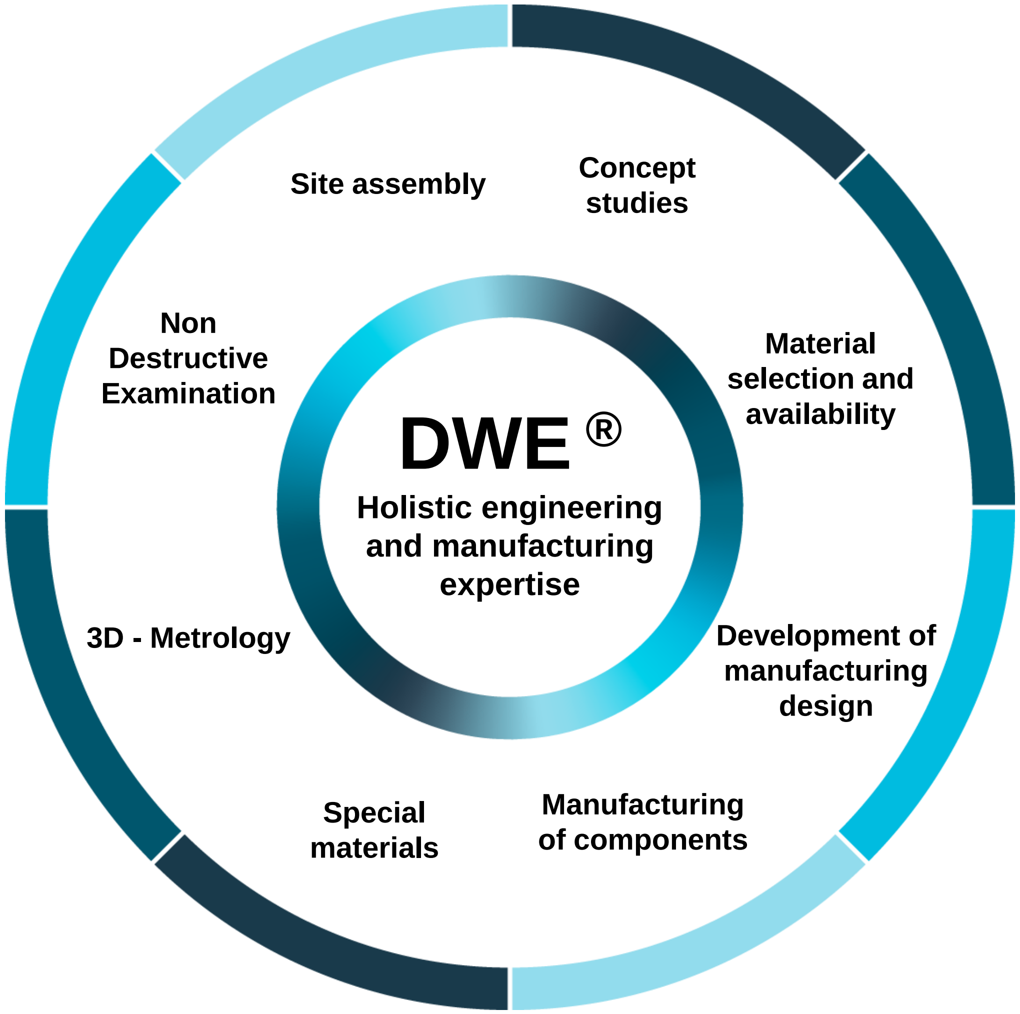
MAN Energy Solutions
Future in the making

MAN DWE® for ITER

Reactors, apparatus, and decarbonization

MAN DWE® for physical research facilities

Service Portfolio - Overview



From physical theory to fusion reactor

Vacuum components such as plasma vessels, cryostat vessels or injection components engineered and manufactured in Deggendorf

