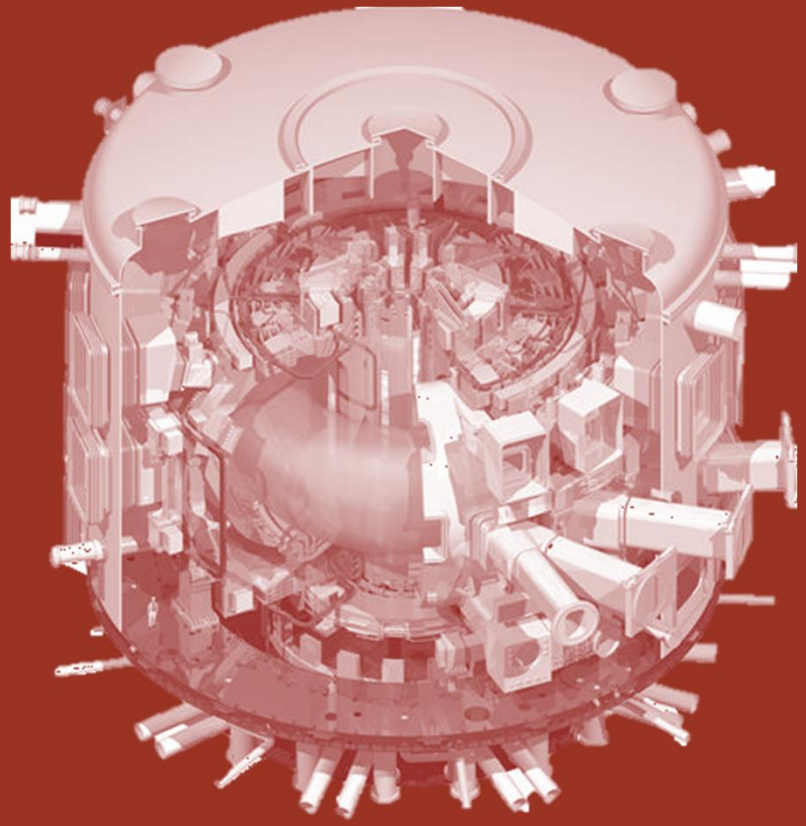
ESTEYCO

División Mecánica Estructural

Líneas de trabajo en fusión



Fernando Rueda – Director (*Fernando.rueda@esteyco.com*)

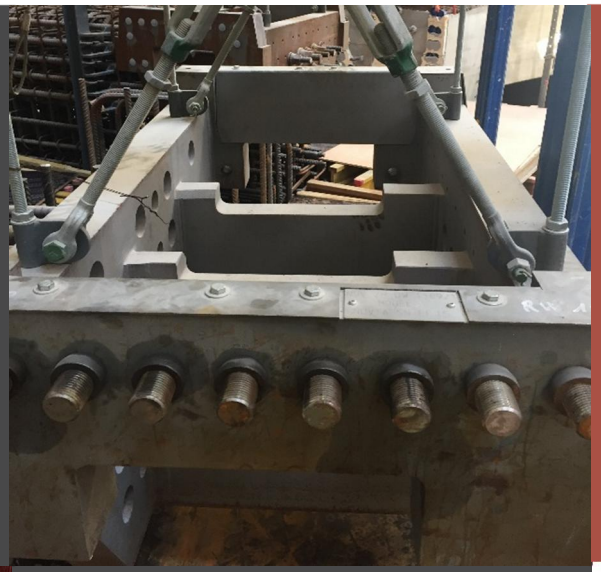
Taller: Oportunidades para jóvenes investigadores en fusión

CIEMAT, Madrid, 22 de junio 2023

OUTLINE

02

Experience in TBM & BB design activities



04

Summary

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ITER Experience

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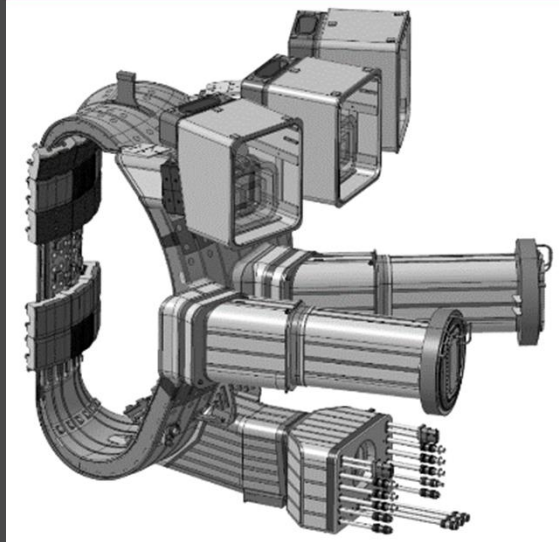
Experience in ITER diagnostics TSM



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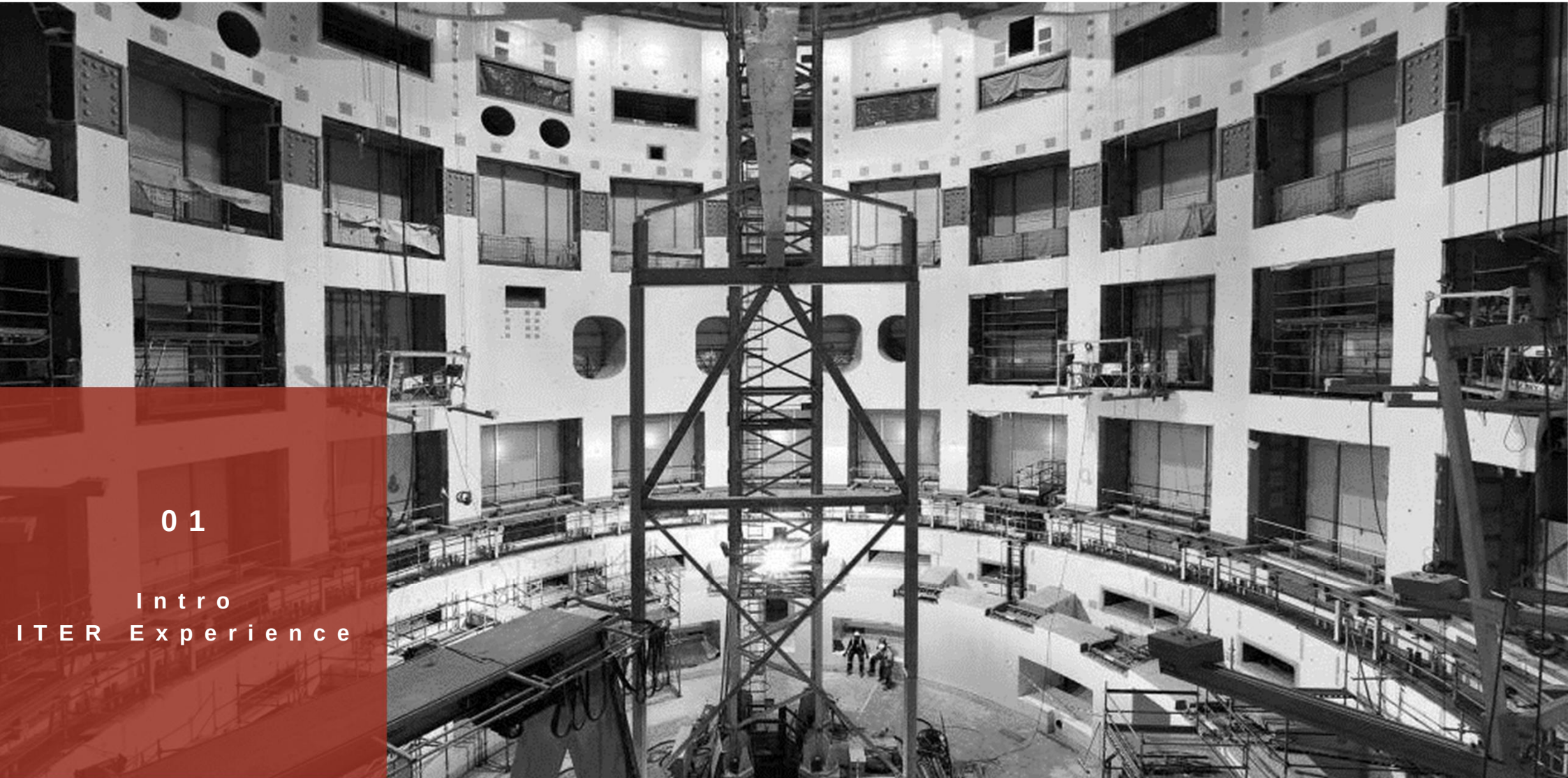


