3DMC 3D METROLOGY CONFERENCE

METROMECÁNICA
INDUSTRIAL METROLOGY

LARGE VOLUME METROLOGY AT ITER PROJECT

Basque Country, Spain 28/09/2023

About us

We provide true and relevant dimensional information

2003 Metromecánica

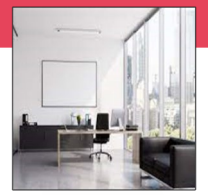
2007
First international projects

2011
Automation projects

2014
Metrology laboratory opening, Vizcaya

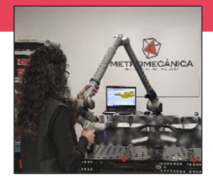
2014
ITER International Nuclear Fusion Project

2015
Office opening Toulouse Metromecanica Corporation



2017
Office opening Madrid

2019
Garmo Instruments



2020
Office opening Saint Nazaire

2023
20th Anniversary

What makes us different

We develop automatic measurement solutions, create metrology products and perform dimensional inspection services

Offices	0006	Employees	0050

- Aeronautics
- Automotive
- Transport
- Energy
- Appliances
- GICs
- AEC

What we offer

METROLOGY SERVICES

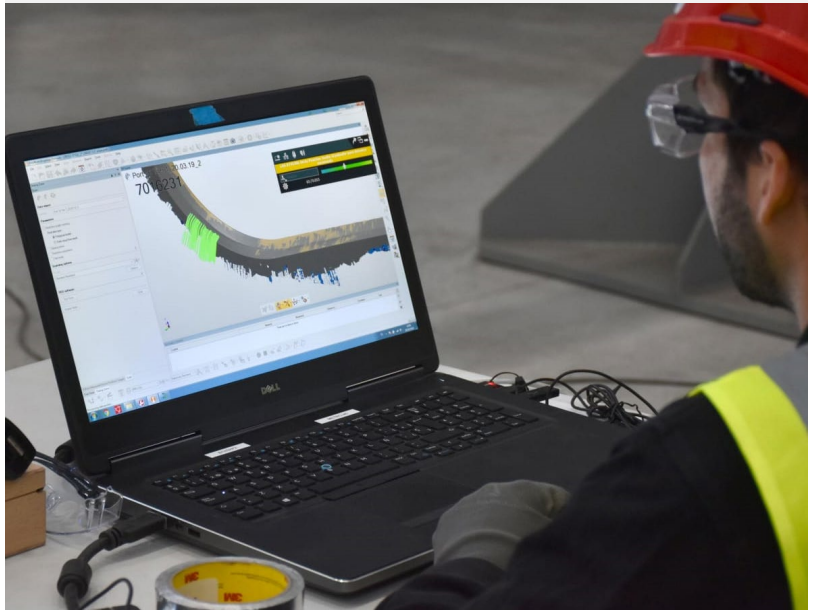
- Measurement of parts and assemblies
- Geometry in machinery and production lines
- 3D Scanning and Reverse Engineering
- AEC, high volume scanning, digital twin

AUTOMATION

- We select the technology you need
- We integrate dimensional inspection equipment in production lines
- Autonomous solutions, digitized data
- We carry out turnkey projects

PRODUCT

GAPGUN®
FARO
VECTRO®
ABB
RENISHAW
ISI ROB
SA SpatialAnalyzer



ITER TOKAMAK

- THE TOKAMAK IS AN EXPERIMENTAL MACHINE DESIGNED TO HARNESS THE ENERGY OF FUSION.
- ITER WILL BE THE WORLD'S LARGEST TOKAMAK, WITH A PLASMA RADIUS (R) OF 6.2 M AND A PLASMA VOLUME OF 840 M^3.
- INTERNATIONAL PROJECT: China, the European Union, India, Japan, Korea, Russia and the United States

A GIANT

23000t

Machine weight

10X THE CORE OF THE SUN

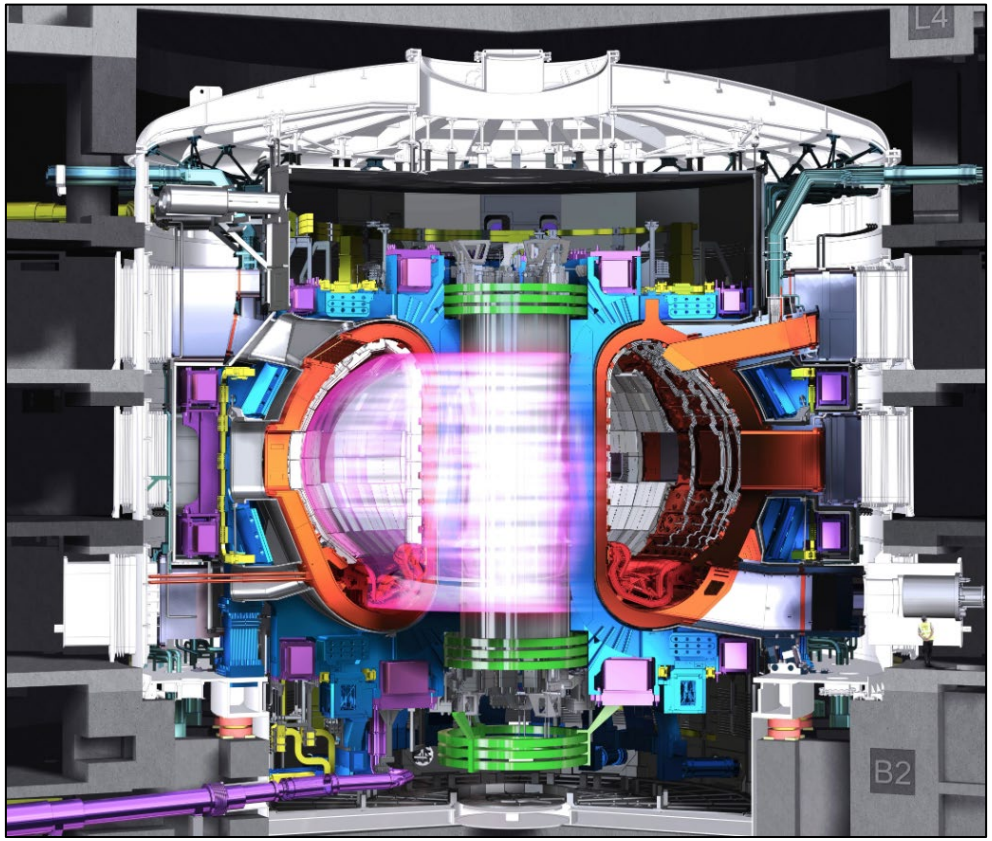
150million°C

Plasma temperature

FUSION ENERGY

500MW

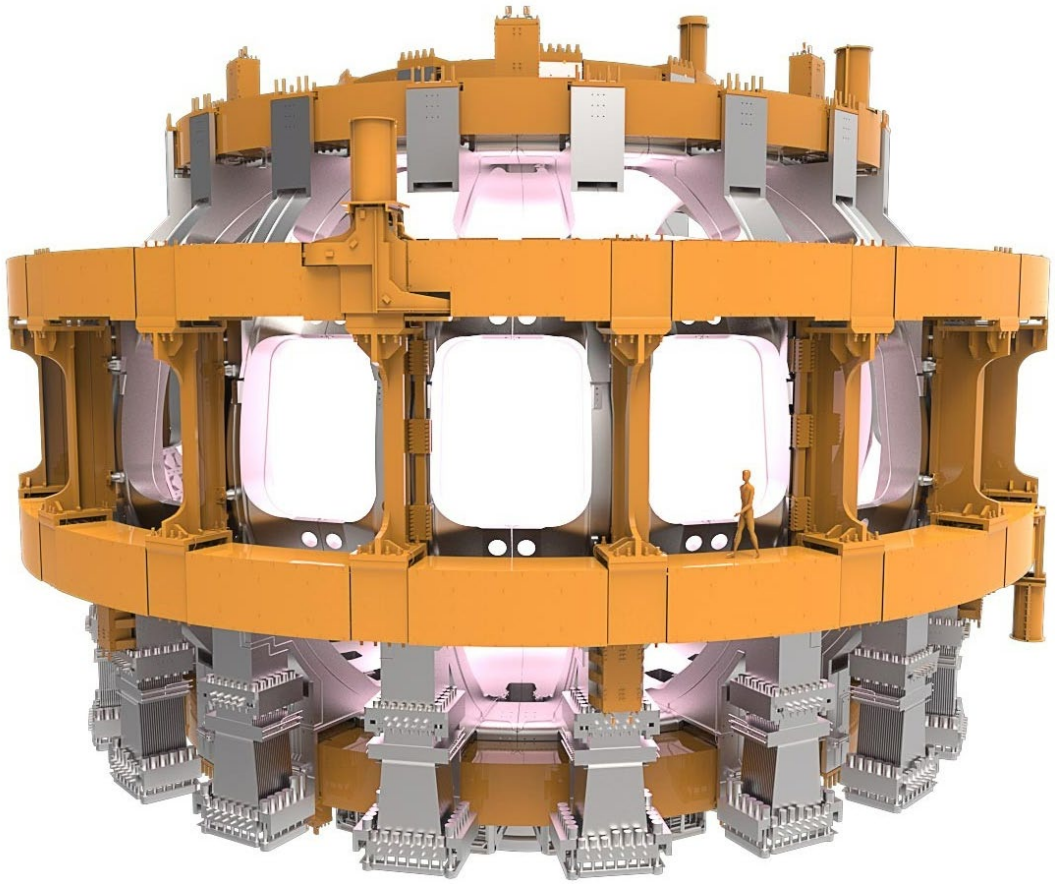
Output power



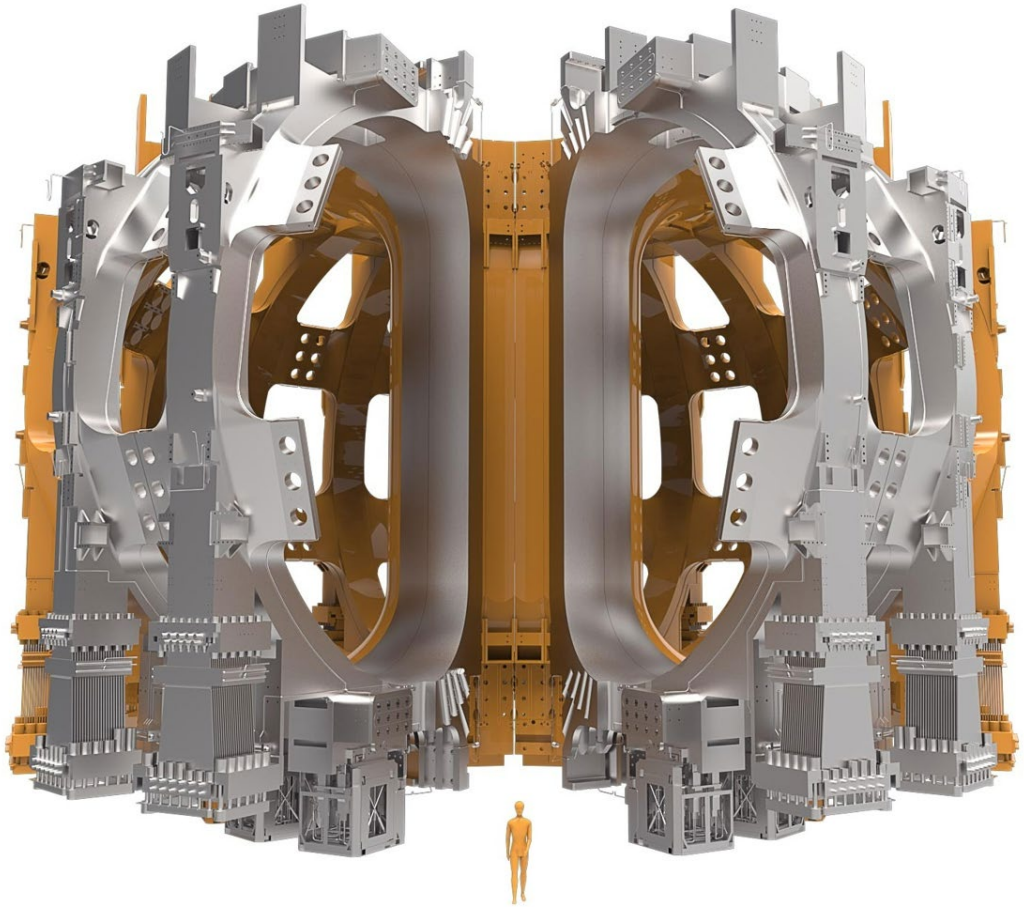
ITER TOKAMAK: MAGNETS

The ITER magnet system will be the largest and most integrated superconducting magnet system ever built.