MAN DWE® for physical research facilities

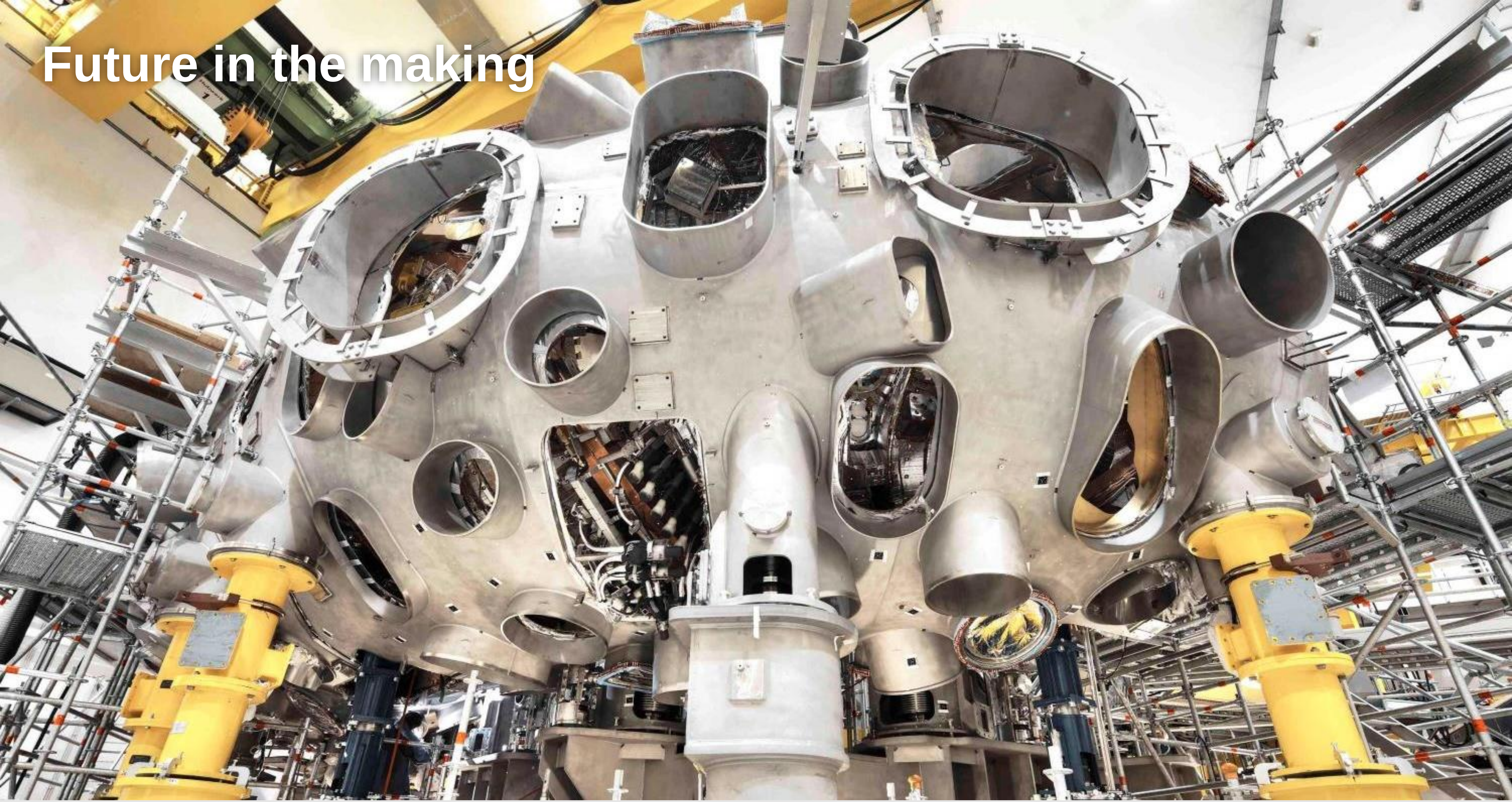
Service portfolio - Engineering

Engineering

- Material selection and availability
- Development of manufacturing design
- Stresses in stainless steel under vacuum conditions
  - Thermal and residual stress calculation
  - CFD stress calculation
- NDE concept for complex welded shapes
  - Ultrasonic Testing
  - Radiography Testing
  - TOFD (Time of Flight Diffraction)
  - Phased Array
- Assembly concept and schedule
- Considering code requirements (e.g. ASME; AD2000 etc.)
- Budget development

Original 3D design model from W - 7X plasma vessel

Future in the making



MAN DWE® for physical research facilities

Service portfolio - Manufacturing

Products

- Vacuum vessels
- Cryostat vessels
- Ports / Nozzles / Injectors
- Support structures

Special materials

- Stainless steel
- Nickel based Material
- Titanium
- Zirconium

Available techniques

- Plate cutting
- Rolling
- Special forming
- Welding
- Milling
- PWHT
- Cleaning, up to Electro polishing
- Separate production hall for stainless steel processing