01

Intro
ITER Experience

Introduction

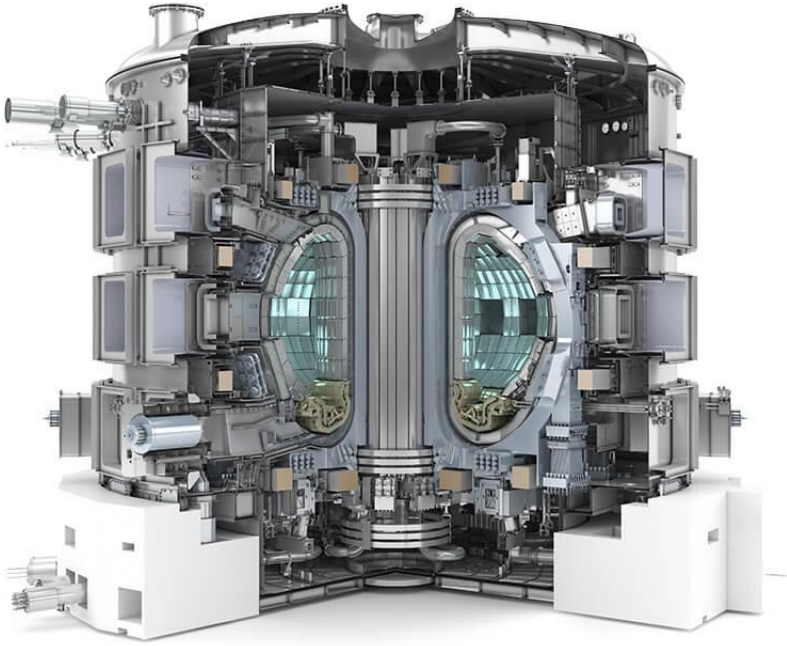
ESTEYCO Mechanics

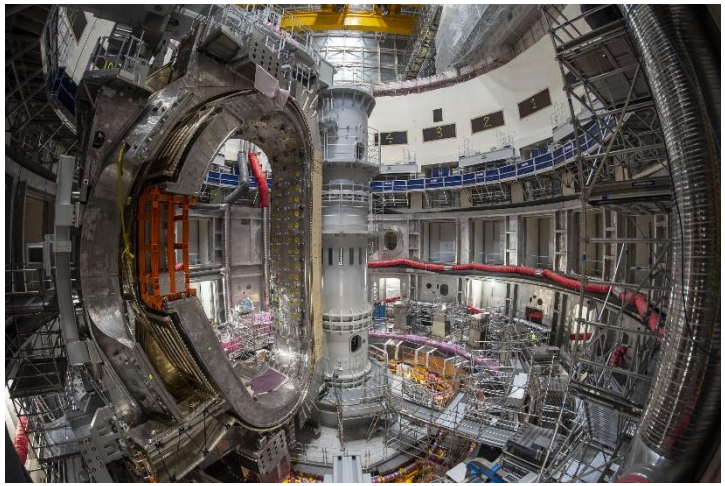
The advanced structural mechanics group within ESTEYCO

A multidisciplinary team of engineers addressing non-conventional problems in the general field of structural mechanics

Design, analysis, prototyping & testing of complex structures and mechanical systems

Actual engineering problems in actual industry that demand going beyond what is common practice in standard design processes

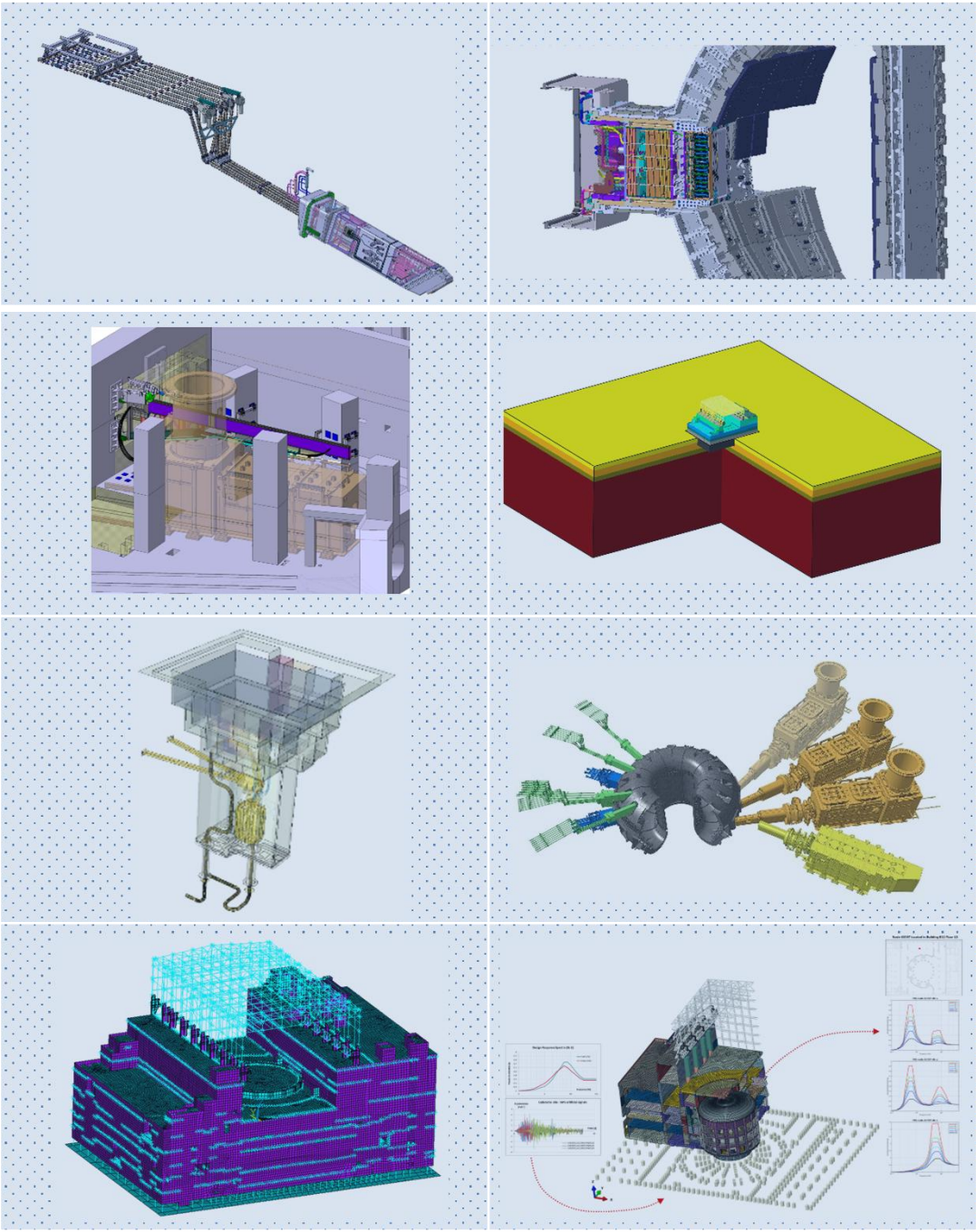




Introduction

Experience in ITER

- Strong and increasing involvement in ITER:
  - Working on ITER related projects intensively since 2009.
  - Nowadays, participating in the ITER project through a number of specific contracts with both the European Domestic Agency (Fusion for Energy) and directly with IO.
- Global (mechanically speaking) understanding of ITER and its main components.
- Worked on many ITER main components (TBMs, NBIs, ICRH Antenna, EC UL, RHS, etc.) and, in particular, the Tokamak machine and its main parts.
- Worked on the derivation of DDDs, Load Specs, Interface sheets, etc.
- Developed specific advanced methodologies for the analysis of transient events (thermal & dynamic -seismic and EM-) of many ITER components.
- Increasing involvement in IFMIF-DONES



Introduction

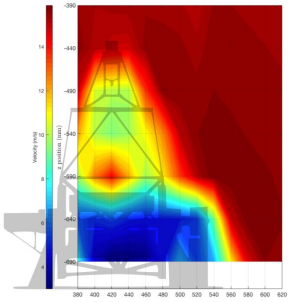
Experience in ITER – key contracts

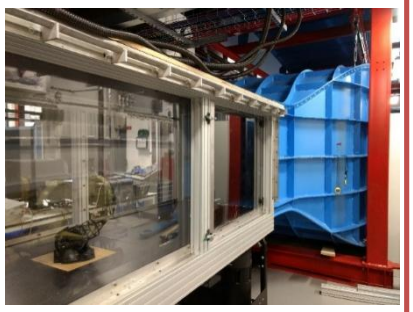
- [IO] IO/20/CT/6000000312 “Development, validation and implementation of the reconstruction and Tokamak simulation algorithms and implementation in a practical software obeying CODAC requirements and signal interfaces”. 6 M€ - 4+2 years
- [F4E] F4E-OMF-1023-01 “Provision of services related to the planning, preparation, execution, evaluation, reporting and checking of analysis and calculations involving seismic loads, transient dynamic loads or other accidental loads in several ITER Systems and Components” (2019-2024). 1.9 M€ - 4 years
- [F4E] F4E-0950-01, “Preliminary and pre-final design of the HCPB & WCLL TBM set – Analyses and design validation” (2019-2023): Design by analysis of the TBM set, implementation of design changes, instrumentation and control. 2.3 M€ - 4 years
- [UKAEA] UKAEA T/VT087/19, “STEP WP5 - Fusion Power Plant - Breeder Blanket Design Challenge” (2019-2020): Development of conceptual designs for fusion Breeder Blankets within UKAEA’s program to start investigating the viability of STEP.
- [IO] IO/17/CT/4300001624, “Design Finalization and Development of Reconstruction Algorithms for the Operational Instrumentation of the Internal Components (Blanket Modules & Divertor)” (2018-Ongoing).
- [IO] IO/17/CT/4300001568, “Definition of TL3 and HVB seismic interface loads with the Tokamak Complex” (2017-2018)
- [IO] IO/17/CT/4300001460, “Manufacturing design of Diagnostics First Walls for EPP#11 – Simulation of welding processes” (2018)
- [IO] IO/CT/16/4300001322, “Cryostat Analysis and Structural Integrity Assessment” (2016-Ongoing): Structural integrity assessment of the ITER Cryostat based on the development of different thermal and structural as well as global and local FE models.
- [IO] IO/CT/16/4300001330, “Vacuum Vessel Pressure Suppression System (VVPSS) Analysis and Structural Integrity Assessment” (2016-2018): Design finalisation of the Vapour Suppression Tanks and relief line and corresponding thermo-hydraulic and thermo-mechanical analyses, as well as structural integrity assessment of the system.
- [F4E] F4E-0503-01, “Framework service contract for the provision of engineering support in the area of seismic, dynamic and structural analyses of ITER buildings and mechanical components – Lot 1: Seismic analysis and design of building and mechanical components of the ITER facility” (2015-2019): 1.5 M€ FWC involving the seismic analysis and design of multiple ITER components, including the derivation of the official FRS for the TKC and the updated set of seismic analyses for the Tokamak machine.
- [F4E] F4E-0503-03, “Framework service contract for the provision of engineering support in the area of seismic, dynamic and structural analyses of ITER buildings and mechanical components – Lot 3: Structural analysis and design of buildings and structures during the construction of the ITER facility” (2015-2019): 1.5 M€ FWC involving the design of multiple critical ITER components, such as the supporting structure for the 23,000 ton Tokamak machine.
- [IO] IO/CT/4300001207, “Pre & Post-Test Predictions of the CSB Scaled Model Tests by FE Non-Linear Analyses” (2015-2016)