POLOIDAL FIELD COILS

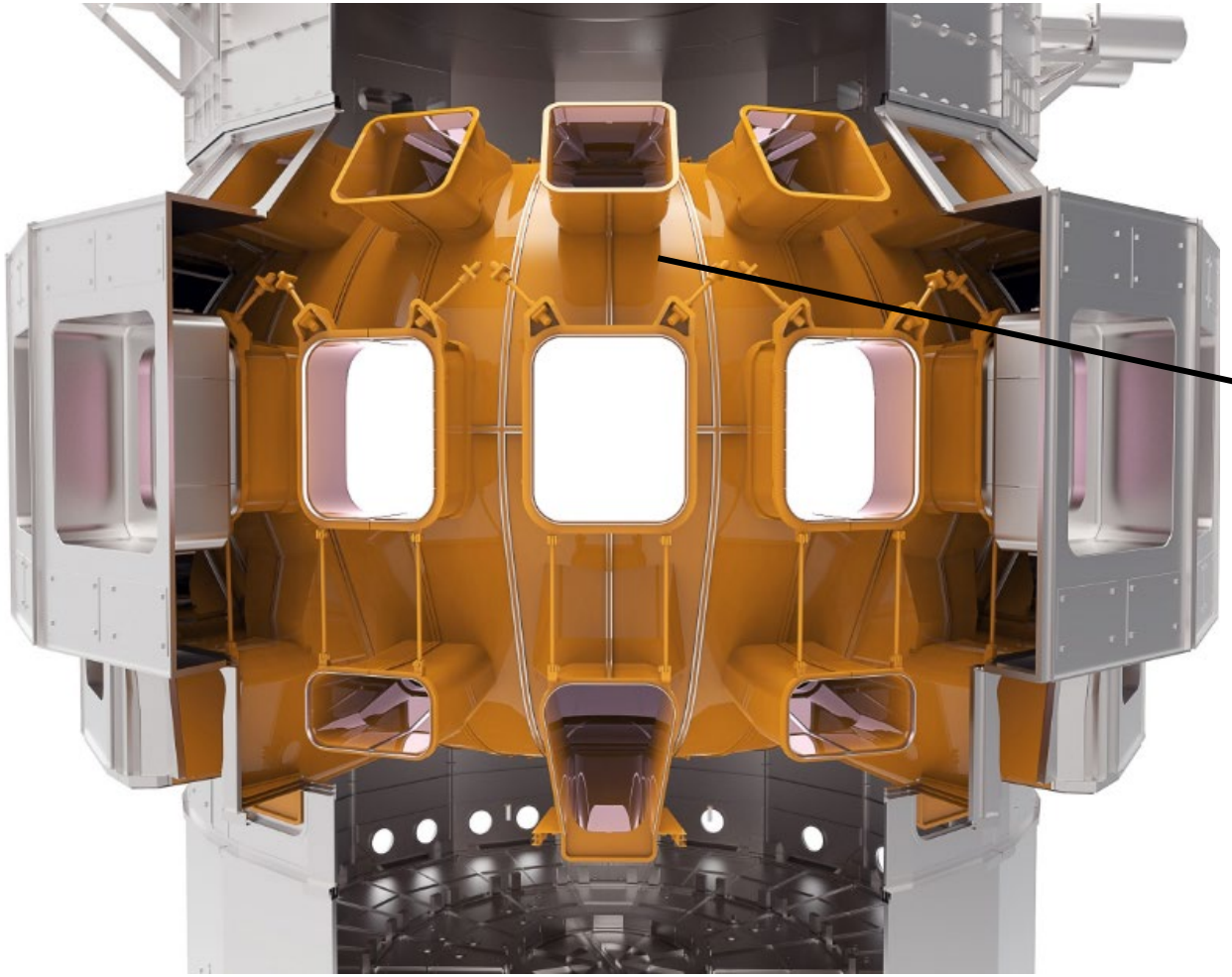


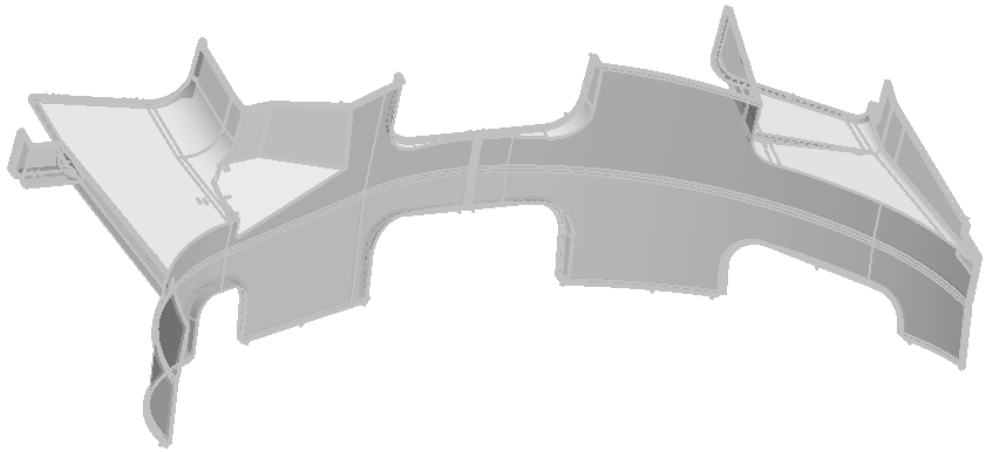
TOROIDAL FIELD COILS



ITER TOKAMAK: THERMAL SHIELDS

To minimize heat loads transferred by thermal radiation and conduction from warm components to the components and structures that operate at 4.5K (such as the magnets)

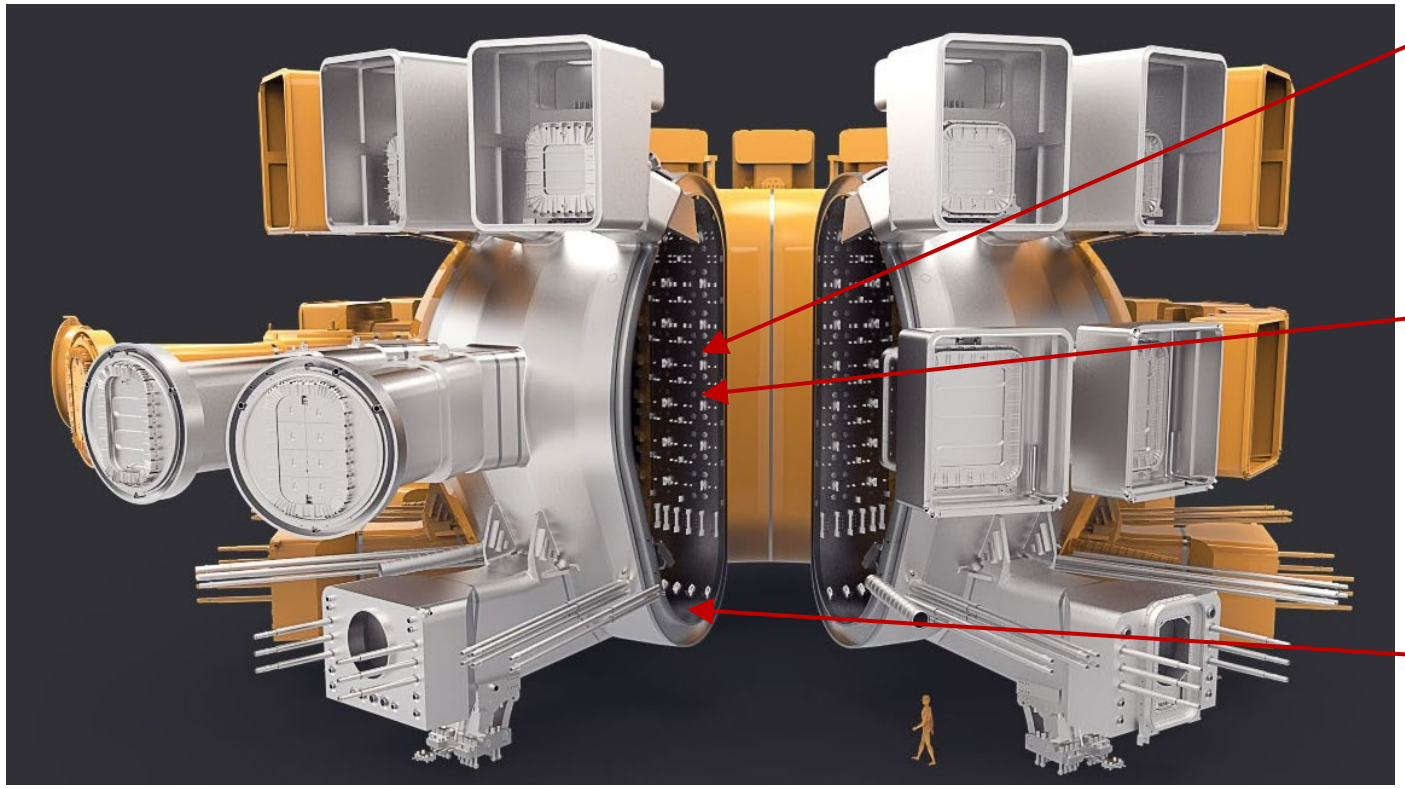




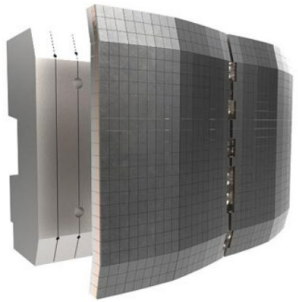
Thermal Shield parts are composed of different segments assembled at different stages.

ITER TOKAMAK: VACUUM VESSEL

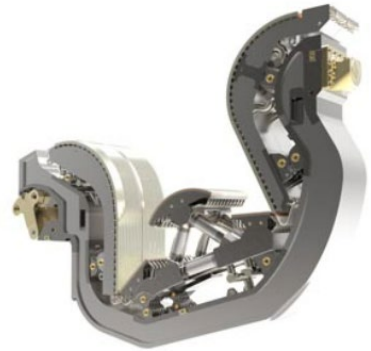
The vacuum vessel provides a high-vacuum environment for the plasma, improves radiation shielding and plasma stability, acts as the primary confinement barrier for radioactivity, and provides support for in-vessel components such as the blanket and the divertor.