Testing

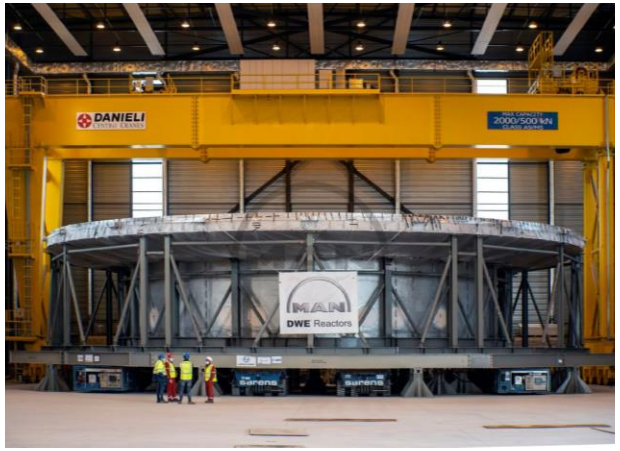
- 3D Metrology
- Helium leakage
- Hydraulic pressure
- Vacuum density
- X-Ray
- Ultrasonic
- Magnetic permeability

MAN DWE® for physical research facilities

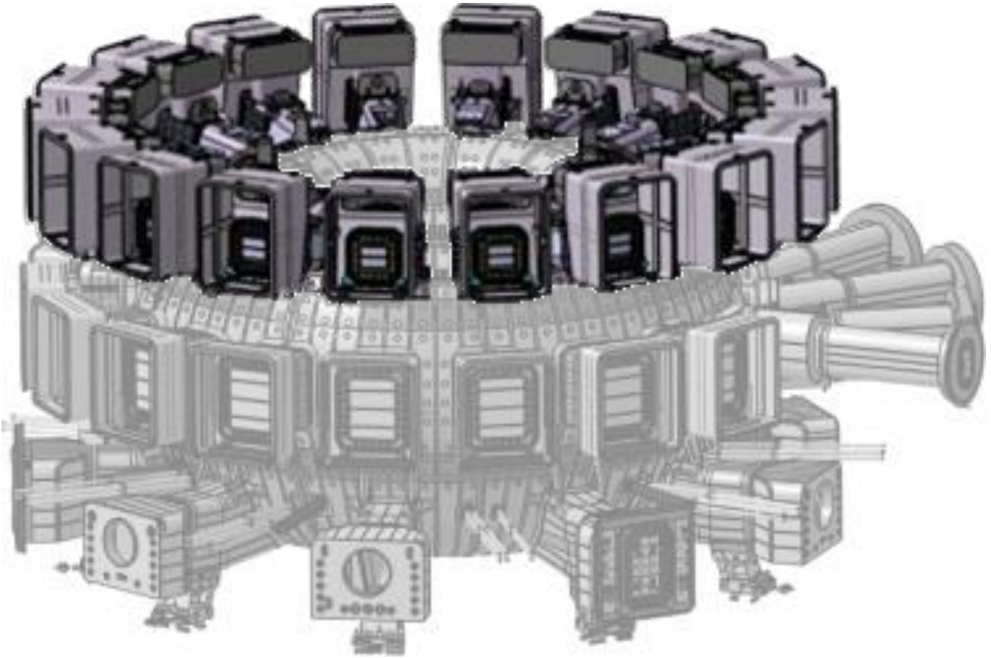
Service portfolio – Site assembly

On site services:

- Transport studies
- Assembly procedures and assembly activities
- Engineers, Welders and Fitters from MAN workshop Deggendorf
- Handling and alignment of components
- Welding and fitting activities
- NDE
- 3D metrology
- Worldwide operation considering local rules and regulations