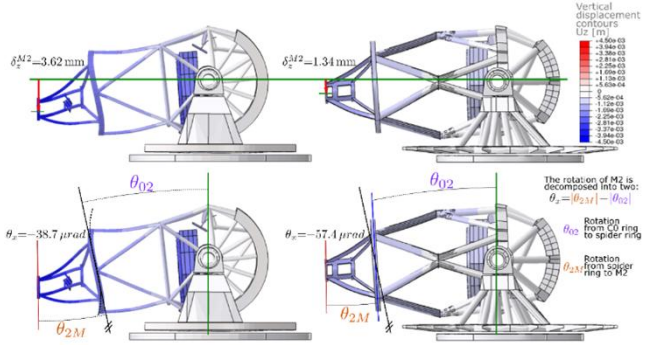
ESTEYCO Mechanics activity is not restricted to ITER, fusion or even Big Science

A strong link with R&D in other industries is promoted and maintained

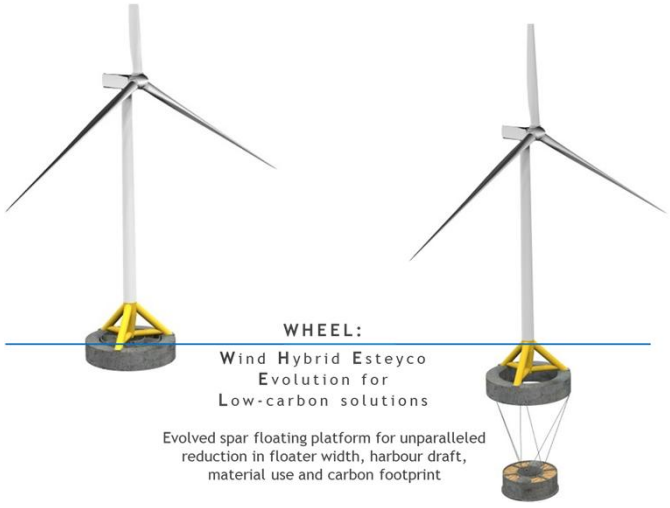
Big Science - EST



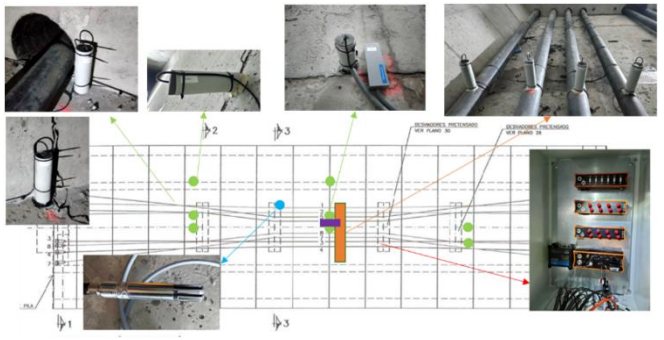




Offshore wind



Infraestructures



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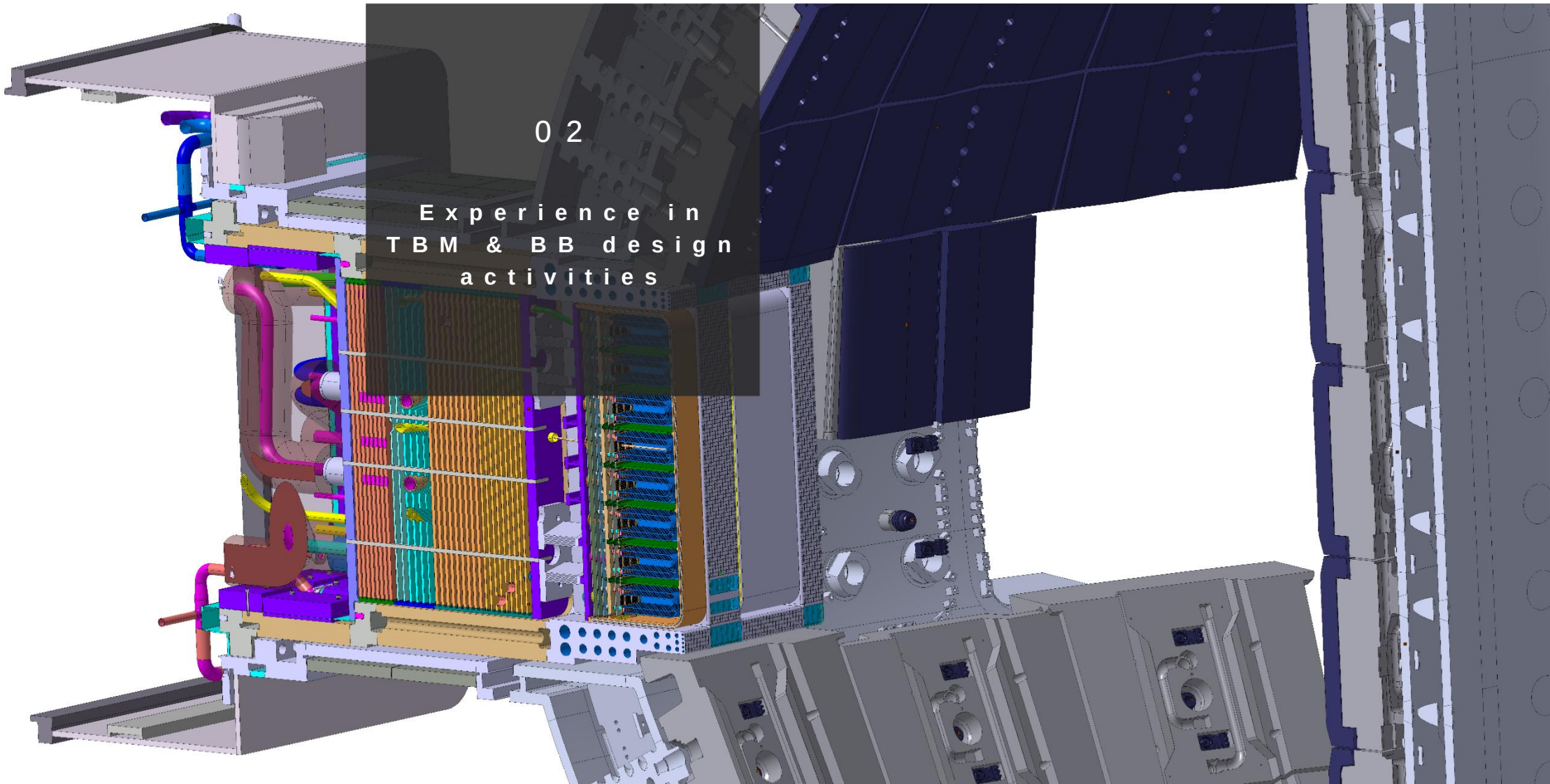


02

Experience in TBM & BB design activities

ITER objectives:

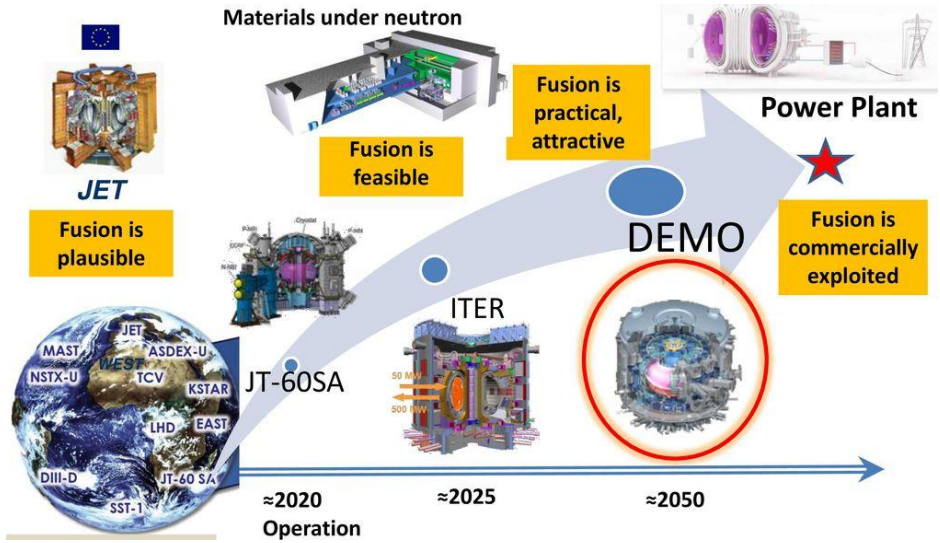
1) Produce 500 MW: $Q_{out} \geq 10*Q_{in}$. (current record in JET: $Q_{out} = 0.67*Q_{in}$).

2) Demonstrate the integrated operation of technologies under conditions similar to those expected in a future power plant (bridge the gap between today's smaller-scale experimental fusion devices).