FIRST WALL PANELS



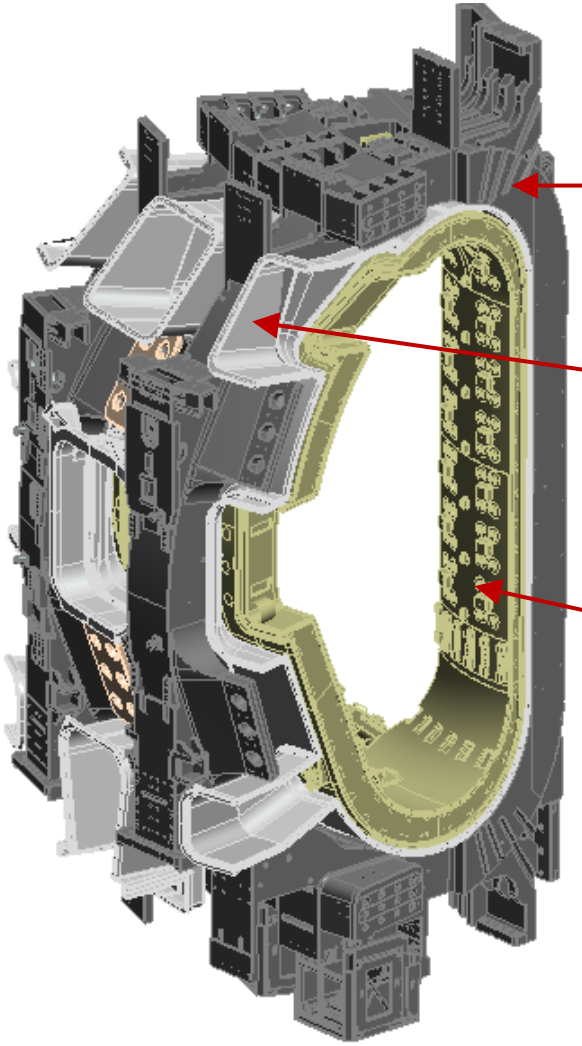
SHIELD BLOCKS



DIVERTOR

ITER TOKAMAK: SECTOR ASSEMBLY

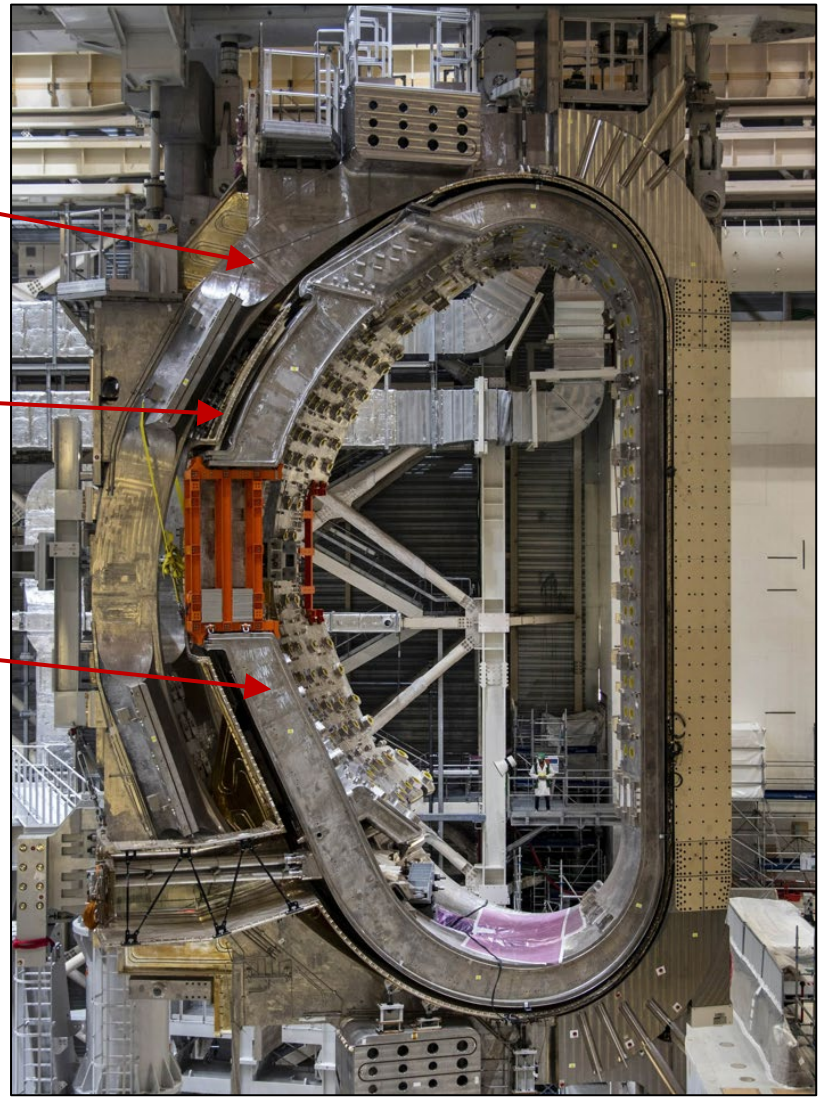
The main components of the sector assembled together:



Toroidal Field Coil

Thermal Shield

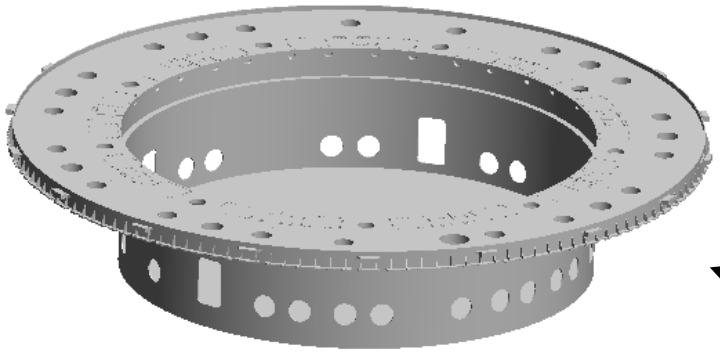
Vacuum Vessel



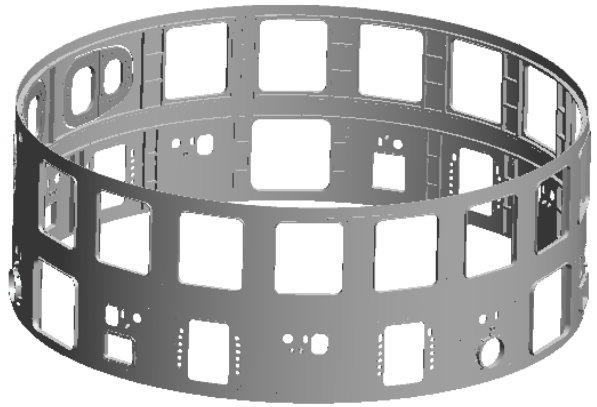
ITER TOKAMAK: CRYOSTAT

The ITER cryostat—the largest stainless steel high-vacuum pressure chamber ever built (16,000 m³)—provides the high vacuum, ultra-cool environment for the ITER vacuum vessel and the superconducting magnets.

Nearly 30 metres wide and as many in height, the internal diameter of the cryostat (28 metres)



CRYOSTAT BASE



CRYOSTAT LOWER CYLINDER

METROLOGY SERVICES IN ITER

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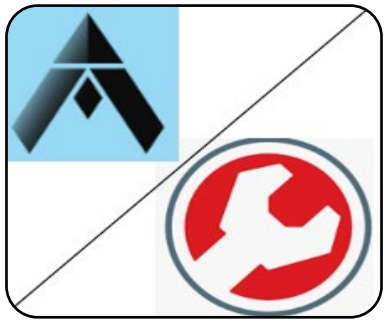
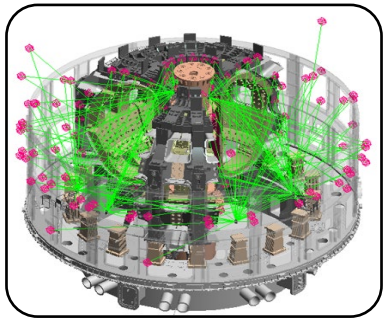


DATA QUALITY

- Factory Acceptance Tests (FAT)
- Site Acceptance Tests (SAT)
- Sub-assemblies
- Final position

SURVEY ACTIVITIES

- Independent parts
- Assemblies
- Installation
- References networks



METROLOGY STRATEGY

- Survey protocols
- Virtual fittings
- Data traceability

METROLOGY SERVICES IN ITER

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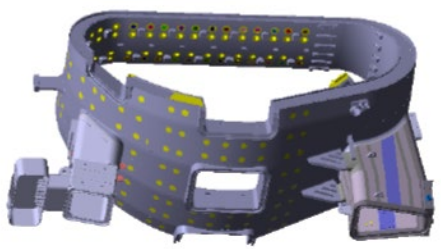
INDUSTRIAL METROLOGY

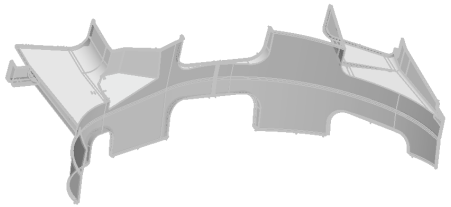
DATA QUALITY

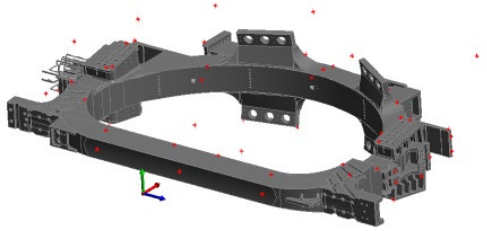
- Factory Acceptance Tests (FAT)
- Site Acceptance Tests (SAT)
- Sub-assemblies
- Final position

DATA QUALITY

GOAL: ENSURE THAT THE AS BUILT DATA COLLECTED IS VALID FOR ANALYSIS AND ALIGNMENT PURPOSES.







ITER

DATA TRACEABILITY

FAT	SAT	Assembly	Installation
Alignment to Datum	Survey Template	Survey Template	Survey Template
Data Quality analysis	Data quality analysis	Data quality analysis	Data quality analysis
		Virtual fitting	Virtual fitting

DATA QUALITY

GOAL:

ENSURE THAT THE AS BUILT DATA COLLECTED IS VALID FOR ANALYSIS AND ALIGNMENT PURPOSES, FROM ITS ORIGIN TO ITS FINAL POSITION.

PARAMETERS AFFECTING DATA QUALITY:

- INTERNATIONAL PROJECT → Multiple Metrology service suppliers across the World.
- METROLOGY SUPPLIERS DIFFERENCES → Experience, environment, equipment.
- DATA TRACEABILITY → Complex assembly process from manufacturing to installation.
- LARGE PARTS → Uncertainty requirements, deformations, hidden interfaces, temperature stability…

SURVEY DATA CHAIN PASS THROUGH DIFFERENT ENTITIES
IT IS CRITICAL TO ENSURE ITS QUALITY IN THE WHOLE PROCESS

DATA QUALITY

METROMECÁNICA INDUSTRIAL METROLOGY

SCOPE OF DATA QUALITY:

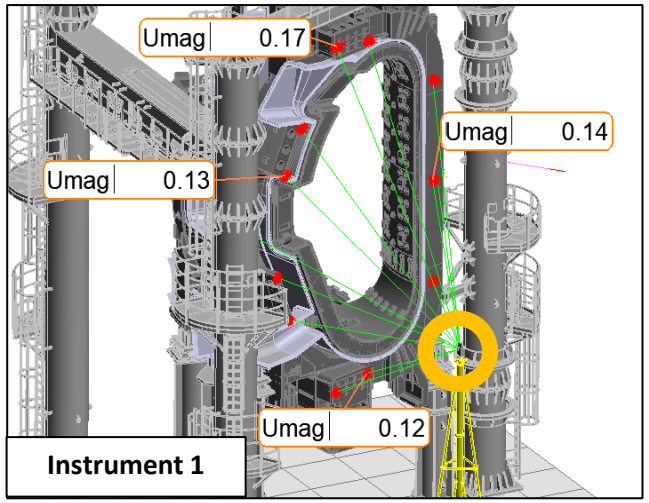
- **BEFORE SURVEY ACTIVITIES:**
  - Field checks
  - Temperature stability.
  - Measuring device specifications acceptable for the uncertainty required. Valid calibration certificates.
  - Specific survey protocol, considering tolerances and environment.

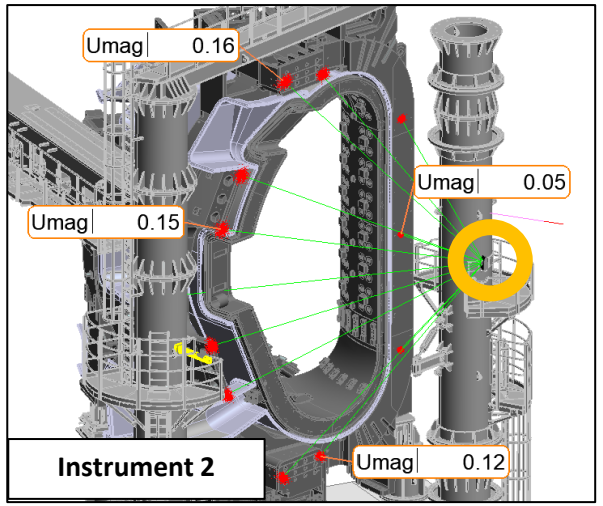
- **DURING SURVEY ACTIVITIES (best practices):**
  - References Network evaluation: good volume, enough common points and instrument positions.
  - Periodic drift checks.
  - Periodic temperature probing and survey data scaling.
  - Measured points with acceptable RMS values.
  - References repeatability and with more than one observation from different instrument positions.