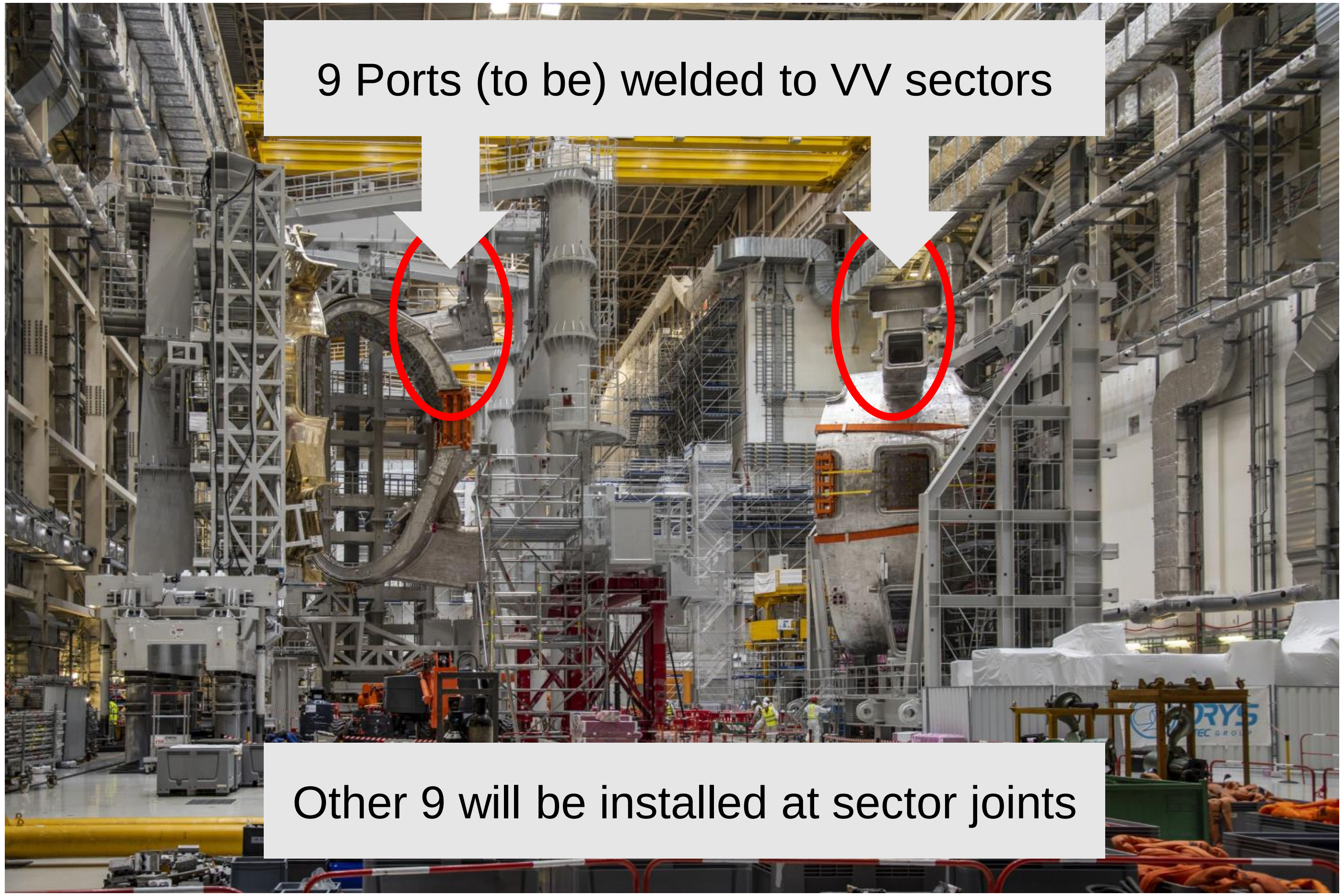
ITER Upper Ports



Scope:

