Ateliers de la Meuse (ALM)
AMOS
Centre Spatial de Liège (*University of Liège*)

A cryostat to test superconducting coils for Japan's JT-60 SA fusion reactor

Outline

- ✓ Presentation of
  - Ateliers de la Meuse
  - AMOS
  - Centre Spatial de Liège (CSL)
- ✓ Broader approach : JT-60 SA
- ✓ Fusion experience
- ✓ Conclusion

Introducing CSL

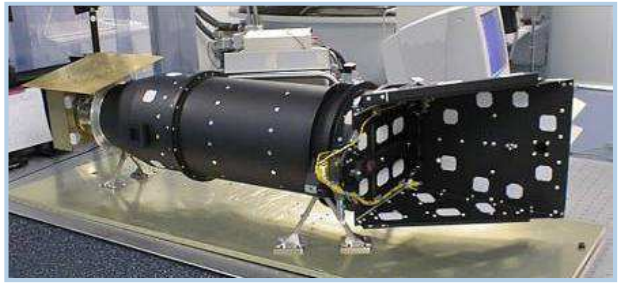
- ✓ Research Centre of the University of Liege
- ✓ CSL was born in Institute for Astronomy and Astrophysics
- ✓ Active in space instruments engineering/testing since the 60's
- ✓ Test facility center linked to ESA
- ✓ Develops space science instruments or subsystems (for agencies or industries)
- ✓ Test space instruments or systems
- ✓ Develops instruments calibration tools and test facilities
- ✓ Involved in Fusion Technology

First Core Business

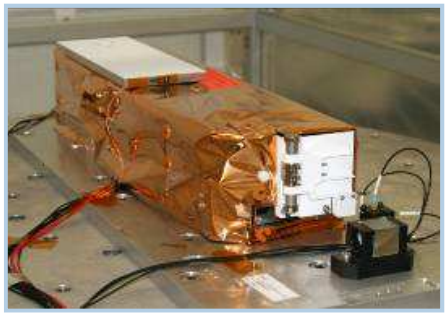
- Space scientific instrument development
  - ✓ optical instrument payloads (telescopes, spectrometers, photometers, cameras...)
  - ✓ instrument architect & integrator : conception and realization
  - ✓ from the translation of science requirements up to the delivery of a space qualified product, and sometimes in-flight commissioning
  - ✓ optics on mechanisms payloads (cryo-mechanisms)
  - ✓ associated electronics development
  - ✓ long experience in Low Temperatures
  - ✓ design - manufacturing - assembly - calibration - test
- ✓ Today Status :
  - ✓ 10 instruments in operation
  - ✓ 15 instruments in development

Space Instruments

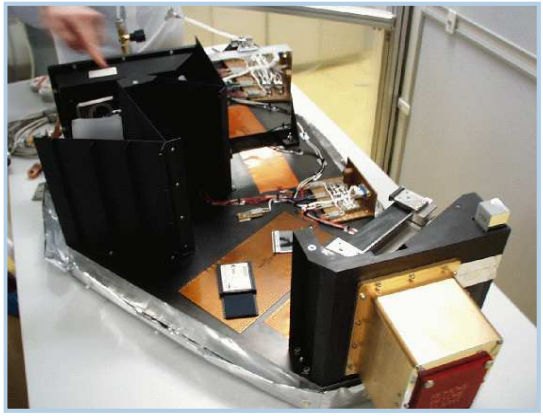
EIT (SOHO, 1995)



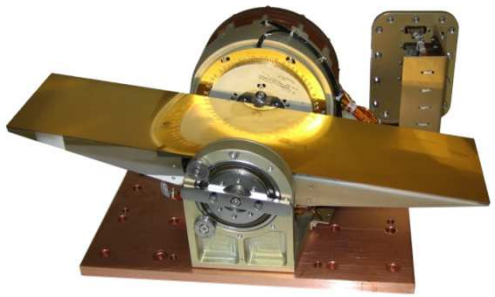
OMC (INTEGRAL, 2002)