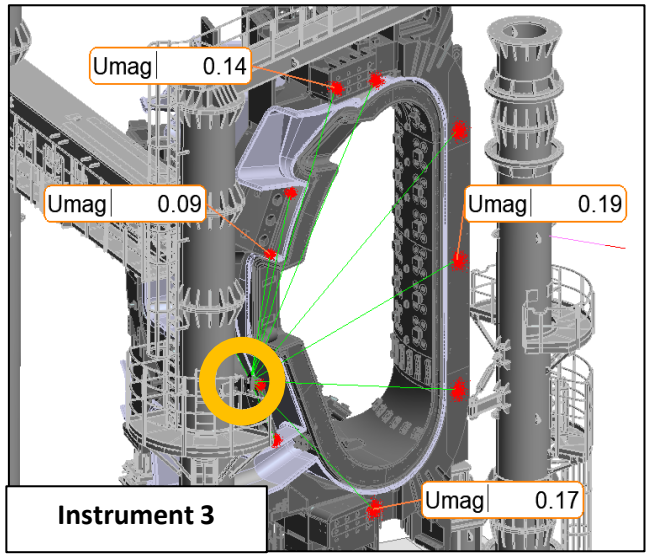
- **POST-PROCESSING ANALYSIS**
  - Uncertainty analysis to ensure acceptable values with respect the tolerance required.
  - Best fit errors to references or datum observed.
  - Ensure that all required data has been collected and provided.

All survey data files from all suppliers are analyzed to ensure the quality

DATA QUALITY: Minimizing uncertainty example



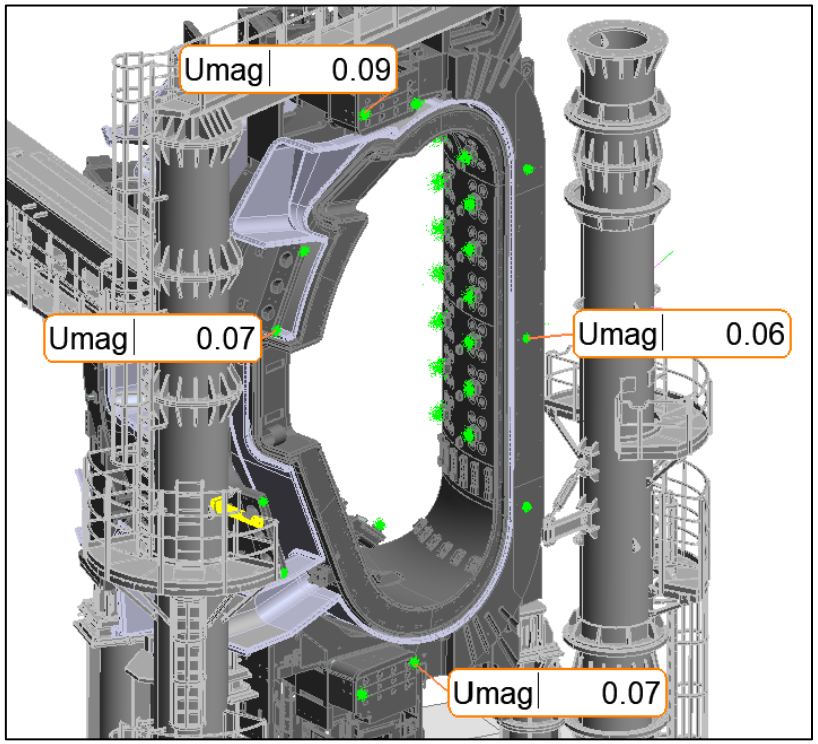




- **Instr 1**: Max uncertainty = 0.17 mm
- **Instr 2**: Max uncertainty = 0.19 mm
- **Instr 3**: Max uncertainty = 0.16 mm

Goal:
To reduce the uncertainty of the survey data.

Unified
Spatial
Metrology
Network



Processed data

Max uncertainty = 0.09 mm

DATA QUALITY: UNCERTAINTY BUDGET

METROMECÁNICA INDUSTRIAL METROLOGY

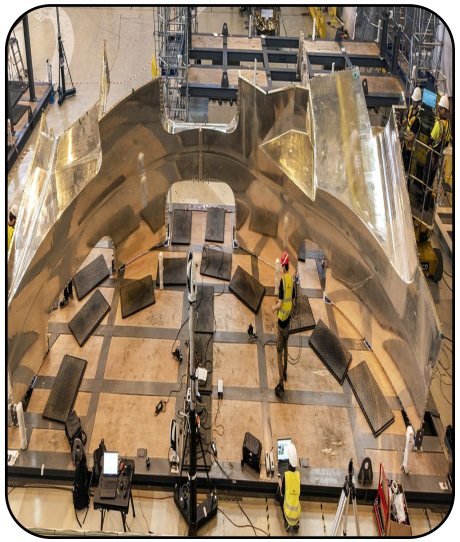
GOAL: TOTAL UNCERTAINTY BUDGET (in 2σ) MUST BE AT MOST 20% OF THE FEATURE TOLERANCE

ASPECTS INCLUDED IN THE UNCERTAINTY BUDGET (as a minimum):

- **MEASURING DEVICE UNCERTAINTY:**
  - Provided by manufacturer.
  - Specific tests to evaluate uncertainty.
- **GLOBAL UNCERTAINTY IN SURVEY SESSION:**
  - Uncertainty Spatial Metrology Network (Spatial Analyzer)
  - Bundle (Polyworks)
- **TEMPERATURE:**
  - Gradient of temperature (at different heights)
  - Temperature probing device uncertainty.
  - Coefficient of Thermal Expansion uncertainty.
- **ALIGNMENT ERRORS TO REFERENCES NETWORKS OR DATUM**
- **DRIFT CHECK ERRORS**

Everything can contribute to the uncertainty budget

METROLOGY SERVICES IN ITER



SURVEY ACTIVITIES

- Independent parts
- Assemblies
- Installation
- References networks

SURVEY ACTIVITIES

METROMECÁNICA INDUSTRIAL METROLOGY

ASPECTS TO CONSIDER FOR SURVEYS IN ITER SITE:

- **ACCESIBILITY:**
  - Scaffolds
  - Cherry Pickers
  - Reduced oxygen space areas
  - Clean areas
  - Metrology equipment transport and set up.

- **SAFETY:**
  - Evaluate environment with ITER safety in advance.
  - Collective and individual protective measures.

Surveys on site doesn't happen in a vacuum. Mind your surroundings

- **LOGISTICS:**
  - Coordination meetings on site (daily and weekly) for coactivities.
  - Work permission registered in ITER Data System.
  - Awareness of coactivities from other suppliers.
  - Availability of the equipment needed.
  - Coordination and transferring data between different metrology teams working in the same activity.

- **SCHEDULE:**
  - Generally tight schedule, delays are costly due to stopping several activities from suppliers.
  - Going back to re-measure is not an option in general.

SURVEY ACTIVITIES

GENERAL GOALS OF SURVEY ACTIVITIES:

- **DIMENSIONAL INSPECTIONS**
  - Site Acceptance Tests
  - CMM measurements
  - Missions off site.
  - Horizontal to Vertical state
  - Supports levelling or adjusting.
  - Specific interfaces during assembly.
  - Large volume scans of rooms, buildings, outside areas…

- **MONITORING DURING ASSEMBLY OR INSTALLATION**
  - Cryostat Base transport and installation in Tokamak Building
  - Cryostat Lower Cylinder transport and installation in Tokamak Building
  - Sectors Assembly in Assembly Hall and Tokamak Building.
  - Additional components: Feeders, Thermal Shield panels…

- **VERIFICATION OF SUPPLIER'S ACTIVITIES:** Validation of components aligned by external suppliers.

- **NETWORK REFERENCES:**
  - Extension of reference network, linking new areas.
  - Monitoring and update current existing networks.

SURVEY ACTIVITIES

MAIN METROLOGY EQUIPMENT USED:

- GENERAL PURPOSE SURVEY
- HIGH DENSITY SCAN (LAS)
- 6 DOF device (T-PROBE)
- ACCURACY (2σ, @10m):
  - AT-960: ±106µm
  - T-probe: ±119 µm
  - LAS: ±66 µm (+ Laser Tracker)
  - AS-1: ±60 µm (+ Laser Tracker)

AT-960

T-Probe

LAS Scan

AS-1 Scan

- BETTER PORTABILITY
- ACCURACY (2σ, @10m): ±106 µm

AT-500

AT-403

- REFLECTORLESS MODE
- ACCURACY (2σ):
  - Discrete: ±106 µm
  - Reflectorless: ±300 µm

ATS-600

SURVEY ACTIVITIES

MAIN METROLOGY EQUIPMENT USED:

- TOPOGRAPHY ACTIVITIES
- REFLECTORLESS MODE
- ACCURACY (2σ, @10m):
  - Reflector: 0.6mm + 1ppm
  - Reflectorless: 2mm + 2ppm

TDRA6000

TS-60

- LARGE VOLUME SCAN ACTIVITIES
- ACCURACY: Up to ±3 mm

FARO FOCUS
+
SWIFT SYSTEM

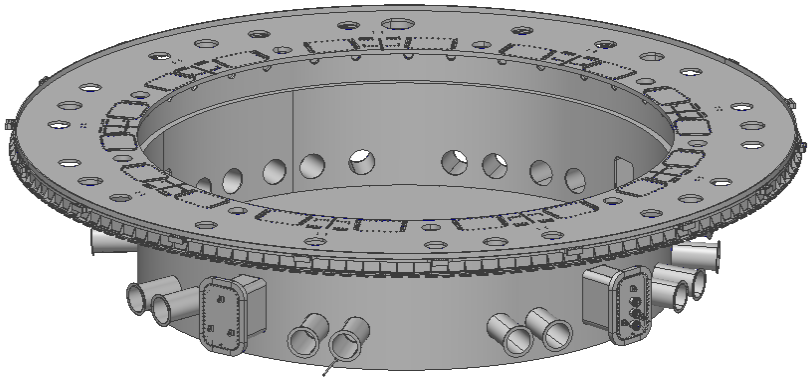
Leica P40

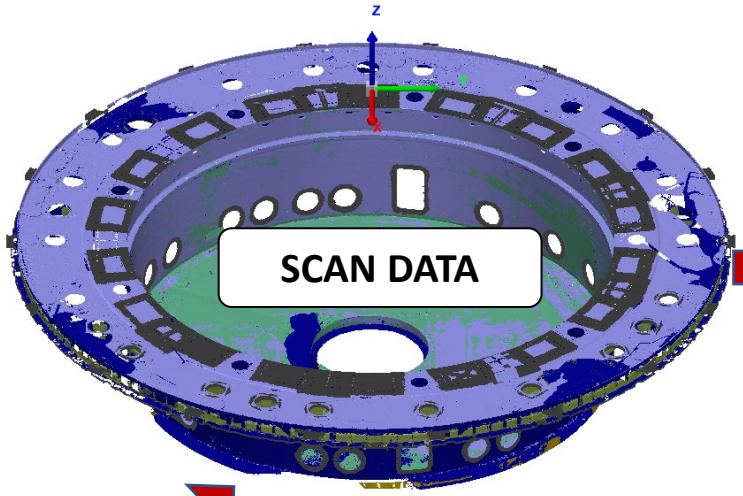
SURVEY EXAMPLES

CRYOSTAT BASE FULL SCAN:

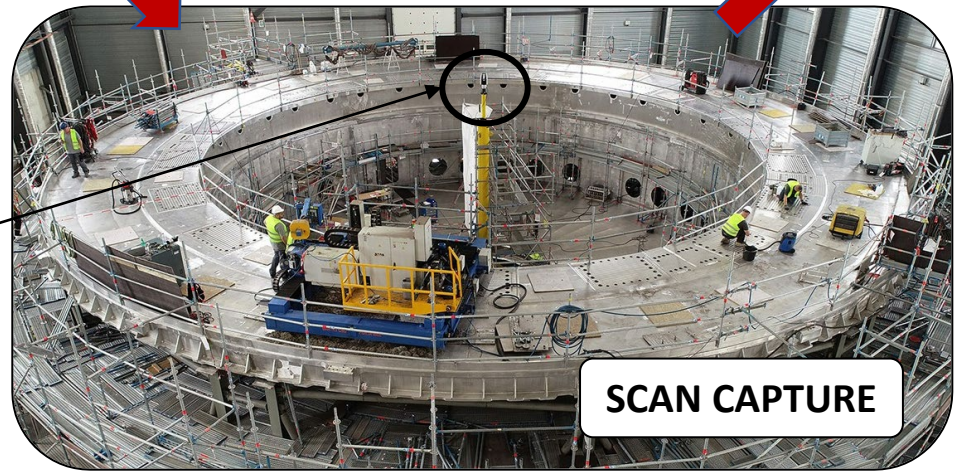
- Complete scan of the Cryostat Base component using P40, AT960 + LAS
- The goal was to create the Reverse Engineering surface for clash analysis.