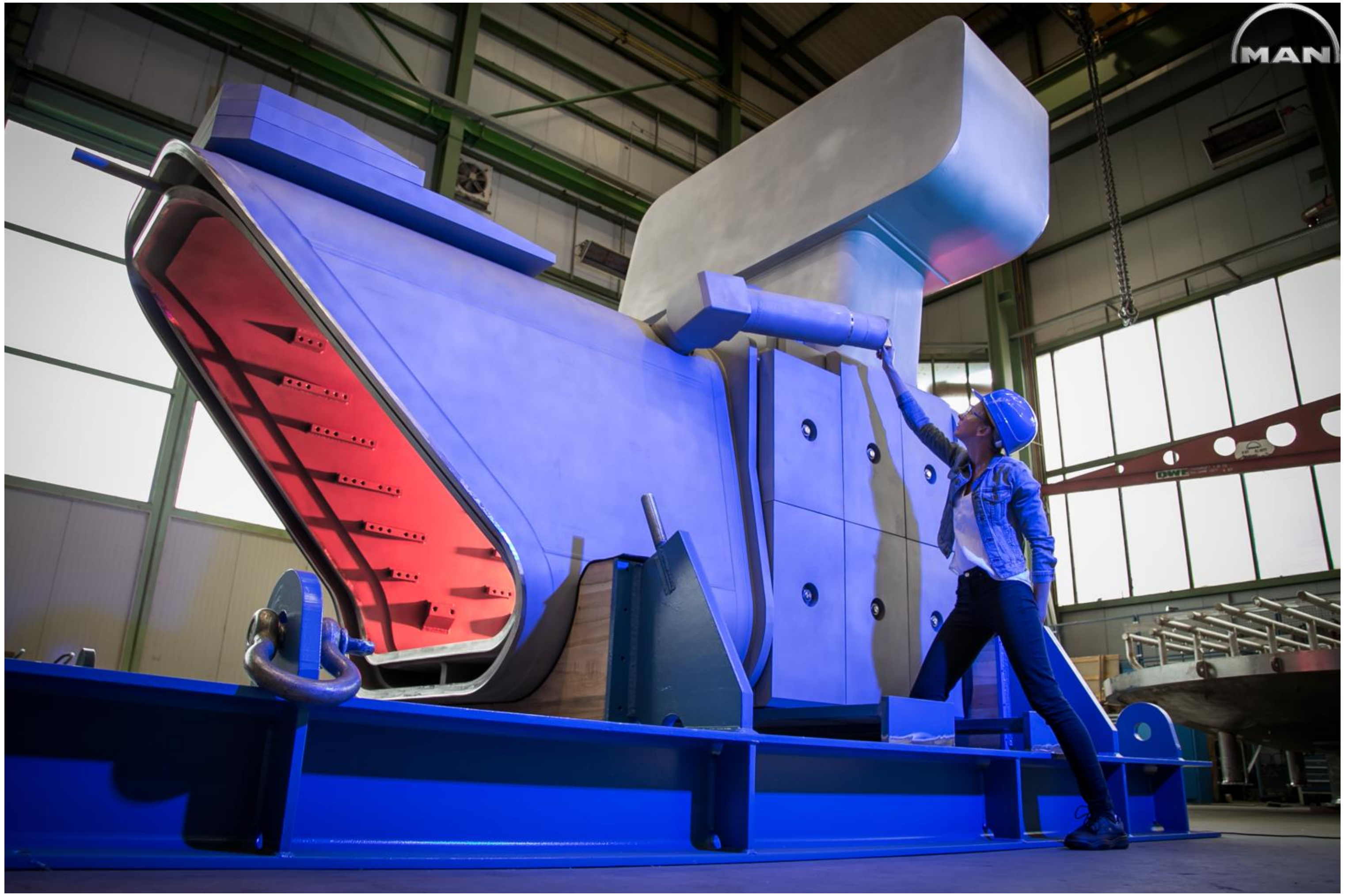
18 Upper Ports + 18 Port Extensions

Final weight: 36 ton each, 640 ton in total



ITER Upper Ports

First Upper Port finished (from 18)



ITER Upper Ports

Upper Port Extension serial fabrication (18pcs)

ITER Upper Ports

Facts and Figures

- Material: 316LN-IG; Main wall thickness to be welded: 30mm / 40mm / 60mm
- Performed works: plasma-cutting, forming, deep-hole drilling, welding, testing, machining
- **More than 3100 meters of weld seams, 100% RT-tested, in total only 12 meters with repairs**
- All seams helium leak tested (without any indications)

Positives and **difficulties:**

- Implementation of new welding and testing technologies (Narrow-Gap TIG, small-diameter Orbital In-bore TIG with filler, Microfocus)
- Excellent shop load due to parallel work on several Ports, permanent engineering workload
- Long procedure preparation and qualification period before start of fabrication (>1 year to 1st plasma cut)
- Long chain of customers (direct customer -> DA -> IO + ANB involvement)
- **Biggest challenge: bureaucratic, slow decision making behavior**

ITER Upper Ports

Nine Upper Port Extensions now in storage due to sanctions

ITER Cryostat Assembly

Scope overview

PREASSEMBLY – 4 MAIN COMPONENTS

Preassembly of main components in Temporary Cryostat Workshop: Weld seams marked in red