SWAP (PROBA-2)



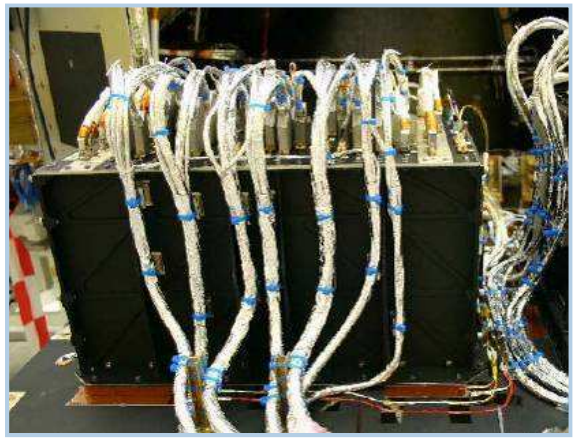
FUV-SI (IMAGE, 2000)



PACS Cryo mechanism and Electronics (Herschel,2009)

HI (STEREO, 2006)

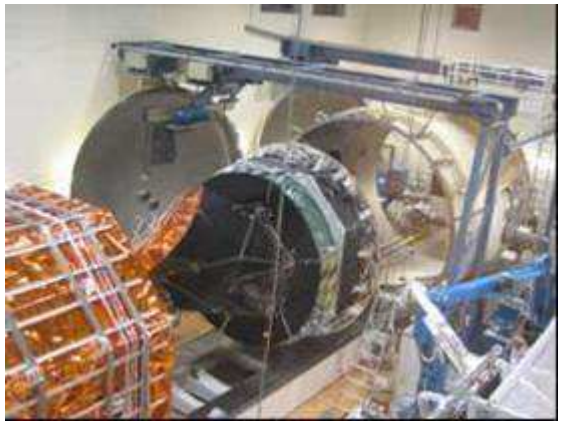
COROT Baffle & Cover (2006)



Second Core Business

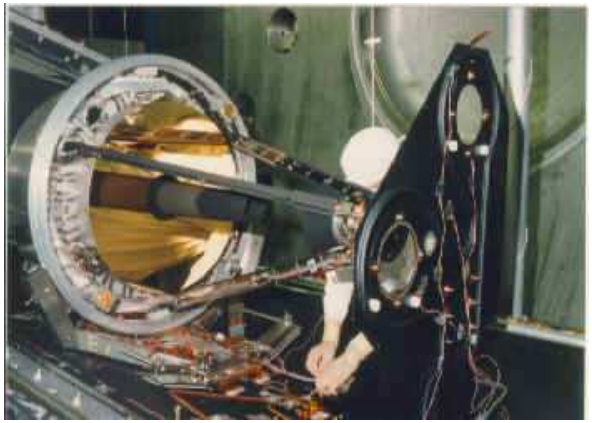
- Space environmental testing
  - ✓ validation of space H/W for qualification before flight model manufacturing or for acceptance before flight
  - ✓ optical performances measurements and optical calibration
  - ✓ from instrument to spacecraft
  - ✓ mechanical tests
  - ✓ thermal - vacuum tests
  - ✓ Low temperature laboratory : tests and measurements
    at 4.2 to 1173 [K] (-269 to 900 [°C])
    on hardware from samples to Spacecraft
  - ✓ irradiation tests
  - ✓ all test services covered by Product Assurance/Quality Assurance system (certification ISO9001:2008 / ESA ECSS-Q-20-07A)