CAD NOMINAL

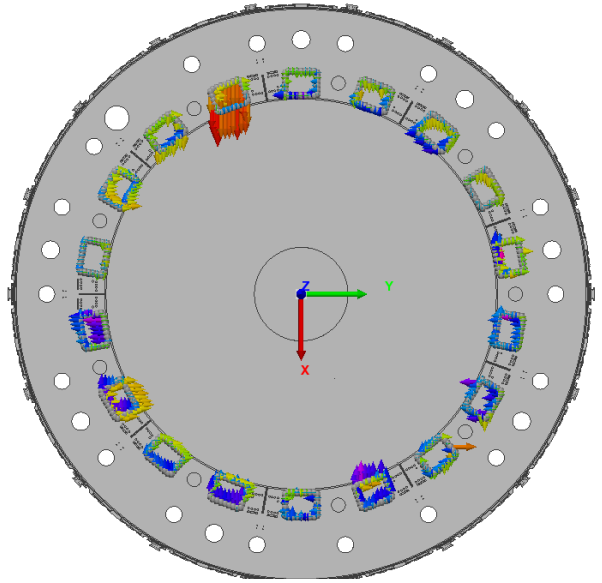


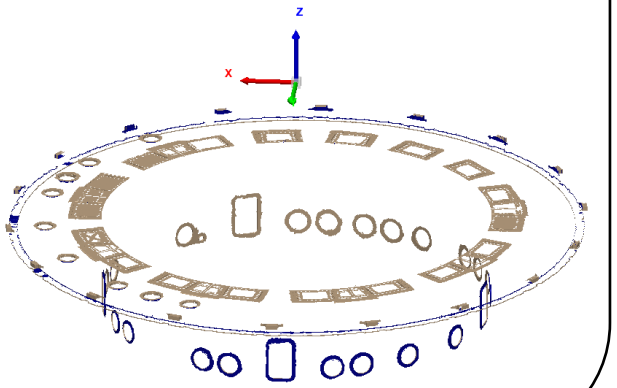


Laser Tracker



DATA ANALYSIS

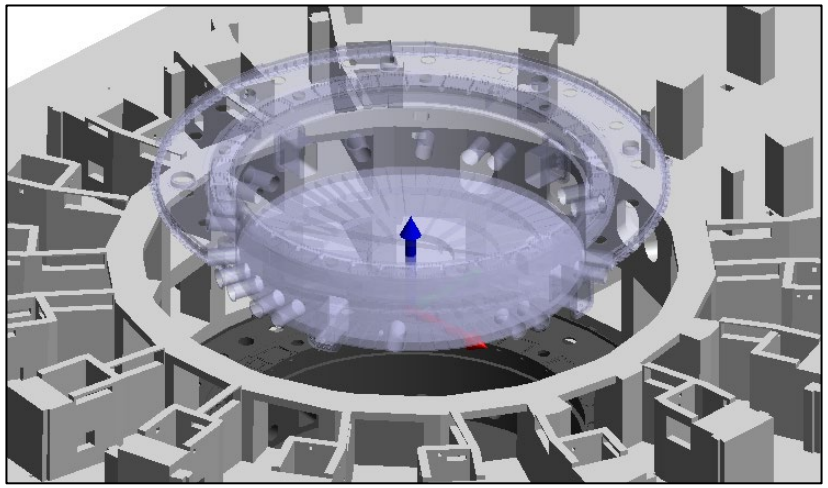


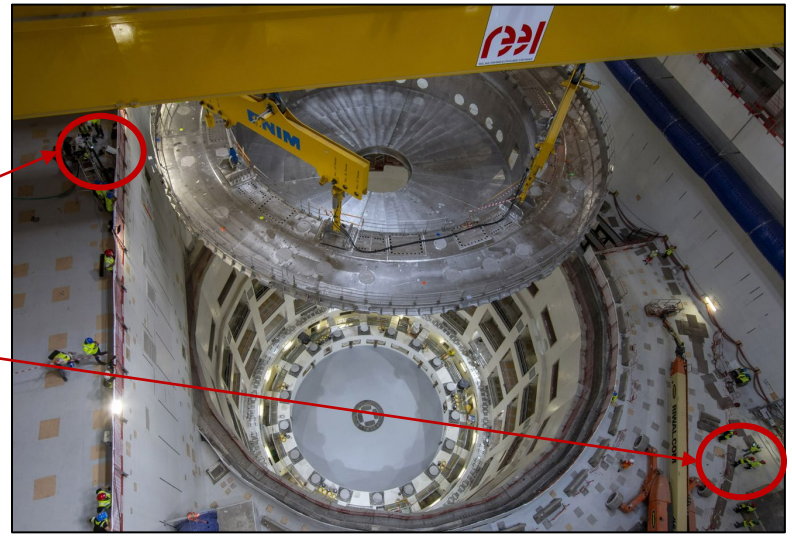


SURVEY EXAMPLES

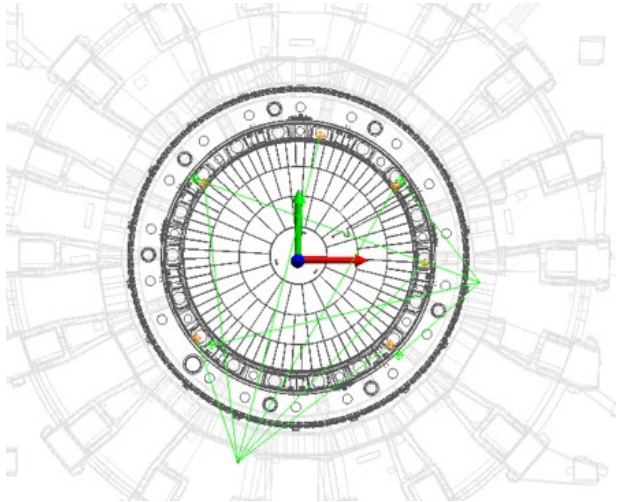
CRYOSTAT BASE INSTALLATION:

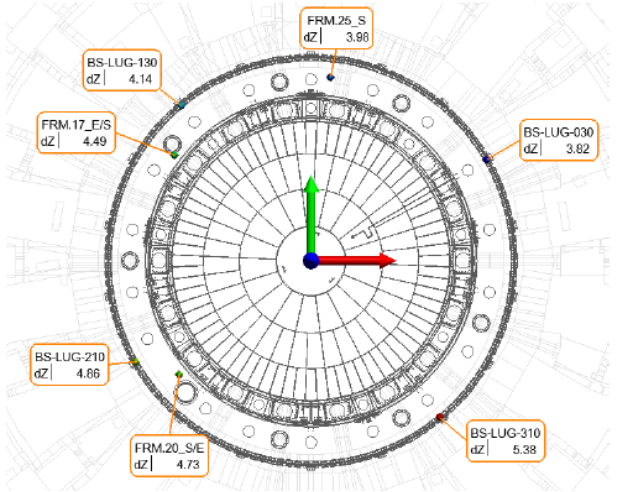
1. Monitoring transport between buildings
2. Monitoring lifting to Tokamak Building
3. Dimensional Inspection in final position





Monitoring during installation

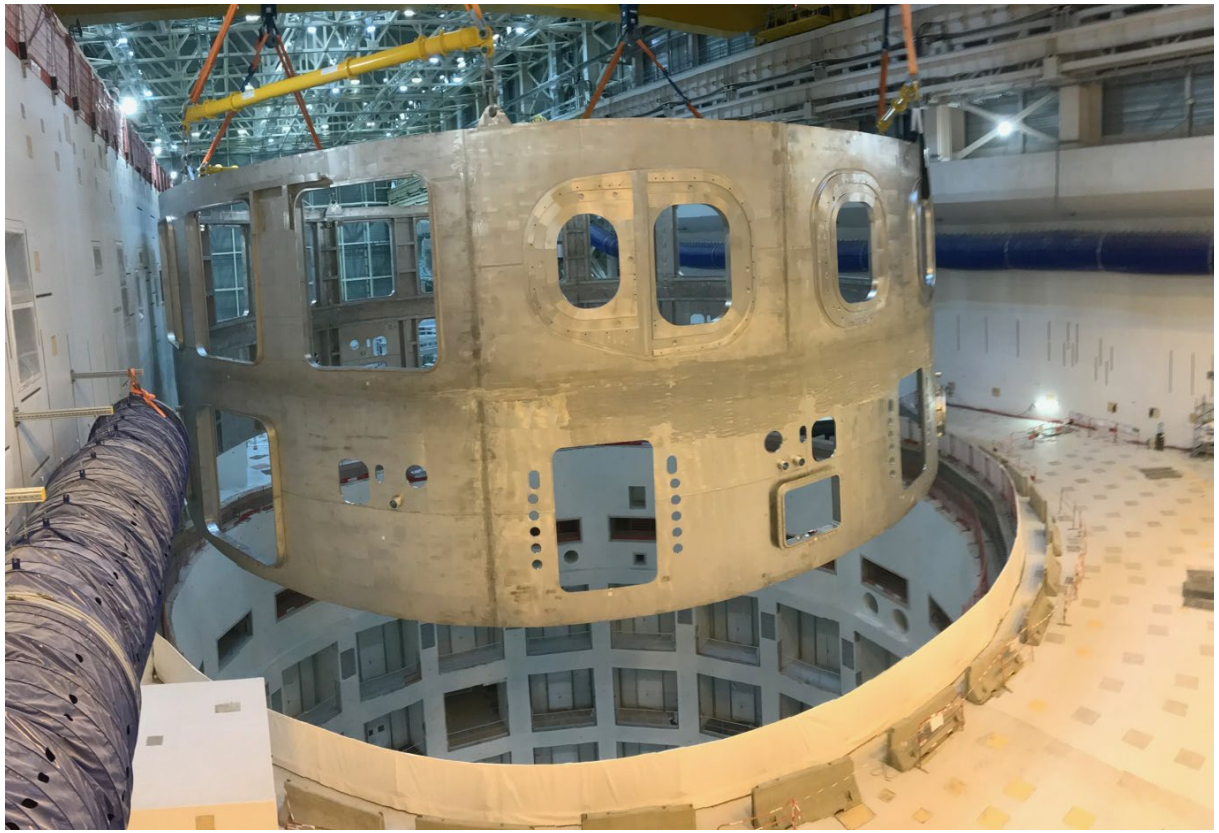


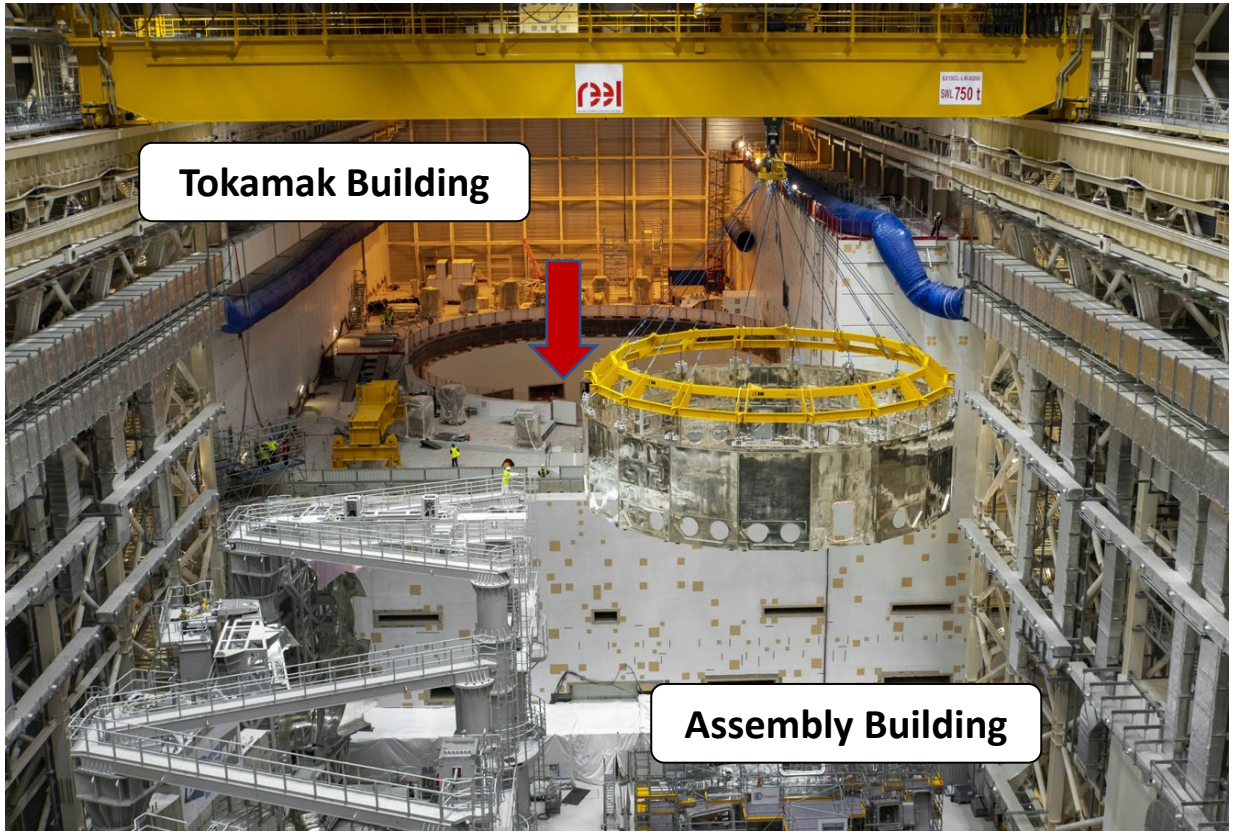


SURVEY EXAMPLES

THERMAL SHIELDS AND CRYOSTAT LOWER CYLINDER INSTALLATION:

Similar approach than for Cryostat Base.