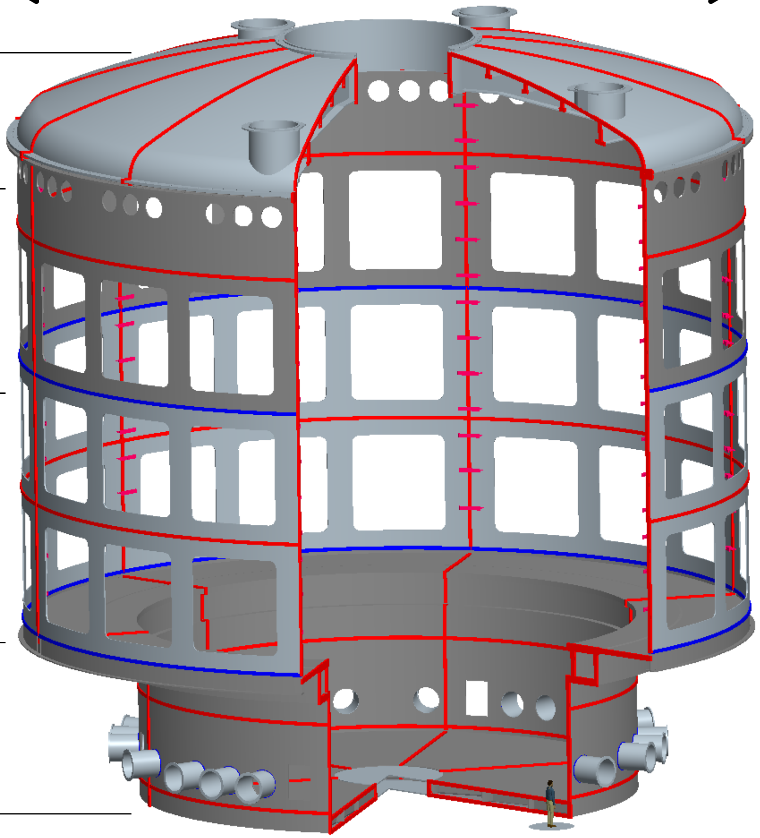
TOP LID
Weight = 600 ton
ø 29 500mm x 4 200mm
12 x 30°-Sectors

UPPER CYLINDER
Weight = 600 ton
ø 29 000mm x 9 000mm
2 x 6 x 60°-Sectors

LOWER CYLINDER
Weight = 800 ton
ø 29 000mm x 10 500mm
2 x 6 x 60°-Sectors

BASE SECTION
Weight = 1350 ton
ø 29 000mm x 6 000mm
3 x 6 x 60°-Sectors

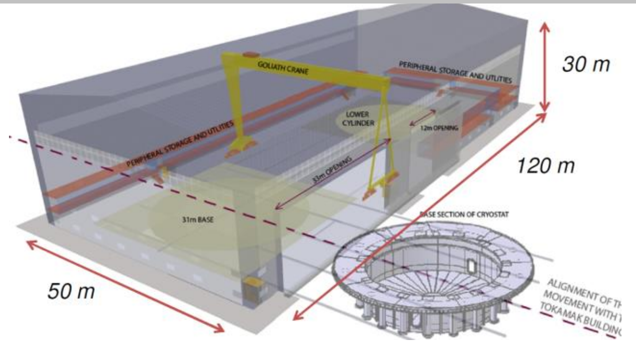
Ø 29 500 mm



29 000 mm

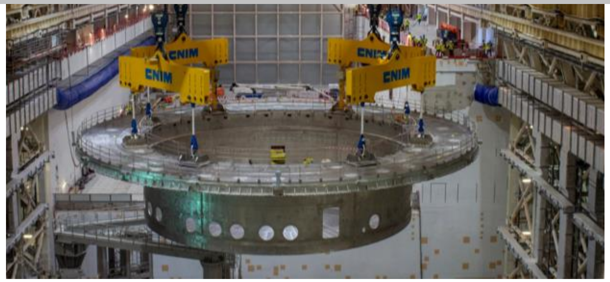
Customer: Larsen&Toubro / India:

- Provision of 54 individual components
- Provision of Temporary Cryostat Workshops for pre-assembly of the four main components