Some Tests

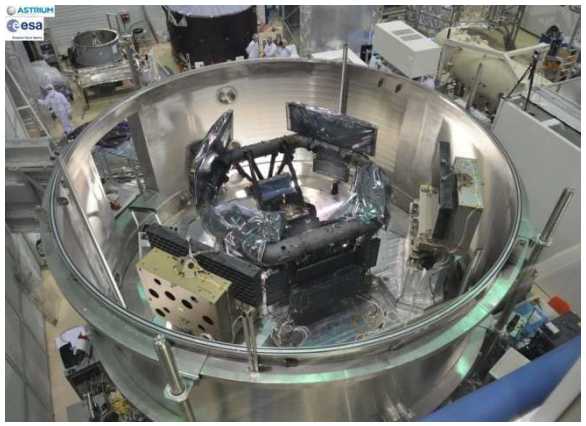


Planck S/C – 0.1 [K]

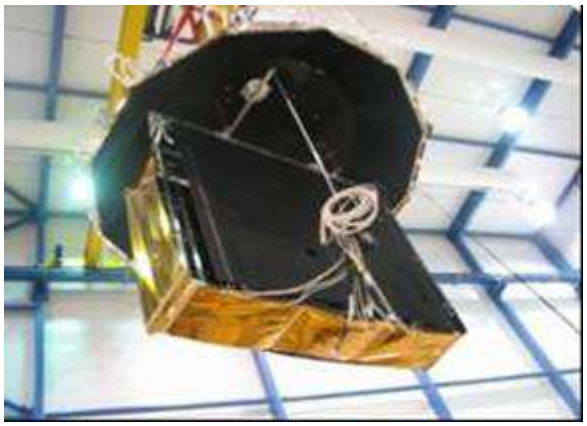
JWST TMA COL – 12 [K]



ISO Telescope – 10 [K]



GAIA PLM – 110 [K]

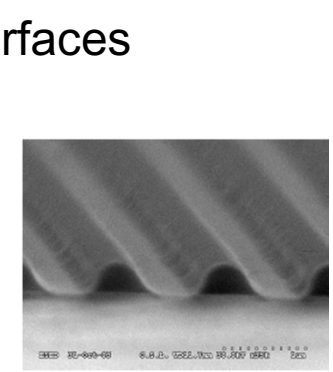


ASTRA Solar arrays – 70 [K]

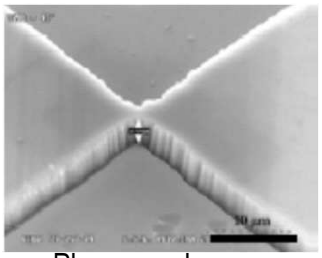
Herschel Telescope – 60 [K]

Other Business

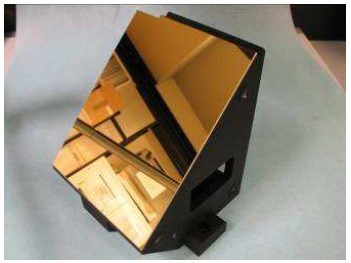
- Research and Development, Technology transfer
  - ✓ coatings and advanced surfaces
  - ✓ micro-fabrication
  - ✓ solar energy
    - o solar concentration
    - o solar simulation
  - ✓ smart sensors
- Fusion Energy Research
- Processing of Synthetic Aperture Radar images (SAR)



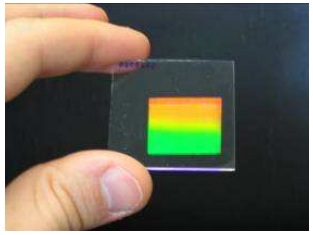
Holographic recording of diffraction gratings