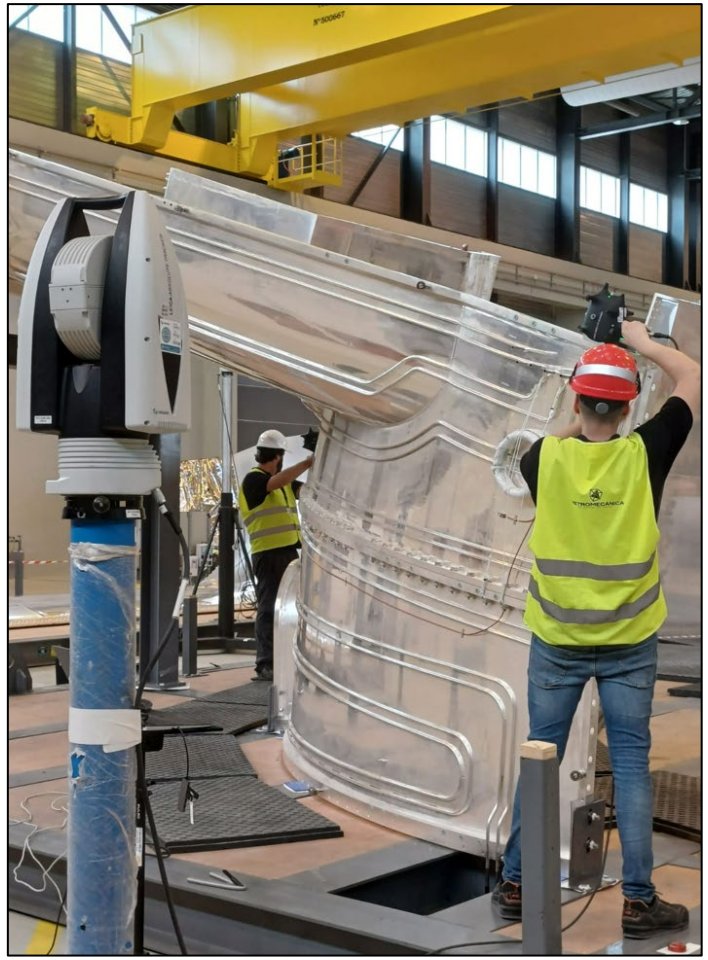


SURVEY EXAMPLES

THERMAL SHIELD SCANS:

- Full scan of 10 Thermal Shield Components.
- Equipment used: AT960, T-Probe, LAS x2, LAS-XL, AT600.
- Metrology workers involved in the activity: 7.

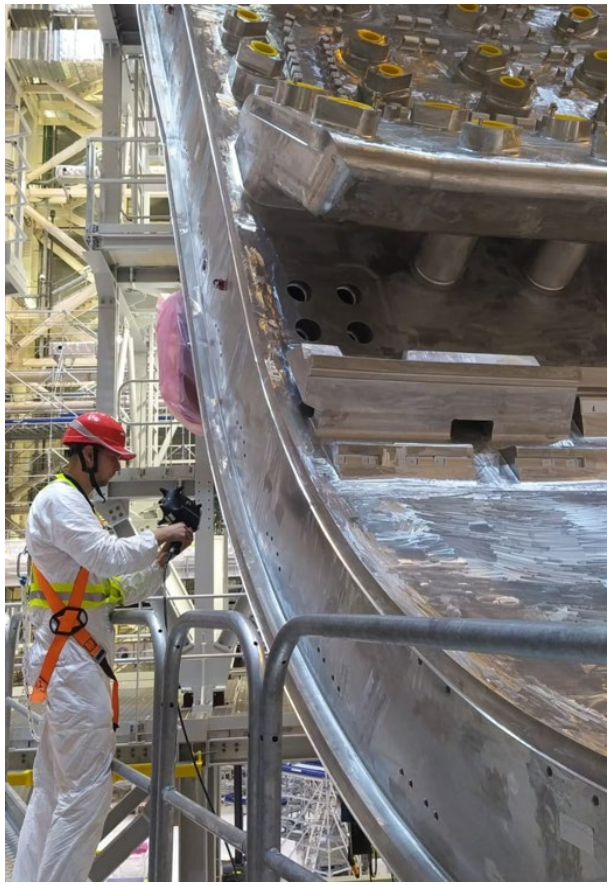
Coordination between metrology teams was critical to keep the schedule to collect all the data keeping the data quality.

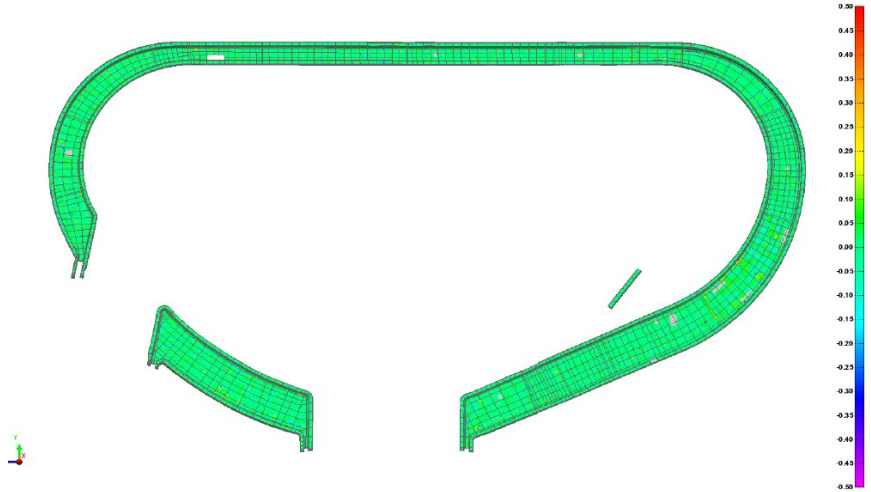


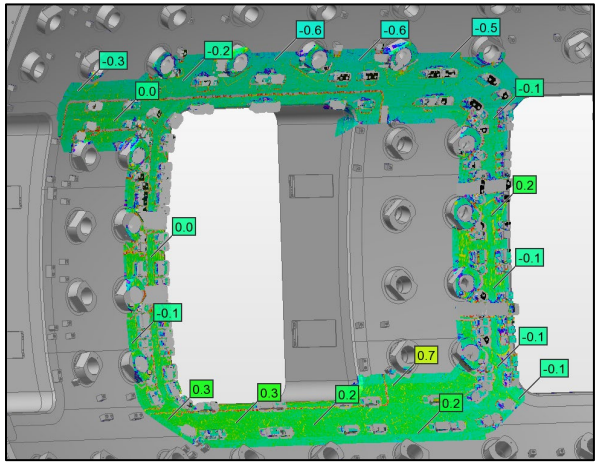
SURVEY EXAMPLES

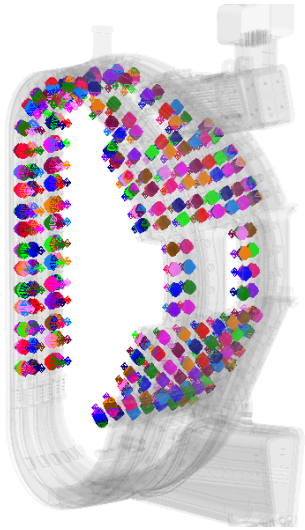
VACUUM VESSEL SECTORS 7 AND 8:

- Survey of critical features on Vacuum Vessels in the Assembly Hall.
- Metrology workers involved in the activity: 5.
- Equipment used: AT960, T-Probe, LAS x2, LAS-XL, AT600.
- Cherry Picker needed during the whole survey.