FINAL ASSEMBLY

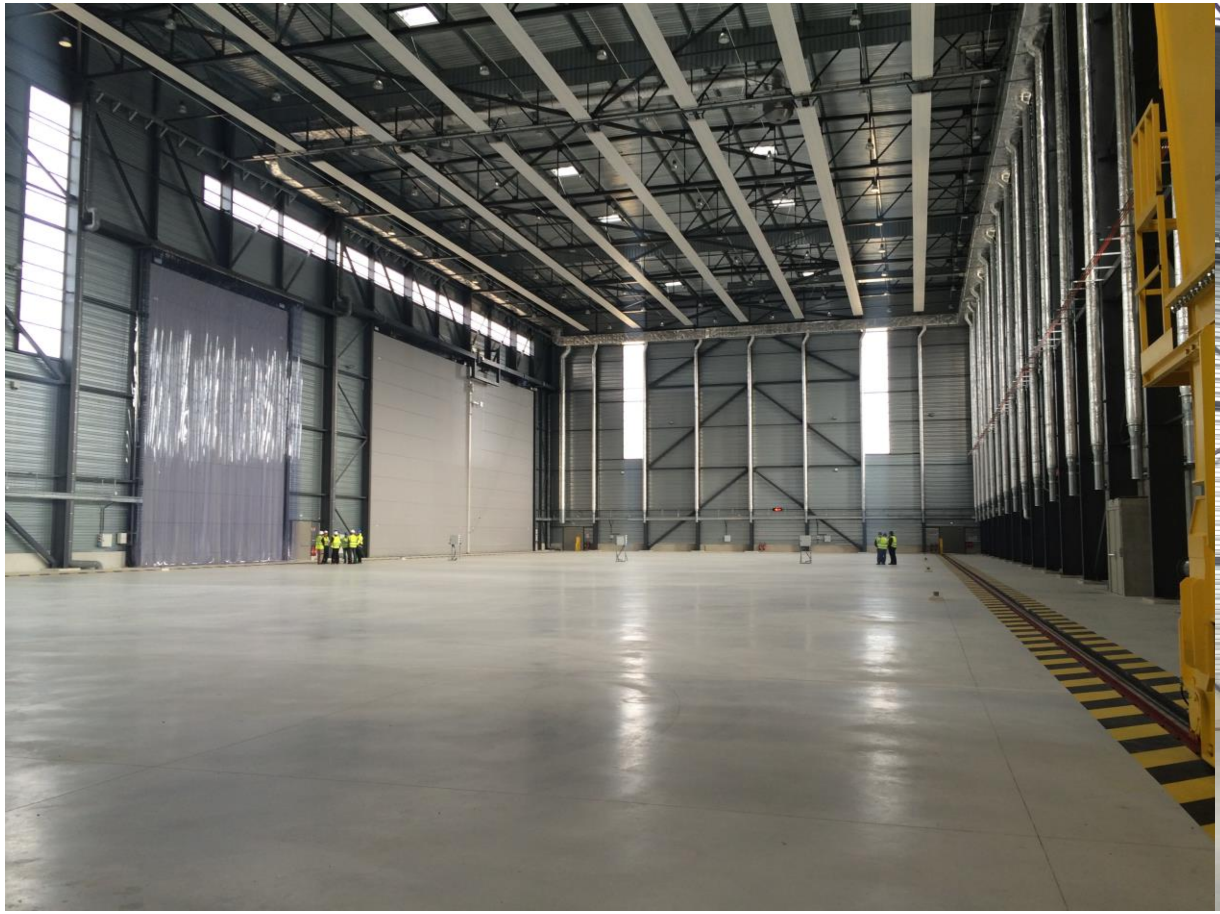
Final assembly in Tokamak Pit - Weld seams marked in blue