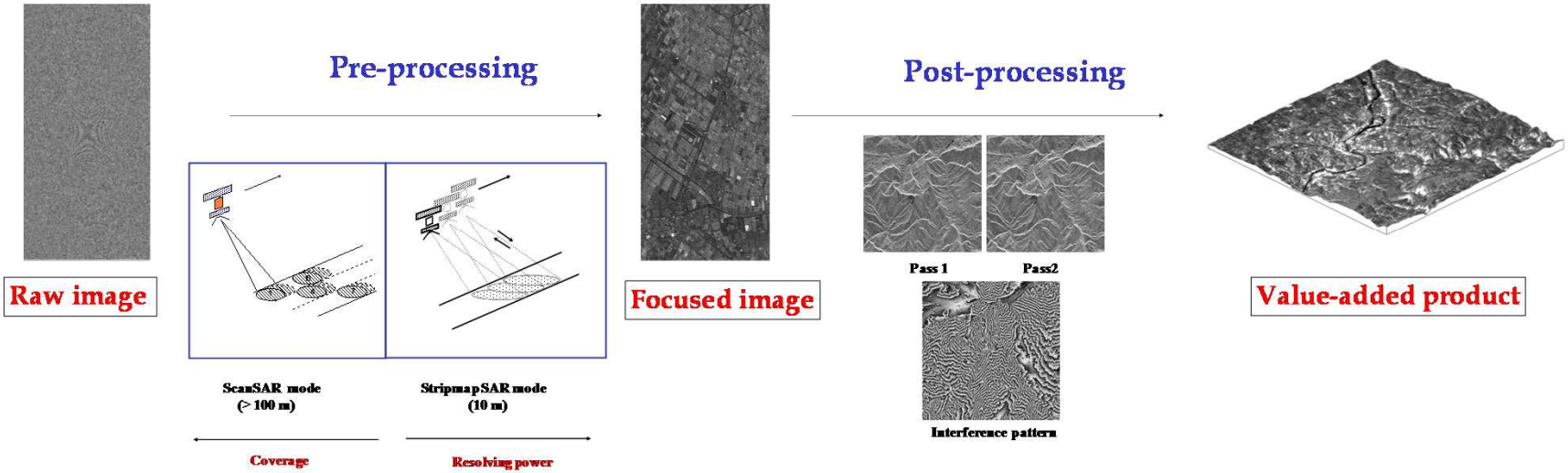
Phase mask (ZnSe dry etching)



MIRI (JWST) mirrors



Reactive Plasma Beam Etching

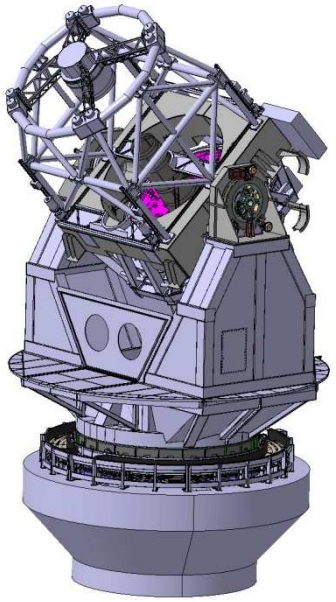


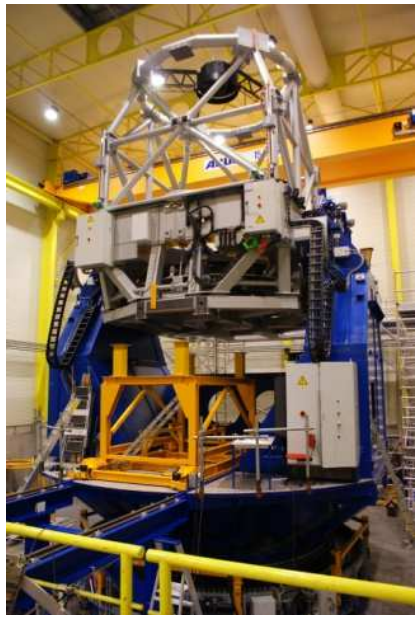
Partnership

- ATELIERS DE LA MEUSE (16th century, ALM since 1872)
  - manufacturing of vacuum chambers
  - manufacturing of mechanical systems
  - manufacturing of nuclear waste containers
  - large capabilities : turning up to 9.5 [m], milling up to 15 [m]
  - delivery of thermal vacuum testing facilities
    - 9 [m] diam. space simulation chamber (Kazakhstan)
    - 6 [m] diameter space simulation chamber (India)
    - 11 [m] * 7 [m] * 6.5 [m] cryostat for JT-60SA TF coils test (CEA - France)