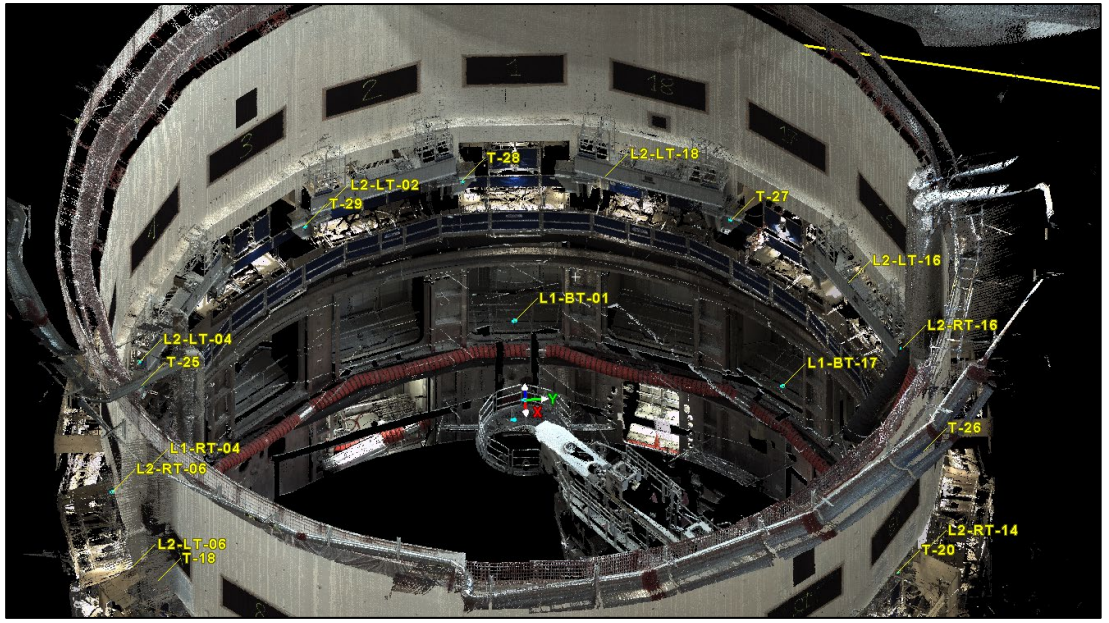


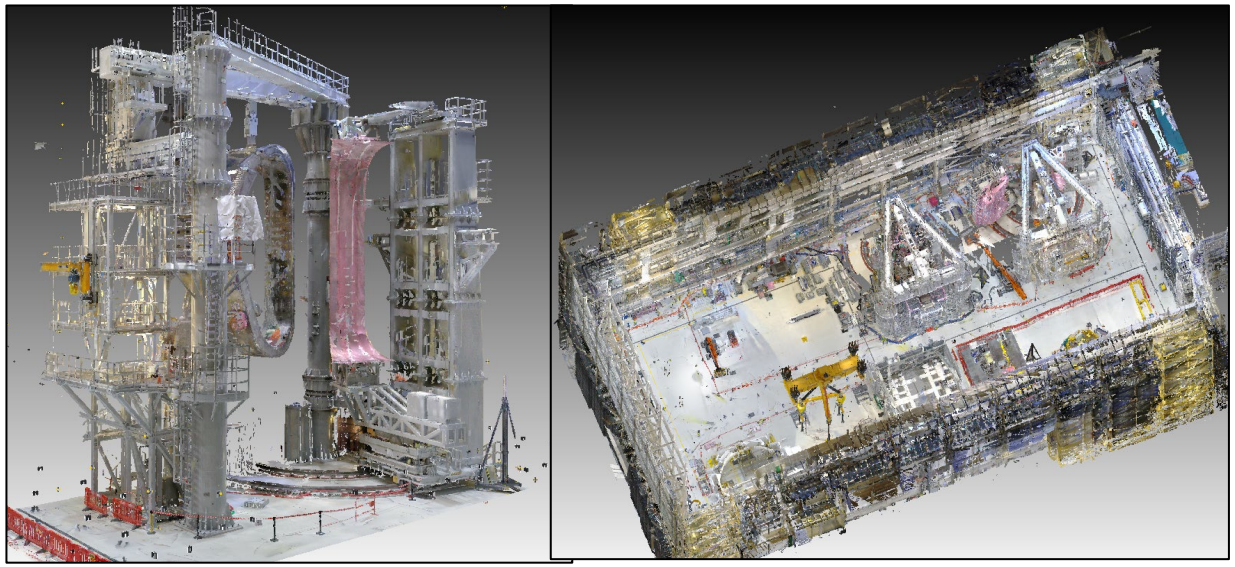


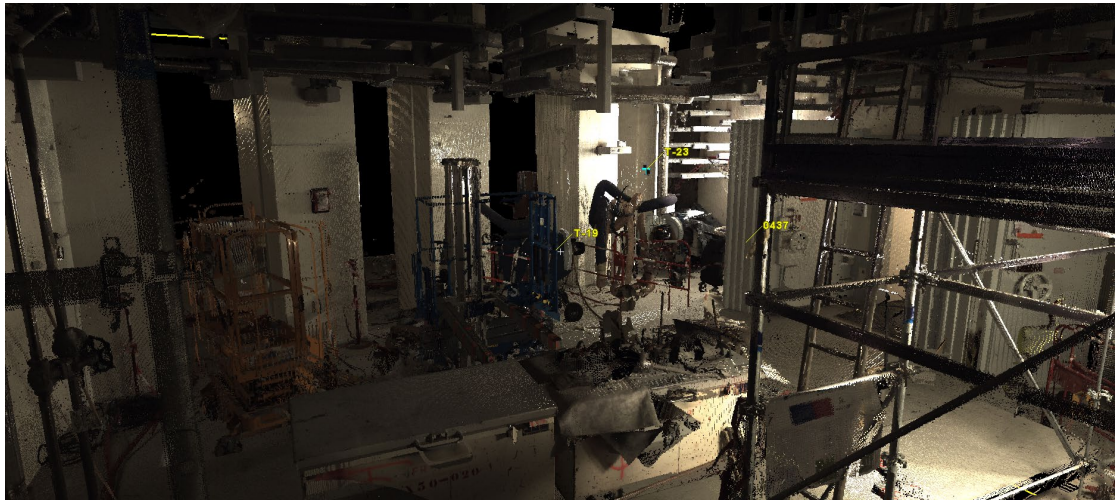
SURVEY EXAMPLES

LARGE VOLUME SCANS:

- Large volume scan of certain areas for Building Information Model (BIM) and 4D study.
- Equipment used: P40, FARO FOCUS with Swift System.





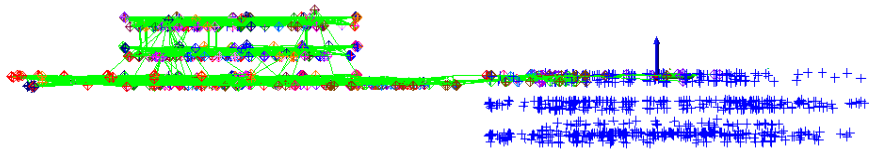


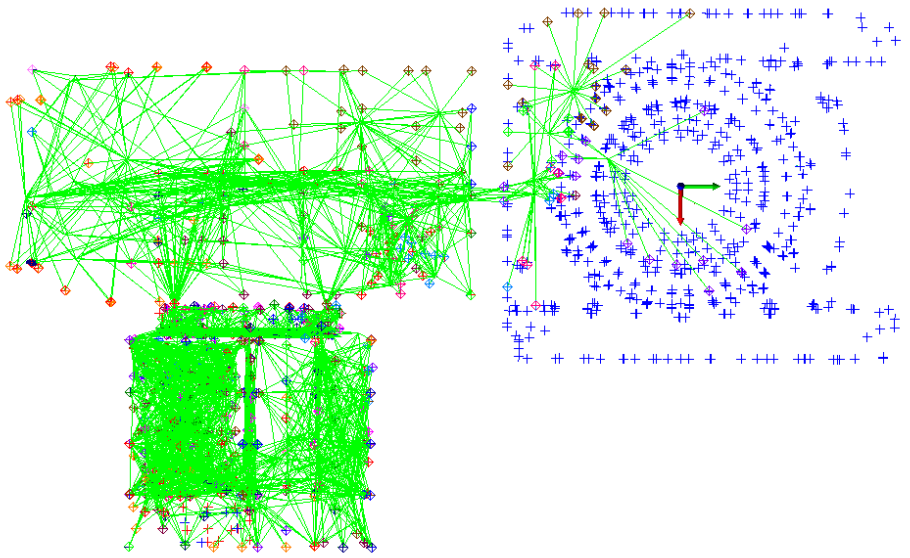
SURVEY EXAMPLES:

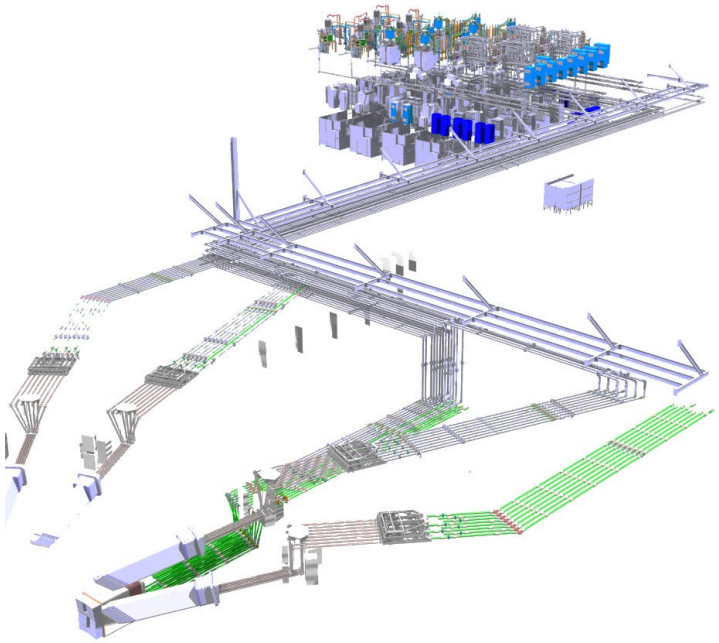
NETWORK REFERENCES:

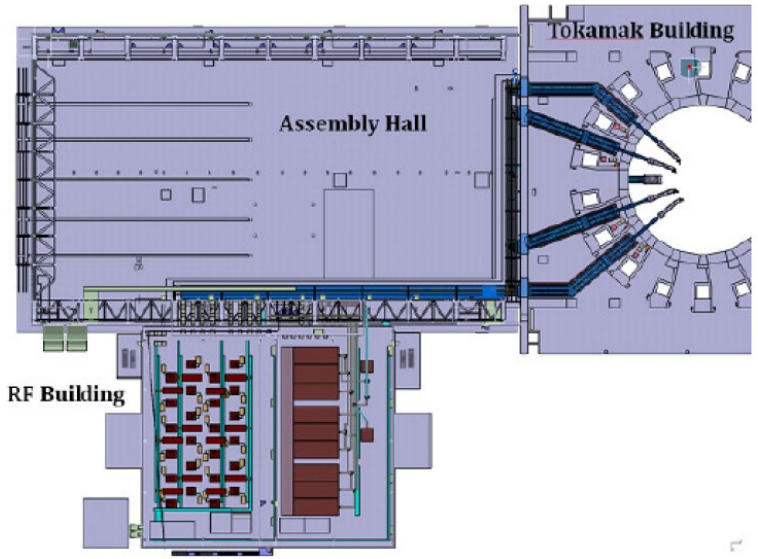
Example of monitoring and buildings linking through openings for Transmission Lines installation:

- Position of some interfaces in the Tokamak Building define the final installation position of components in the RF Building.
- Everything is aligned to Tokamak Building reference network.
- Each building with different construction stages → continuous monitoring.