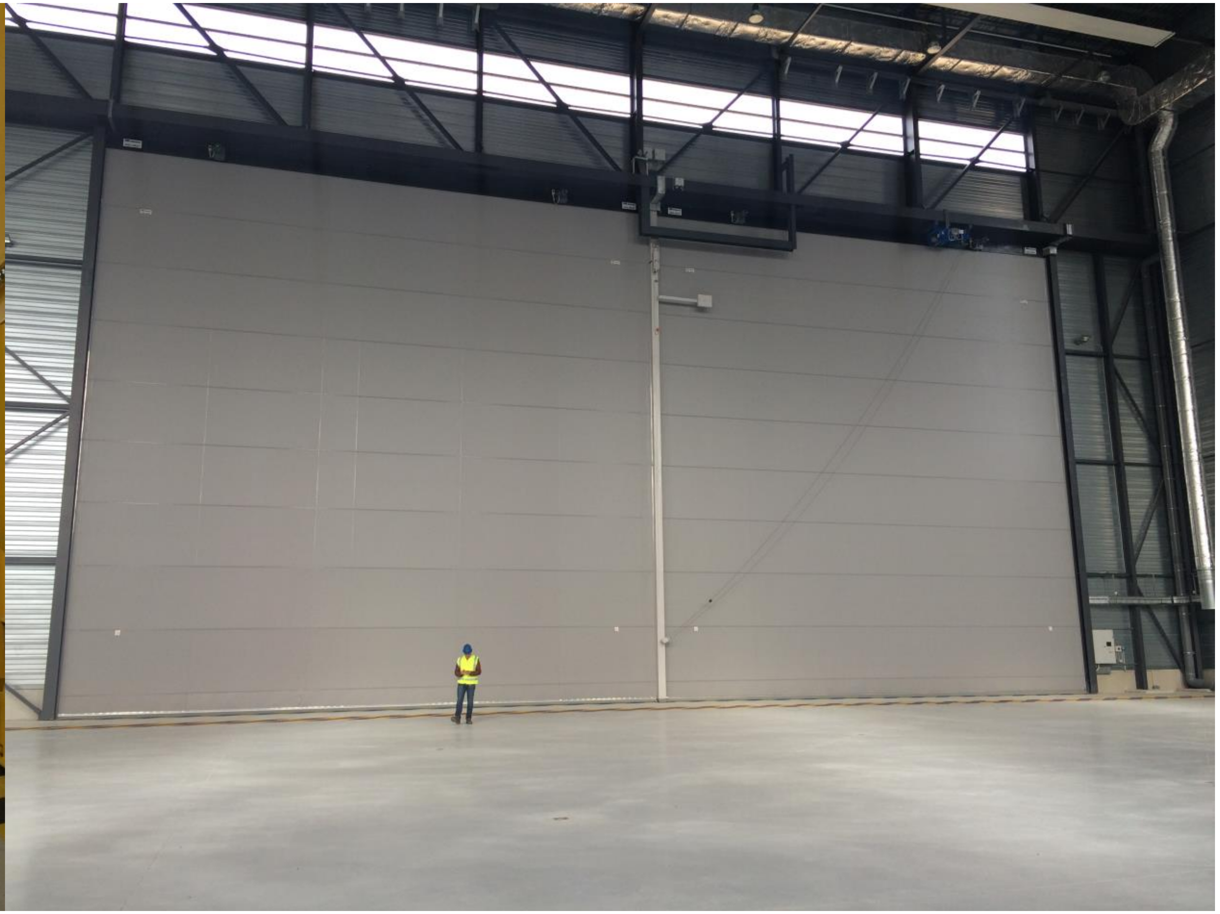


Material: stainless steel 304L, total weight: 3550 ton, **wall thickness: 50mm (90%) to 200mm**

ITER Cryostat Assembly

Start in an empty workshop





ITER Cryostat Assembly

Receipt of first Base Section components

ITER Cryostat Assembly

Base Section finished and ready for transport

ITER Cryostat Assembly

Lower Cylinder during assembly

ITER Cryostat Assembly

Lower Cylinder finished

ITER Cryostat Assembly

Top Lid Segments

ITER Cryostat Assembly

Top Lid completed

ITER Cryostat Assembly

Base Section lifted from assembly frame

ITER Cryostat Assembly

Base Section lowering into Tokamak Pit

ITER Cryostat Assembly

Facts and Figures

- Material: 304L stainless steel
- Main wall thickness 50mm
- 200mm thick plates welded by Narrow Gap TIG
- **Total weld length ca 2000m, mainly welded manually**
- **Deposited filler material: more than 15 ton**
- **Sitework duration: 2015 - 2022**

ITER Sector repair works

Reasons for MAN decline

- Requirement of a fix price. Risk too high for MAN
- Proposed time schedule too short and therefore unrealistic for scope of work under given regularities
- Time schedule is highly depended on “third parties”
- Delay damages are not acceptable
- Payment conditions are not acceptable
- Potential scope split to several vendors may lead to unfavorable ratio between engineering / site work