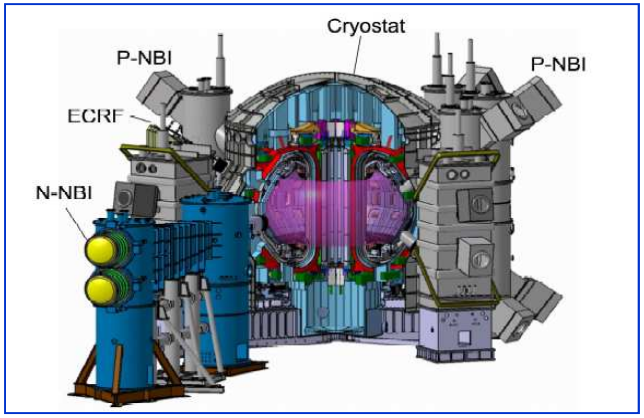
Partnership

- AMOS (since 1983)
  - System Engineering for complex optomechanical projects
  - building vacuum - mechanical - optical ground systems
  - on board optomechanical equipment
  - turn key telescopes medium size Ø 1.8 [m] (ATS - Cerro Paranal - Chile) to large size Ø 3.6 [m] (ARIES - Nainital - India)
  - mechanical design
  - mechatronic design
  - optical design





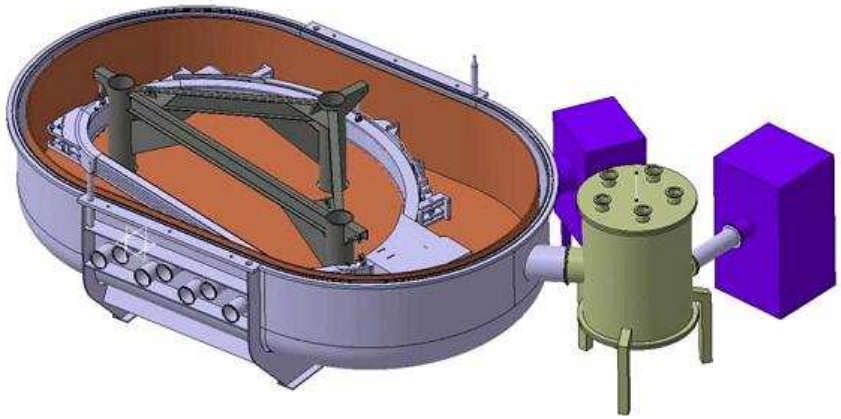
JT-60SA

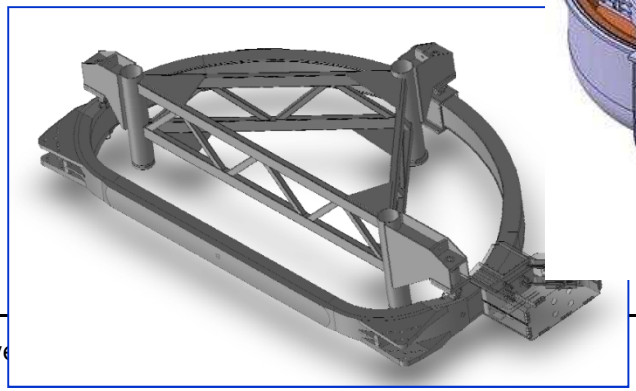


- Broader Approach
  - ✓ JT-60SA : JAEA tokamak upgraded to superconducting
  - ✓ Compensation to Japan for ITER location in France
  - ✓ In-kind participations of the EU countries
  - ✓ Within other contributions, 18 Superconducting toroidal field magnets provided by EU (9 by Italy, 9 by France)
  - ✓ Need to test all these magnets at operating conditions before delivery
  - ✓ Test Cryostat developed by Belgium and France
  - ✓ vacuum vessel, vacuum system, coils test support, and thermal liquid nitrogen shields by ALM and CSL (B)
  - ✓ cryogenic system, electrical and safety system, test performance by CEA Saclay (F)