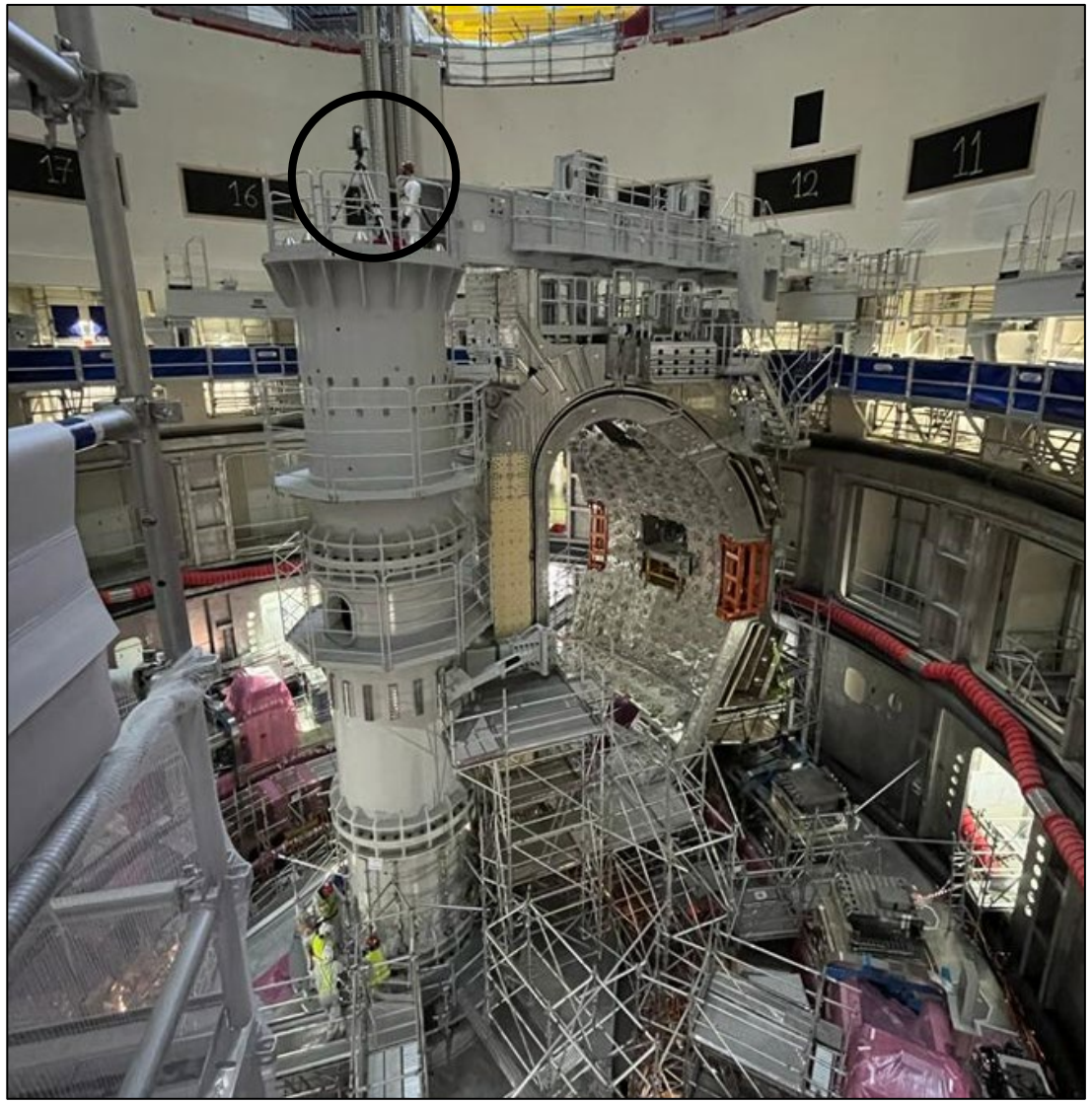


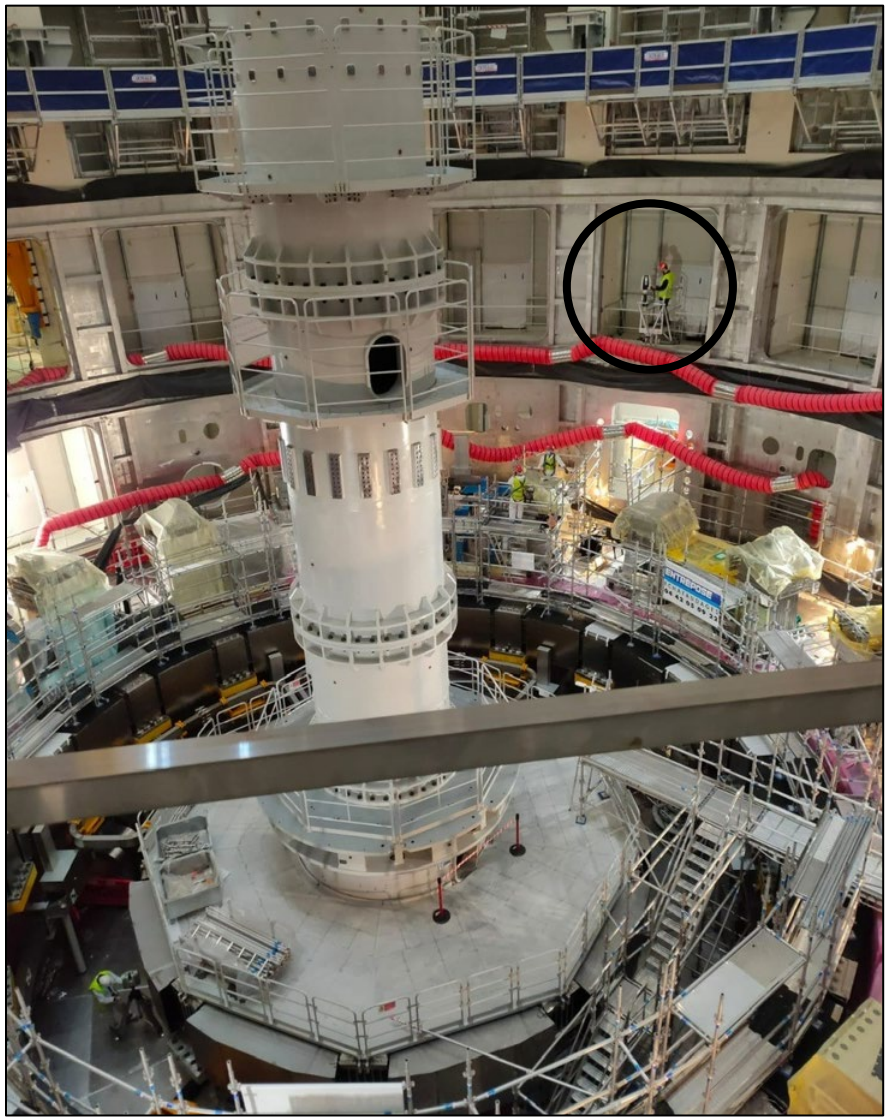


SURVEY EXAMPLES:

NETWORK REFERENCES:

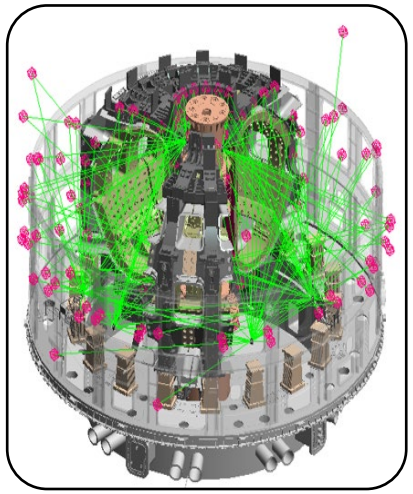
Measuring Network in Tokamak Building





METROLOGY SERVICES IN ITER

METROMECÁNICA
INDUSTRIAL METROLOGY



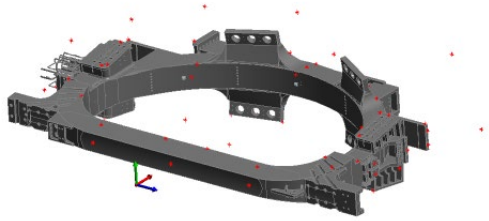
METROLOGY STRATEGY

- Survey protocols
- Virtual fittings
- Data traceability

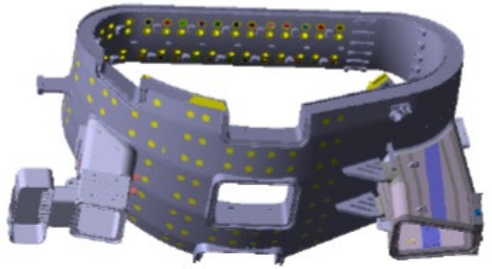
METROLOGY STATEGY

VIRTUAL FITTING:

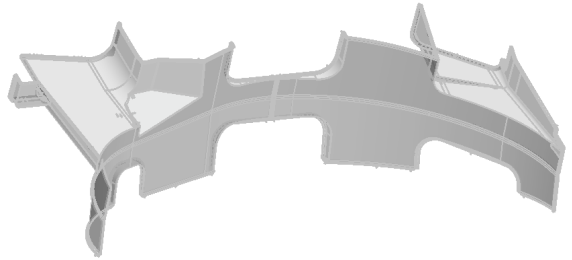
SURVEY DATA IS COLLECTED, PROCESSED AND VALIDATED FOR EACH OF THE COMPONENTS OF THE SECTOR.



TFCs



VV

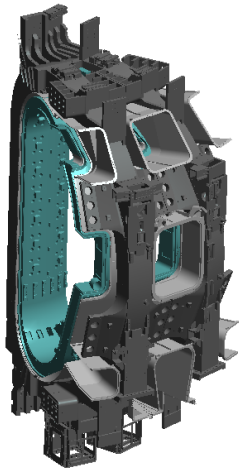


VVTS (IB, OB RH, OB LH)

Sector assembled (virtual alignment)

Based on the analysis of the as built data, for each component:

- Target position for the assembly of the sector will be defined by virtual fitting of the different parts.
- It will be checked that there is no clashes between components.



OUTCOME

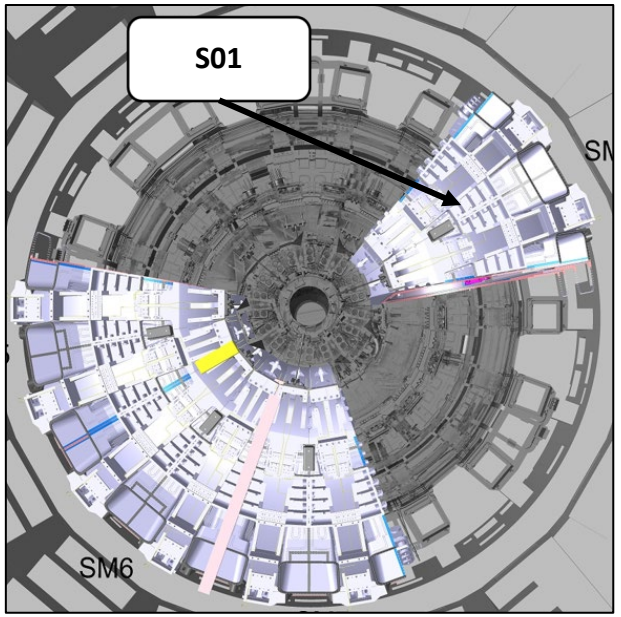
TARGET POSITIONS FOR INITIAL ASSEMBLY IN SSAT

METROLOGY STATEGY

METROMECÁNICA INDUSTRIAL METROLOGY

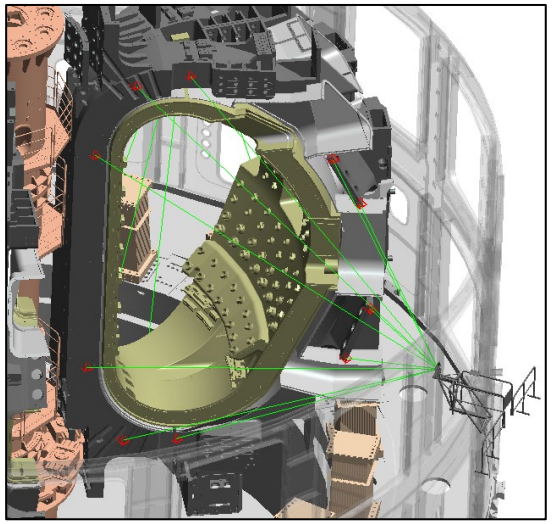
SURVEY PROTOCOLS:

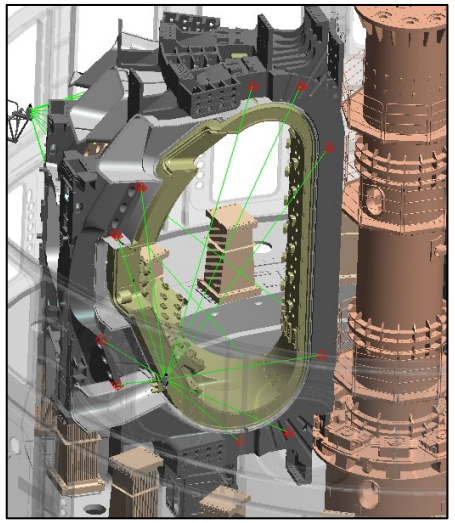
Example of metrology approach for the installation of sectors in Tokamak Building:
The installation of sectors is done sequentially, losing gradually the line of sight to the original References Network.

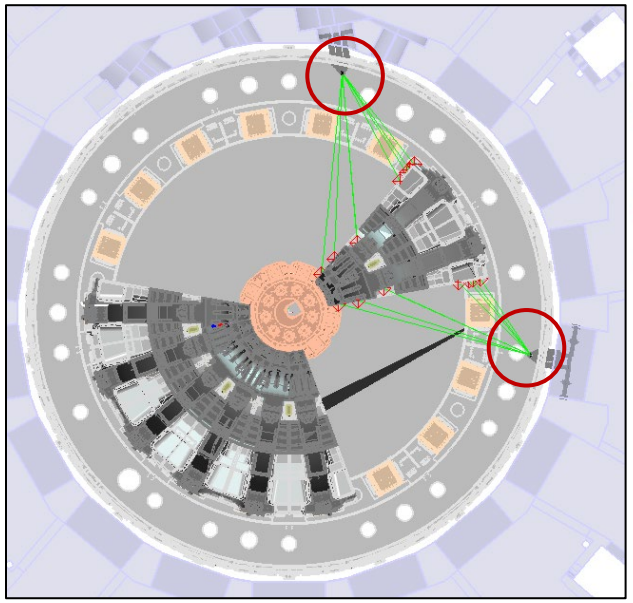


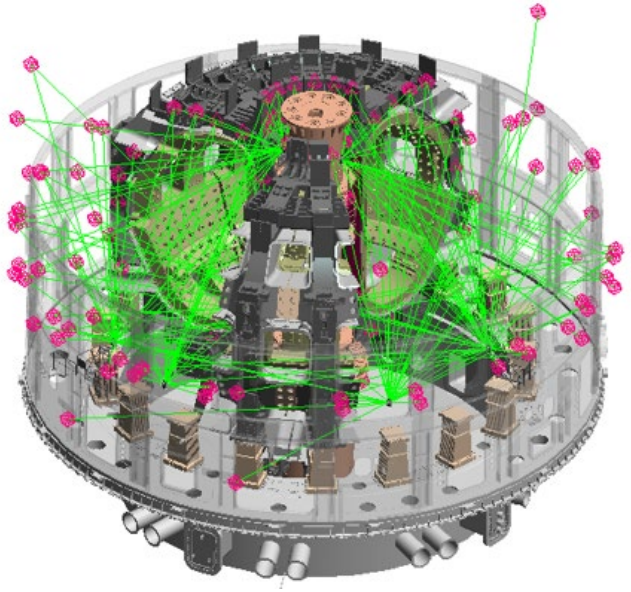
Study required:

- Instrument positions needed for each phase.
- References on the sectors to align it properly to its target position.
- References Network available at each installation phase as well as possible extension of References Network.
- Define areas with reduced accessibility and possible alternative approach.









THANK YOU