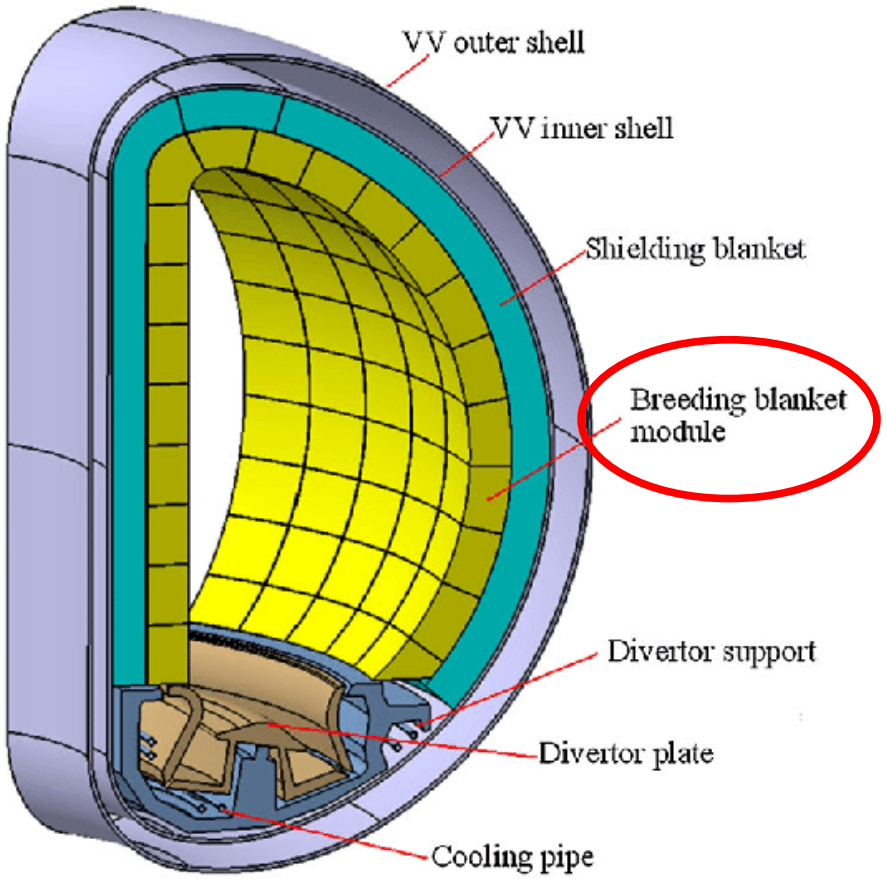
3) Achieve a deuterium-tritium plasma in which the reaction is stable for longer periods of time.

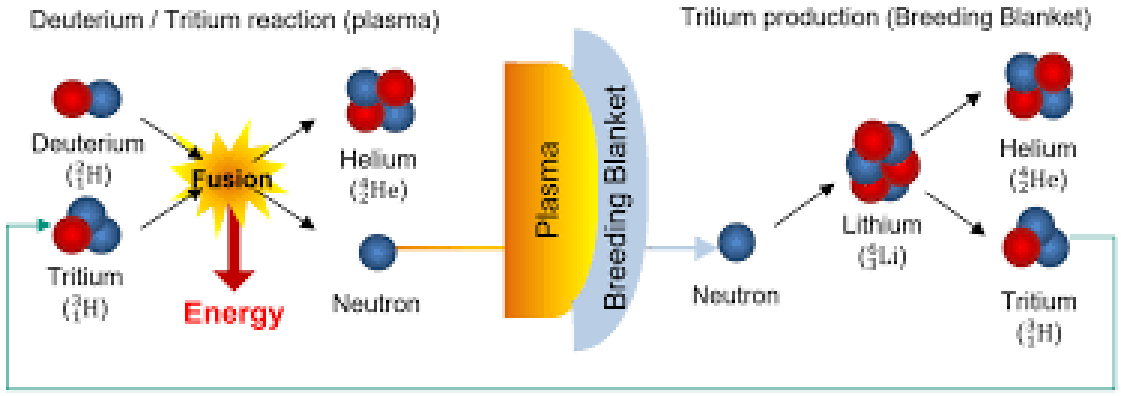
4) Test tritium breeding: demonstrate the feasibility of producing tritium within the Vacuum Vessel. The world supply of tritium (used with deuterium to fuel the fusion reaction) is not sufficient to cover the needs of future power plants. ITER will provide a unique opportunity to test mockup in-vessel tritium breeding blankets in a real fusion environment.

5) Demonstrate the safety characteristics of a fusion device.



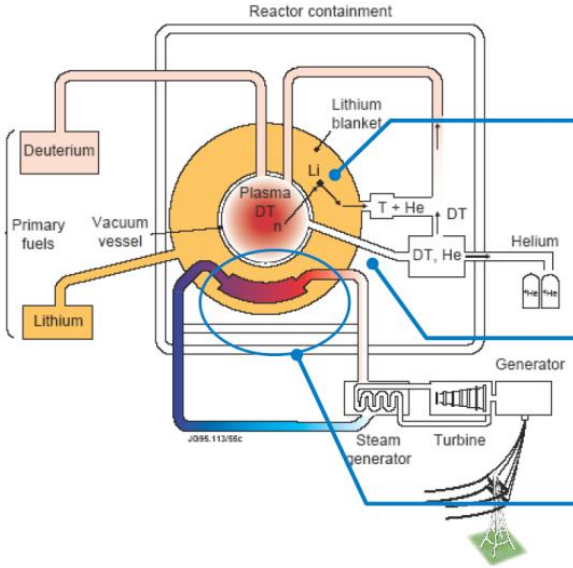
DEMO: Produce electricity and self-generate tritium (not achieved in ITER)





DT Fusion (plasma): $T + D \rightarrow {}^4He + n$ (17.6 MeV)

Tritium Breeding (blanket): $n + {}^6Li \rightarrow {}^4He + T$ (4.8 MeV)



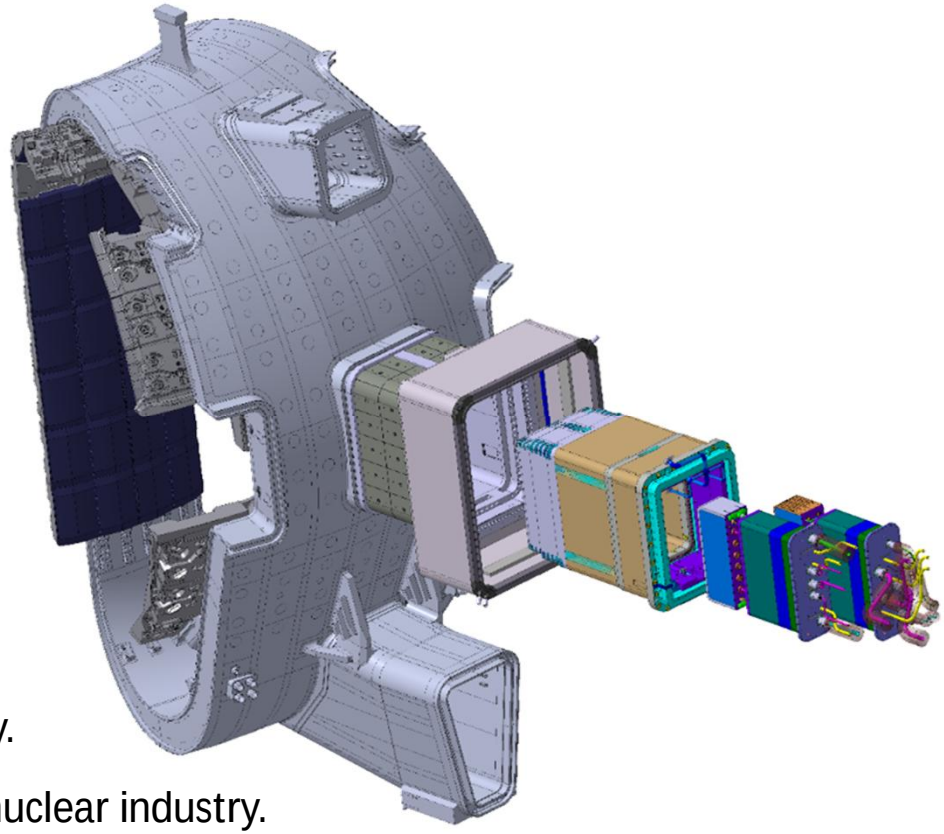
Produce and recover Tritium
(Tritium self-sufficiency)

Tritium consumption:
~0.4 kg/day @ 2.5 GW fusion power)

Protect vacuum vessel and coils against radiation damages/heating

Convert neutron energy into heat

- The TBM project provides test blankets to test and validate design concepts of tritium breeding blankets relevant to a power-producing reactor -> ITER Project Requirement
- Europe has been developing two reference breeder blankets concepts for DEMO to be tested in ITER under the form of Test Blanket Modules (TBMs) Systems:
  - Water-Cooled Lithium-Lead (WCLL).
  - Helium-Cooled Ceramic Pebbles (HCCP).



- Main challenges as a nuclear component:
  - Extremely demanding loads (T -300-550°C- and P -9-18 MPa-)
  - Extremely congested design space
  - EUROFER97 steel has never been used in nuclear industry.
  - Pulsed operation: ~9,000 cycles.
  - New fabrication technologies not yet qualified in nuclear industry.
  - Functional materials (tritium breeder) are presently not used in nuclear industry.