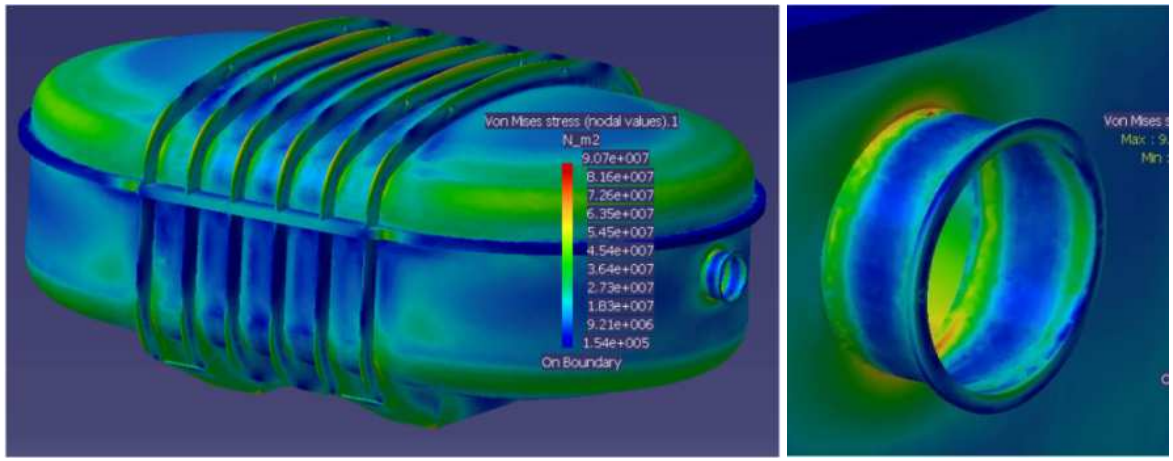
- TF coils requirements
  - ✓ Operating conditions for the magnets :
    - vacuum
    - thermal load minimised by liquid nitrogen shielding
    - nominal current 25.7 [kA]
    - nominal temperature 5 [K],
      tested up to around 7.5 [K] before quench

  - ✓ Mechanical configuration
    - TF coils about 8.4 [m] long, 4.5 [m] wide and 0.7 [m] high, 18 [t] weight
    - TF coils installed horizontally, hanging on a test adaptor
    - isostatic mount with thermal decoupling
    - with electrical and helium connections
      on one side

