, **procurement of tooling/materials**, **special process qualification** (like port welding), and the **assembly of the machine** in the experimental hall.
- ✓ **Assembly Schedule**: Optimization efforts, including detailed planning and qualification of pre-assembly processes (e.g., vacuum vessel instrumentation), aim to keep the schedule on track. The total assembly time, up to the start of integrated commissioning, is estimated at **less than 30 months**, assuming component availability and a two-shift daily operation with Saturday testing.
- ✓ **Integrated Commissioning Phases**: The commissioning, expected to take between **8 and 12 months**, will follow a strict sequence: initial **baking and vacuum pumping**, assessment of cryostat tightness, slow **cool-down** (approx. one month), **magnet charging** (starting with TF, then PF/CS, at limited currents), and finally, commissioning of **water-cooling** and **in-vessel components** (e.g., boronization, magnetic diagnostics, fueling/pumping) before achieving the **first plasma**.

CONCLUDING REMARKS

- ✓ A comprehensive set of auxiliary facilities is under preparation for risks mitigation:
 - FCCTF = Frascati Cryogenic Coil Test Facility for testing Nb3Sn coils in relevant full current conditions
 - REMHA = REMote HANDling Training facility for testing RH systems and procedures
 - ✓ TF magnets are in fabrication phase
 - ✓ VV procurement has been awarded and the start of activities is expected in few weeks
 - ✓ Divertor is moving towards construction phase (after completion of integrated design and qualification activities)
 - ✓ Assembly specification is under review and call for tender will be launched soon
- DTT will be a **unique, flexible, integrated environment** for the testing of high heat flux components of the next generation of tokamaks and will foster a new generation of scientists and engineers in the fusion community

DTT Consortium (DTT S.C.a r.l. Via E. Fermi 45 I-00044 Frascati (Roma) Italy)