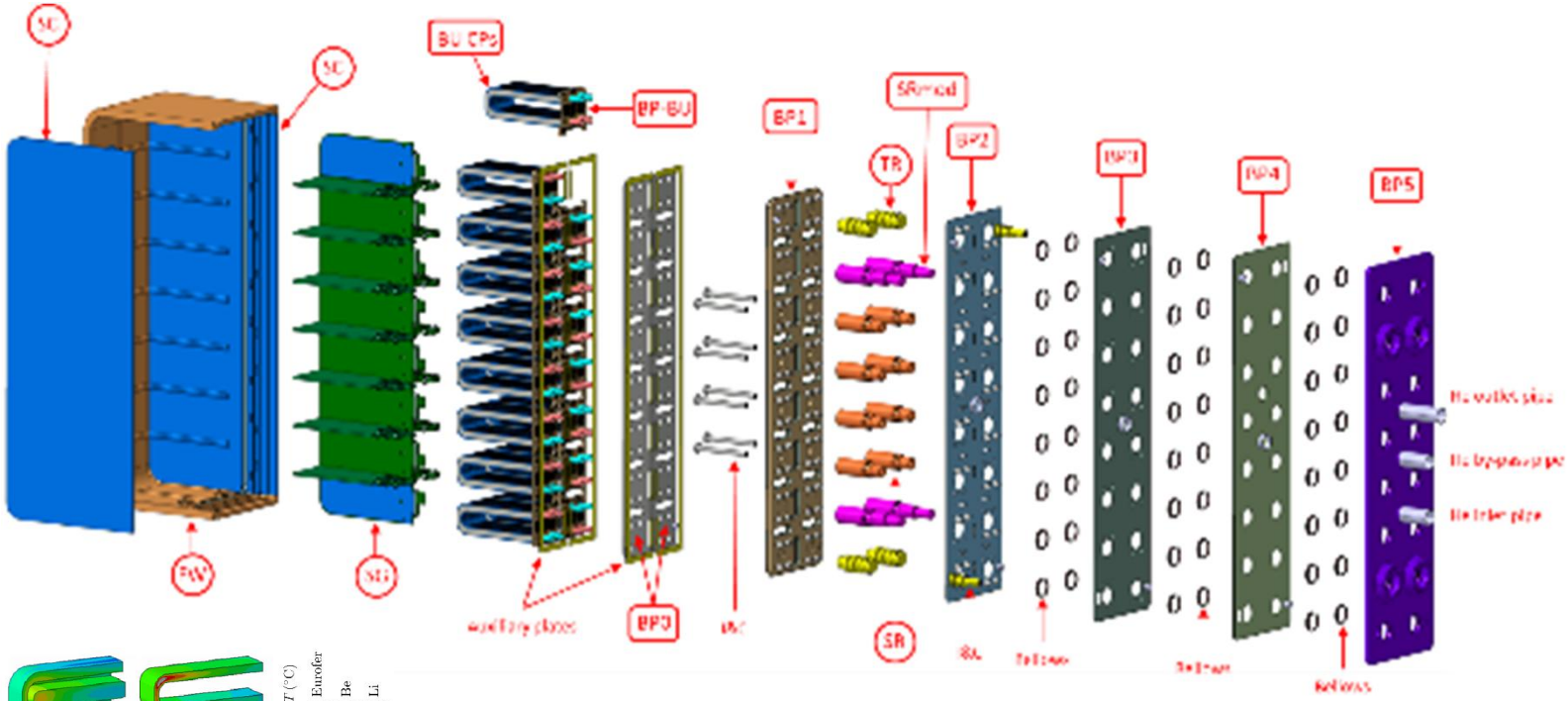
TBM box has to be designed with evolving design rules as C&S are developed

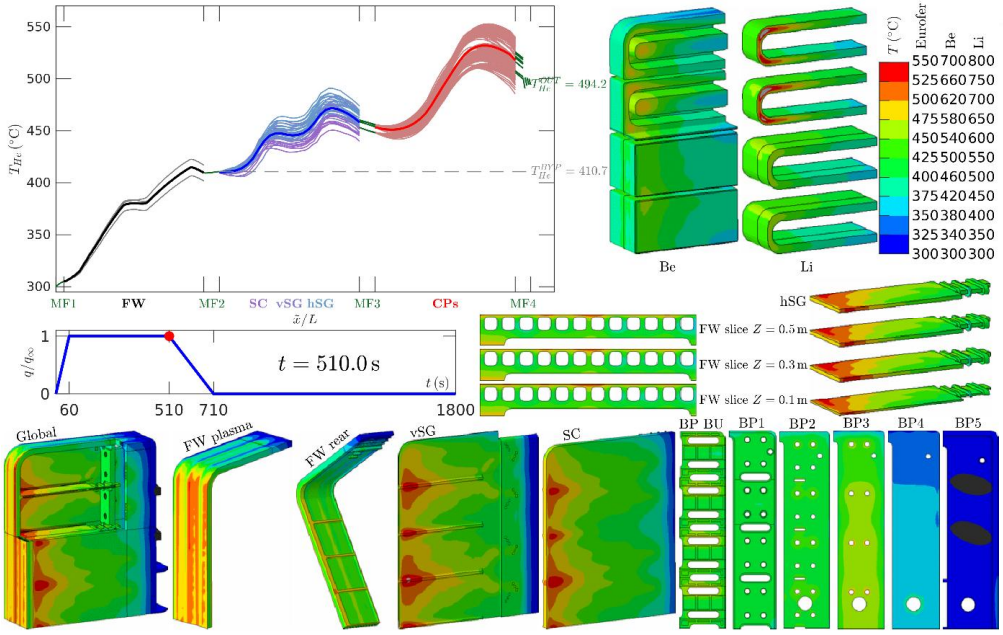
Experience in TBM/BB

European TBM program

- In charge of the HCCP & WCLL TBM set designs for Fusion for Energy.

- HCCP (helium-cooled ceramic pebble)