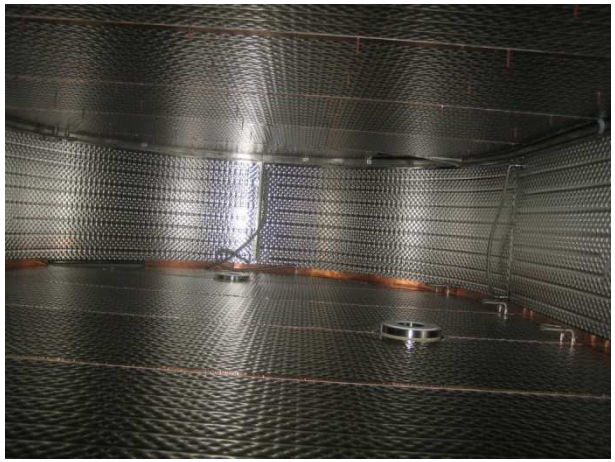




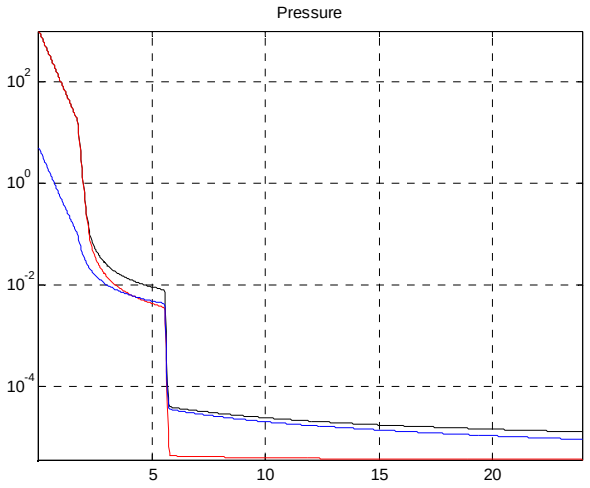
- Cryostat Mechanical design
  - ✓ main vacuum chamber (11 [m] long, 7.2 [m] wide, 6.5 [m] high)
    - with horizontal flange for full opening
    - with interface for TF coil test adaptor and thermal shields
  - ✓ auxiliary vacuum chamber (Valve box, 2.2 [m] diameter, 2.5 [m] high)
    - hosting the valves, circulators, heat exchangers, electrical feeders
    - with interface to helium refrigerator and current leads
  - ✓ full FEM model (SAMCEF) for deformation and stress evaluation
    - due to atmospheric pressure and weight



- Cryostat Thermal design
  - ✓ radiation shields covering the vacuum vessel
  - ✓ electro-polished embossed stainless steel panels
  - ✓ isostatic mount with thermal decoupling
  - ✓ thermal decoupling to TF coil
  - ✓ LN2 intercept for coil adaptor at vessel interface



- Cryostat Vacuum design
  - ✓ large volume 400 [m^3]
  - ✓ primary vacuum to be reached in several hours
  - ✓ secondary vacuum by oil diffusion pump (withstanding high magnetic fields)
  - ✓ computations with CSL software
  - ✓ 2000 [$m^3\ h^{-1}$] rotary and 6000 [$l\ s^{-1}$] diffusion pumps