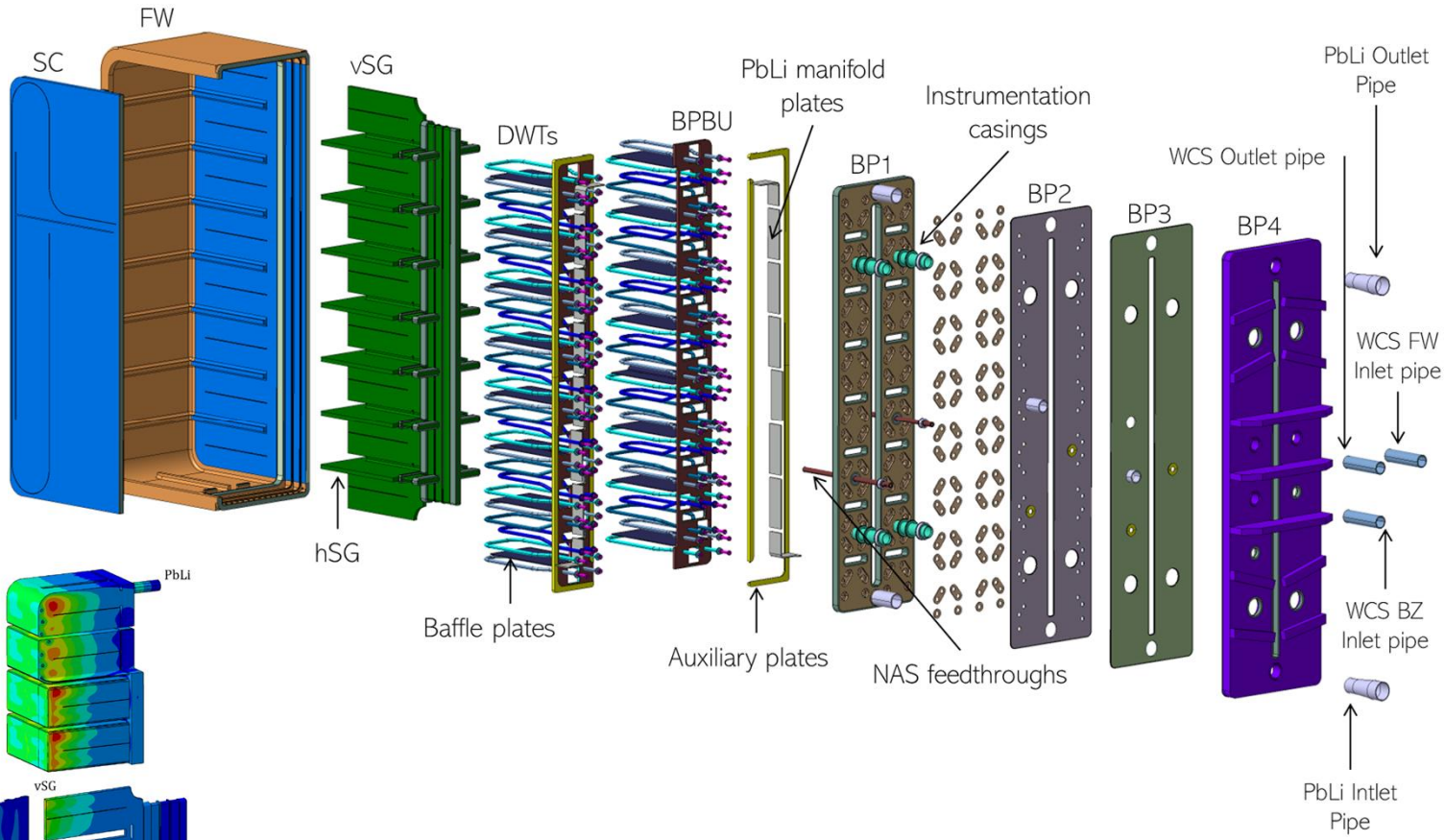


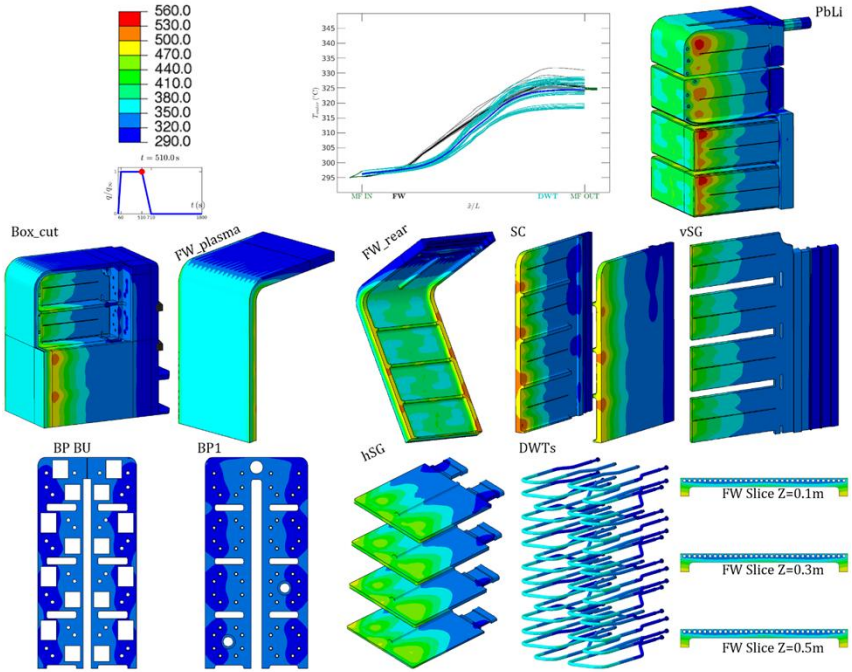
Experience in TBM/BB

European TBM program

- In charge of the HCCP & WCLL TBM set designs for Fusion for Energy.

- WCLL (water-cooled lithium lead) concept





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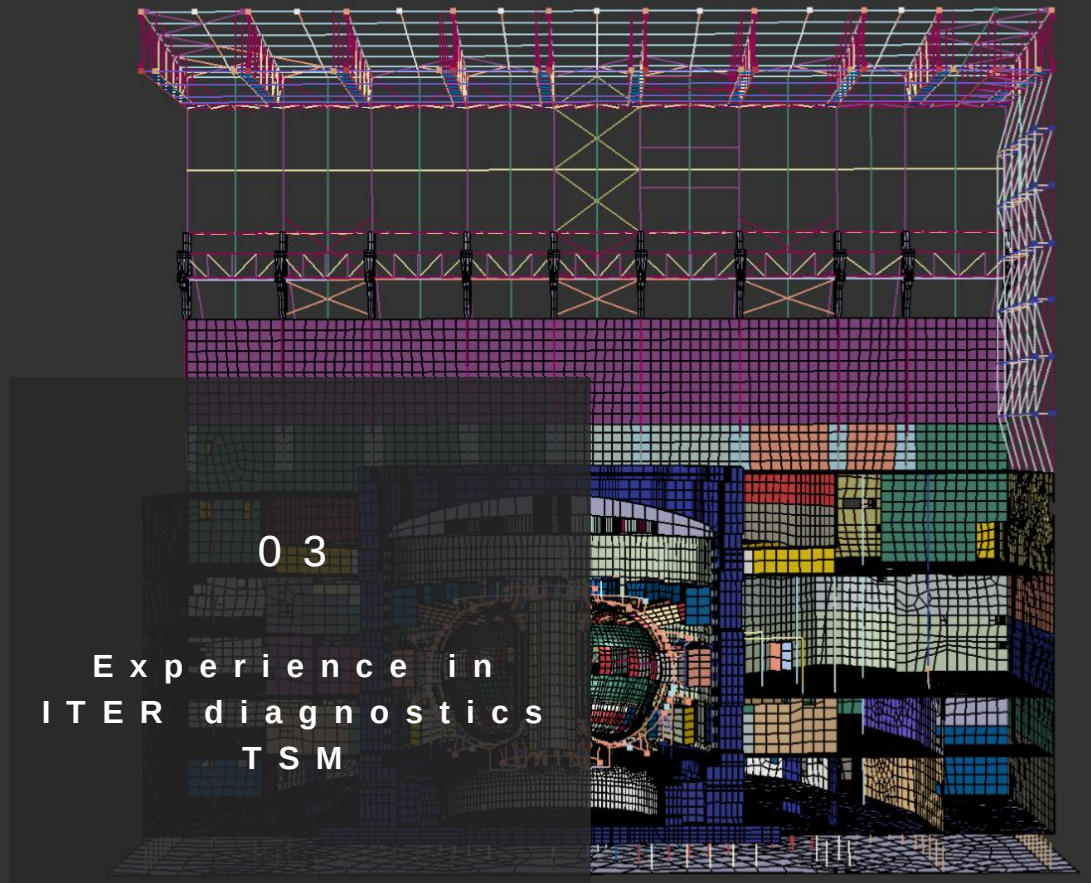


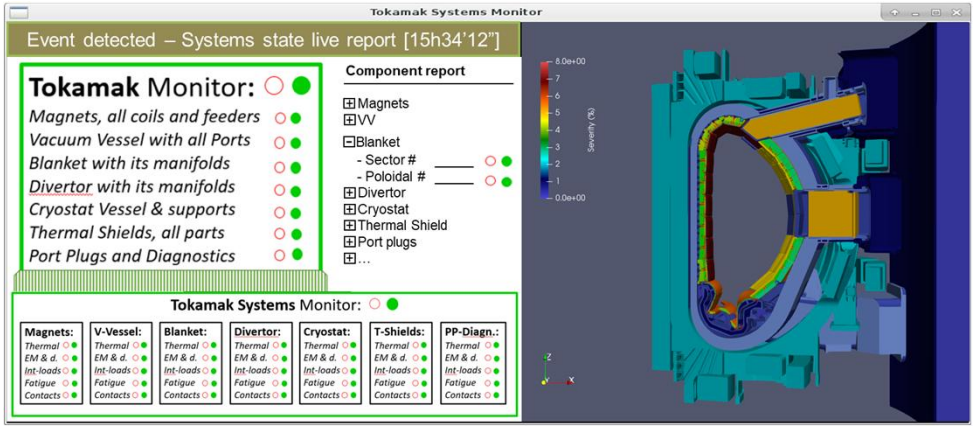
03

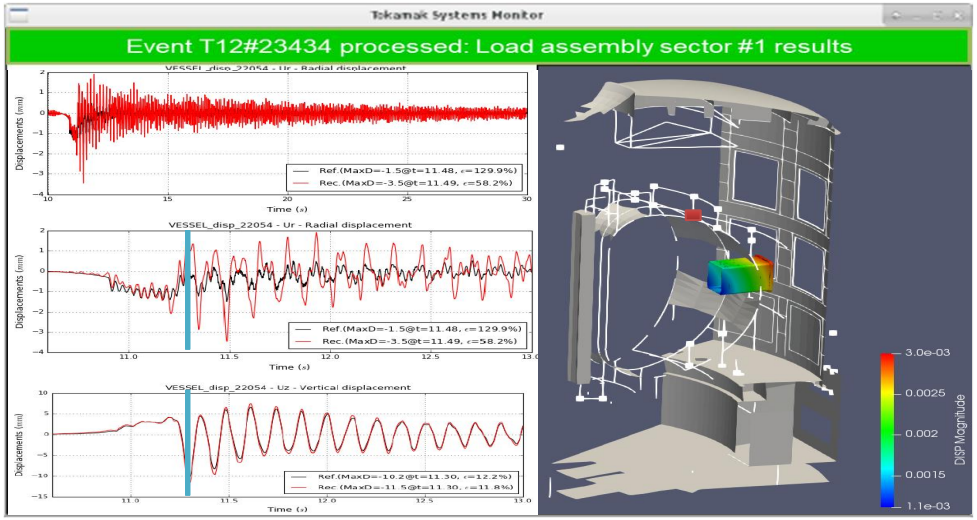
Experience in ITER diagnostics TSM

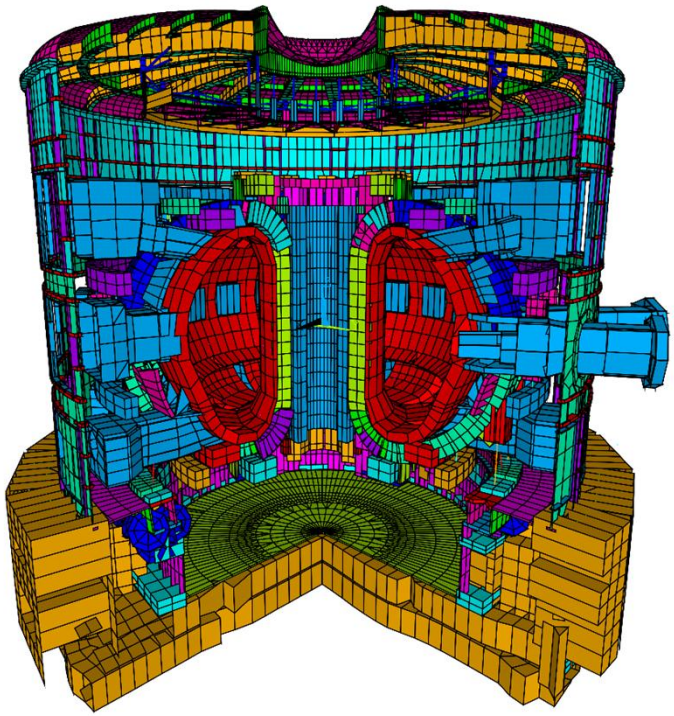
Experience in ITER diagnostics

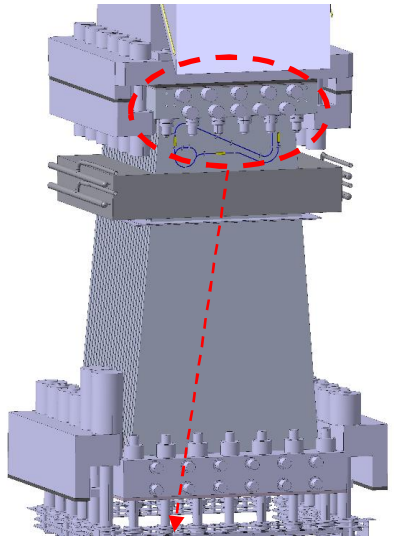
Tokamak System Monitor

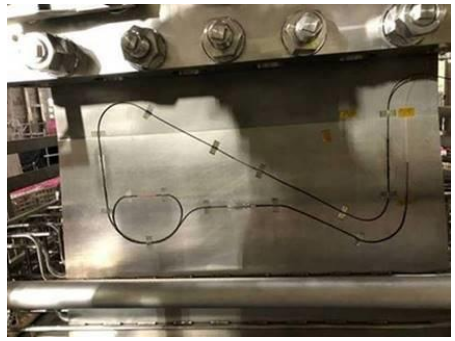
- ESTEYCO is in charge of the development of the ITER "Tokamak Systems Monitor (TSM)", a software which will make use of the available instrumentation to provide an integrated view of the response of the Tokamak in near real time, for comparison with reference design values & management of health and lifetime:
  - The sensors information can be used or indirectly, through the resolution of ill-posed, inverse problems.
  - The outputs of the TSM will be made available in the control room so the operator can react if necessary. Moreover, within minutes, more detailed information will be provided to engineers and scientists so that they can make the necessary adjustments between plasma pulses.





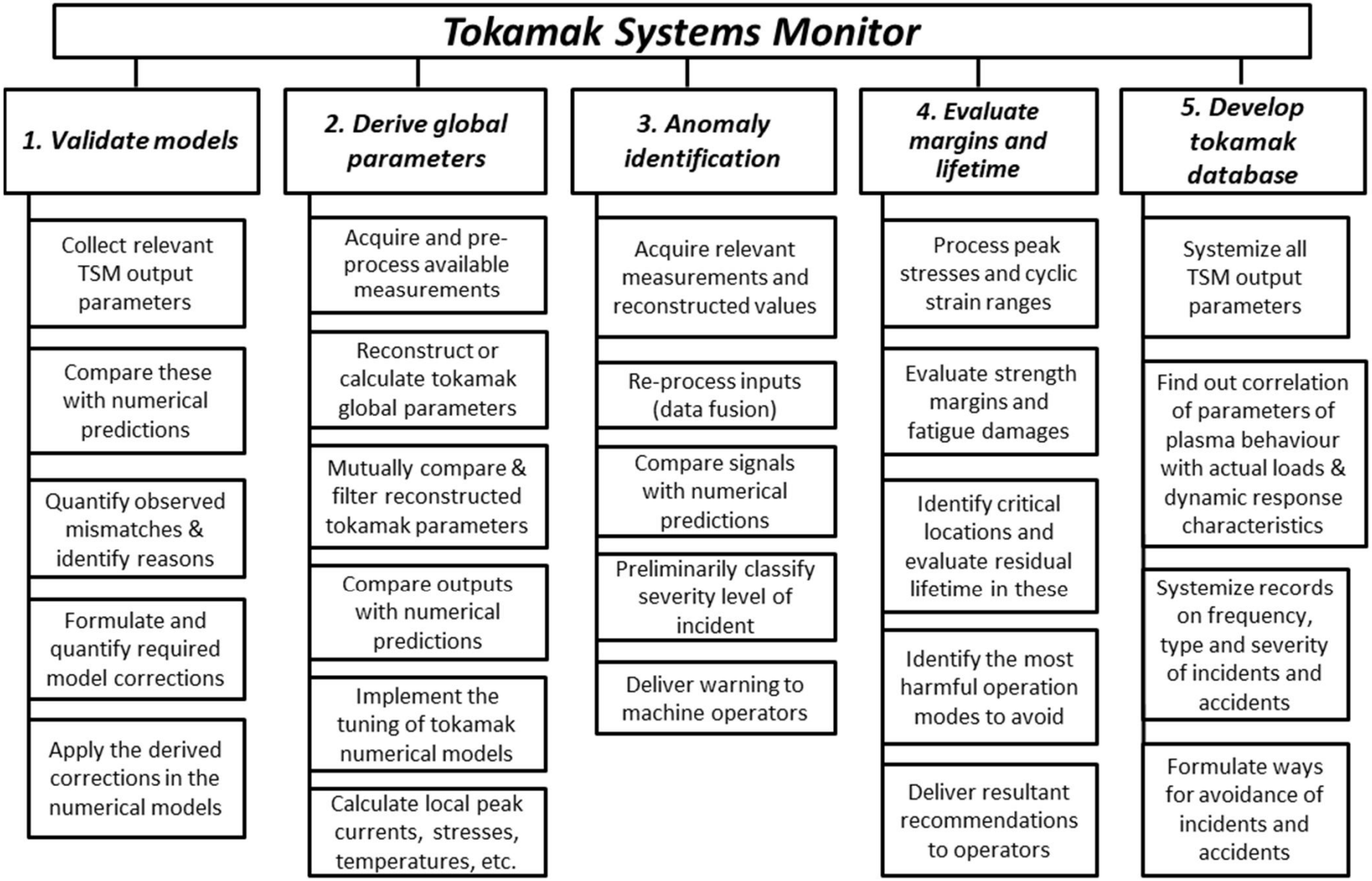






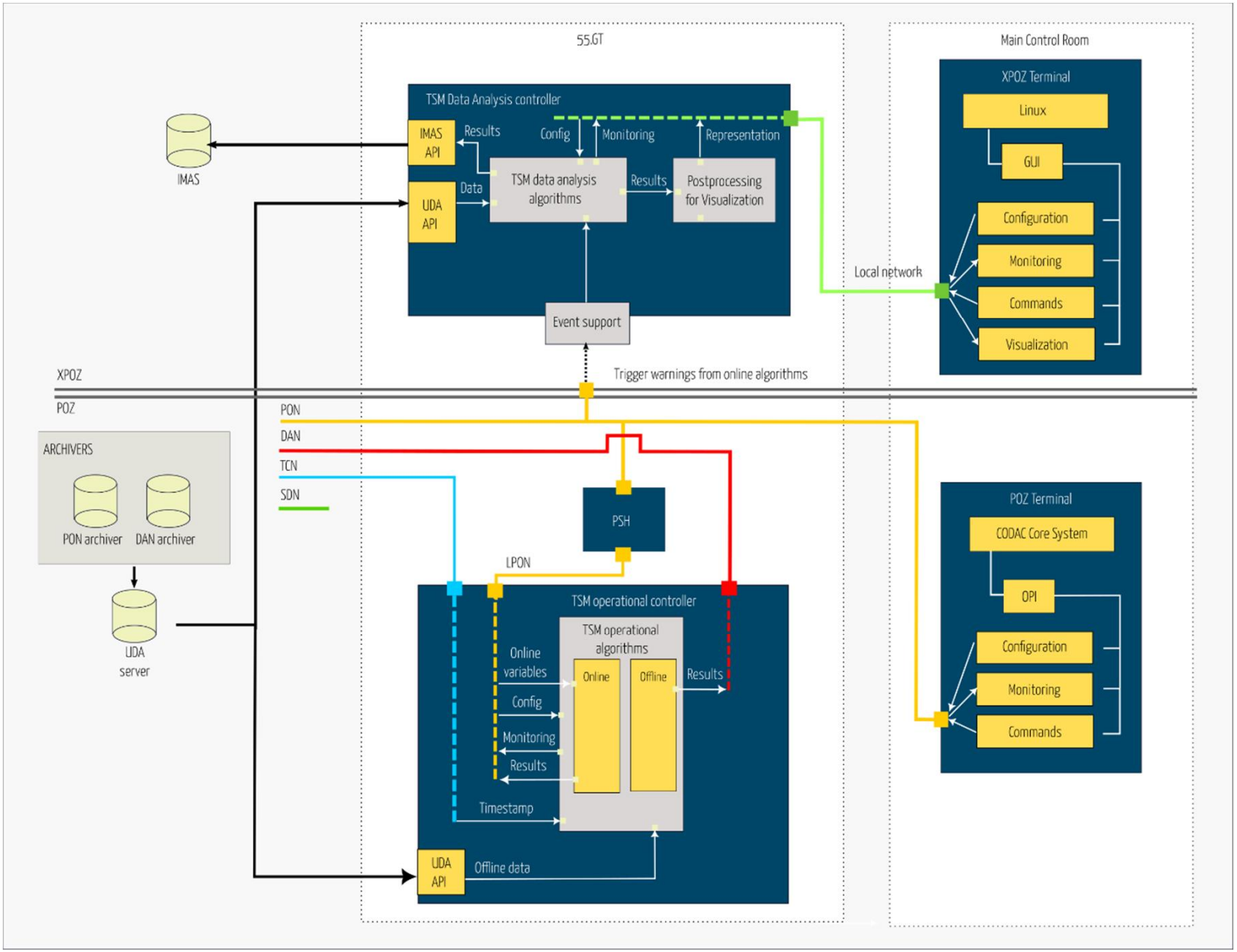
Tokamak System Monitor

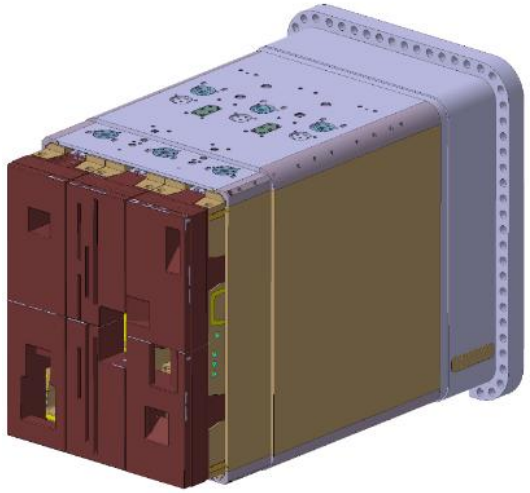
- Functional diagram



Tokamak System Monitor

- Software architecture





- Example: Thermal reconstruction of diagnostics Port Plug under full power operation

ONLINE

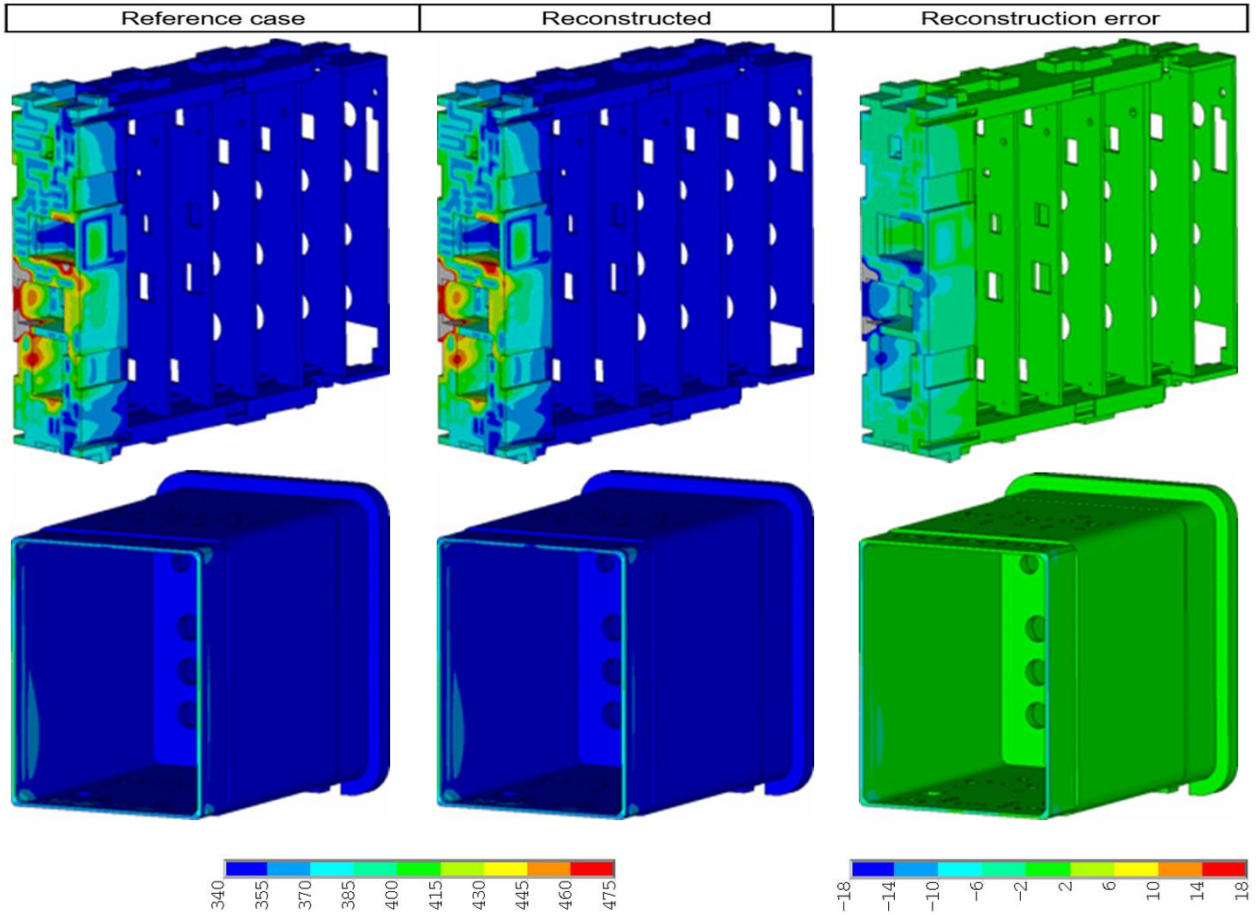
1.- Reconstruct temperature fields of DSM & PPS from sensor readings (inverse problem)

OFFLINE

2.- Reconstruct volumetric heat deposition in DSM / PPS / DFW from the sensor readings at the end of the plateau (inverse problem)

3.- Reconstruct temperature fields of DSM / PPS / DFW by solving a direct problem running a FE simulation

4.- Reconstruct the displacement and stress field by solving a direct problem running a FE simulation



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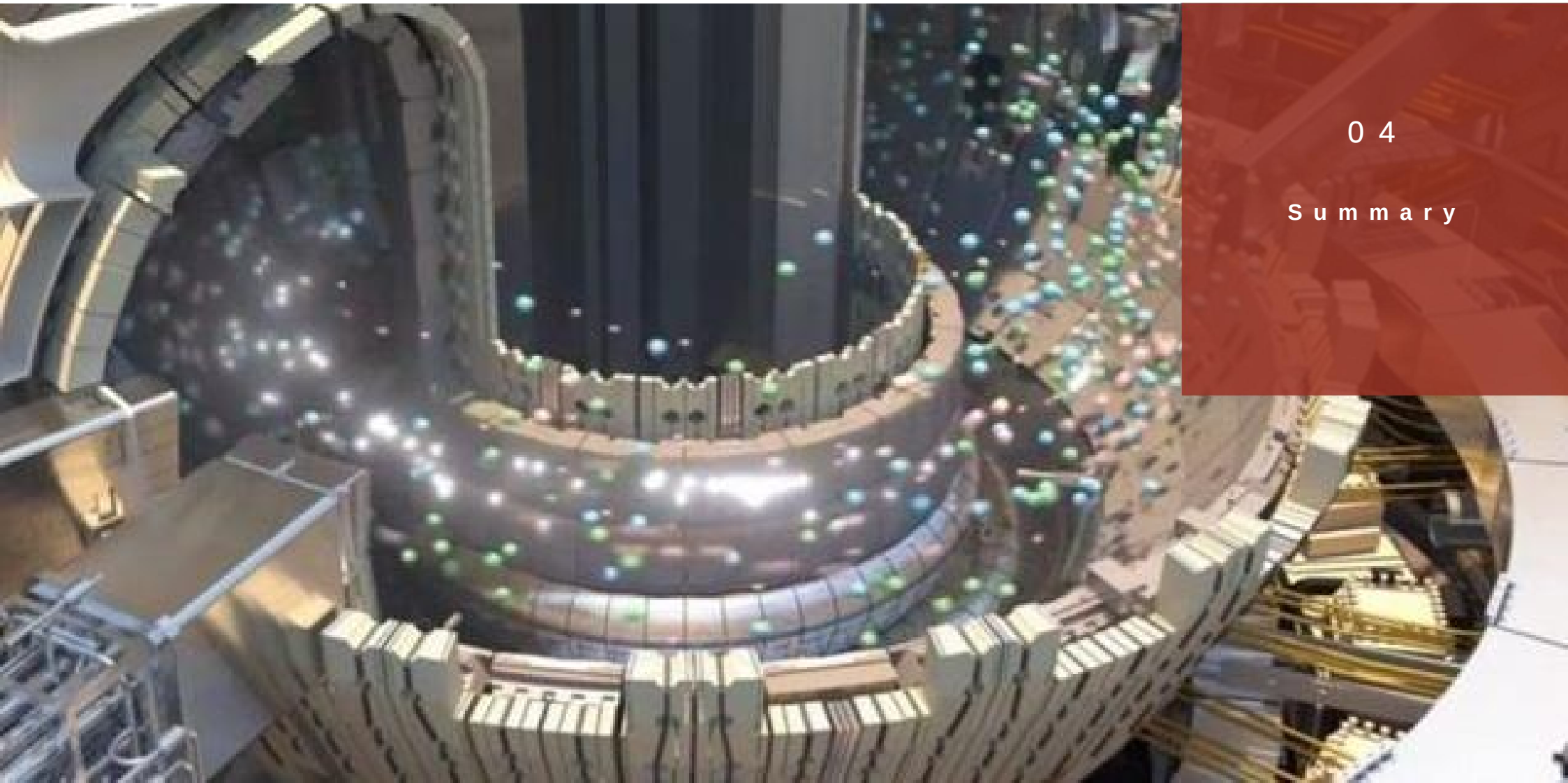

04

Summary

Summary

- Grupo multidisciplinar de ingenieros especializados en problemas no convencionales en el ámbito de la mecánica y las estructuras => Habituados a trabajar en entornos nuevos, donde ni los procesos ni las soluciones están claros
- +15 años de experiencia en ITER. Implicación transversal en la mayor parte de los sistemas de la instalación relevantes mecánicamente: exposición al ambiente de trabajo en fusión.
- Implicación creciente en IFMIF-DONES
- Actividad no restringida a fusión o industria de la ciencia -> ¡¡¡Hay otras cosas muy divertidas y complejas ahí fuera!!!

Summary

- Papel en absoluto restringido a ingenieros de estructuras, muchas otras disciplinas nos son muy necesarias –> buscamos el talento para resolver problemas
- Perspectiva de, y vínculo a, largo plazo. Buscamos carreras largas (hacer las cosas bien lleva su tiempo)
- Plan para incorporar 5 nuevos compañeros en 2023
- Los doctores tienen preferencia, pero en absoluto con carácter restrictivo

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