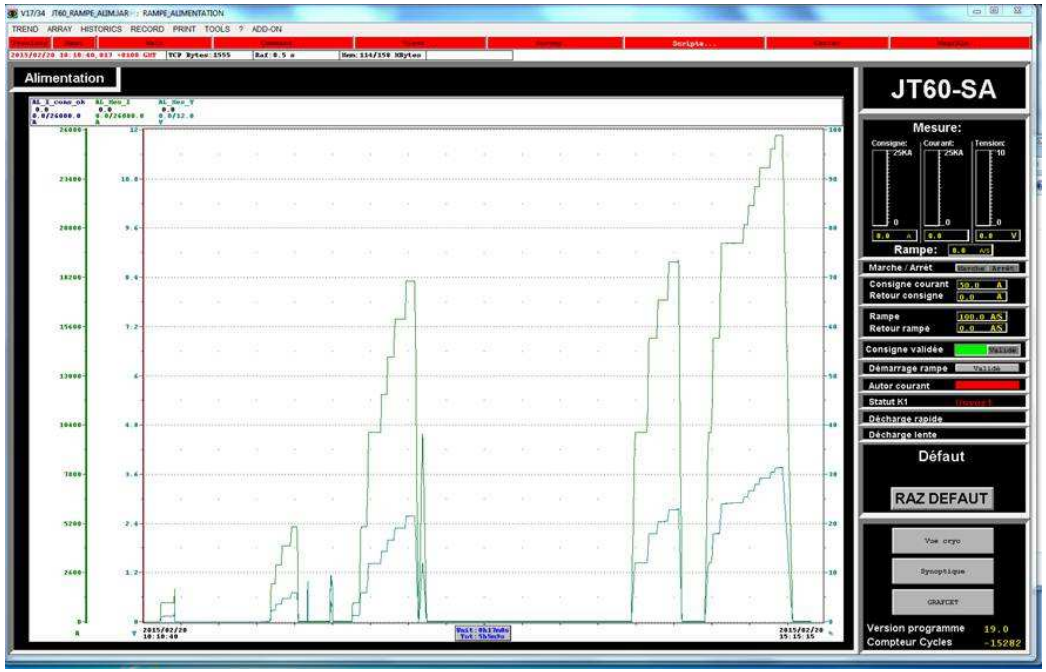


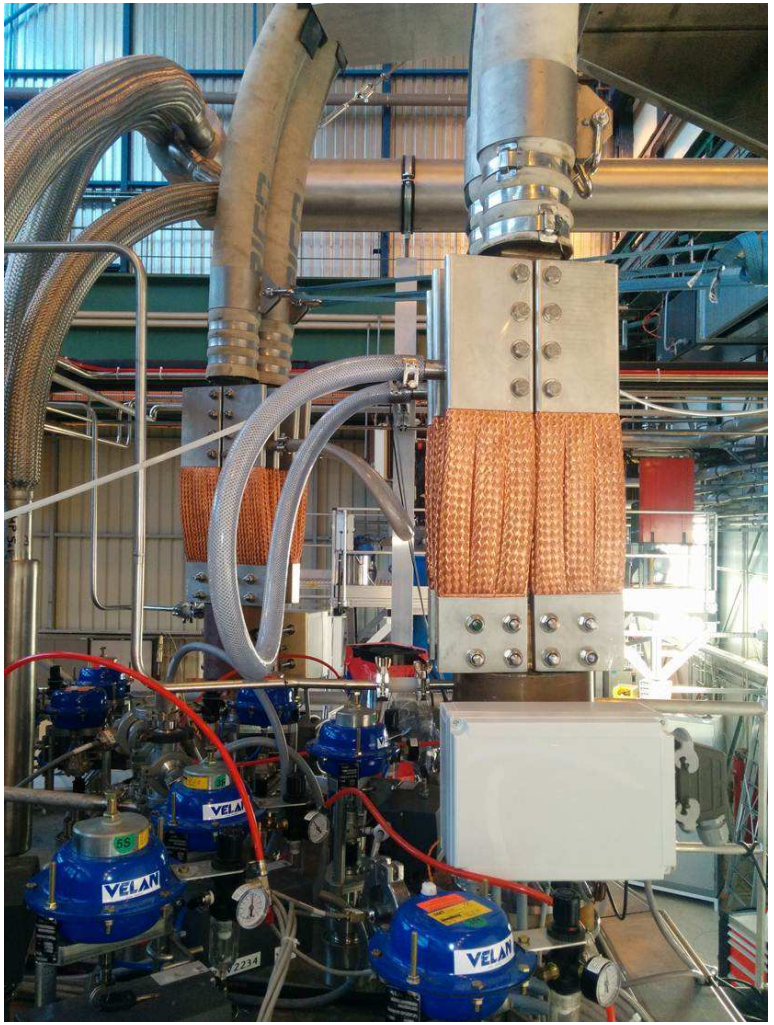
JT-60SA

- Cryostat Manufacturing
  - ✓ Large parts :
    - 60 [t] assembled cryostat
    - approximate volume 400 [m^3]
  - ✓ All main parts machined at ALM :
    - main vacuum vessel
    - main vacuum vessel cover
    - valve box
    - valve box cover
  - ✓ Assembly of vessel, thermal shields, TF coils test adaptor and vacuum system done at ALM

- Cryostat Test
  - ✓ Vacuum test :
    - for main vessel and valve box
    - integrity under atmospheric pressure load
    - evacuation time / ultimate pressure
    - Helium leak tests, global leak rate test (< 10^{-2} [mb l s^{-1}])
    - Helium pressure test of thermal shields up to 5 [barg]
  - ✓ Ambient tests :
    - opening - closing of cover (25 [t] part)
    - installation of TF coil test frame on its isostatic mount
    - magnetic material verification
- Cryostat Integrated in CEA-Saclay

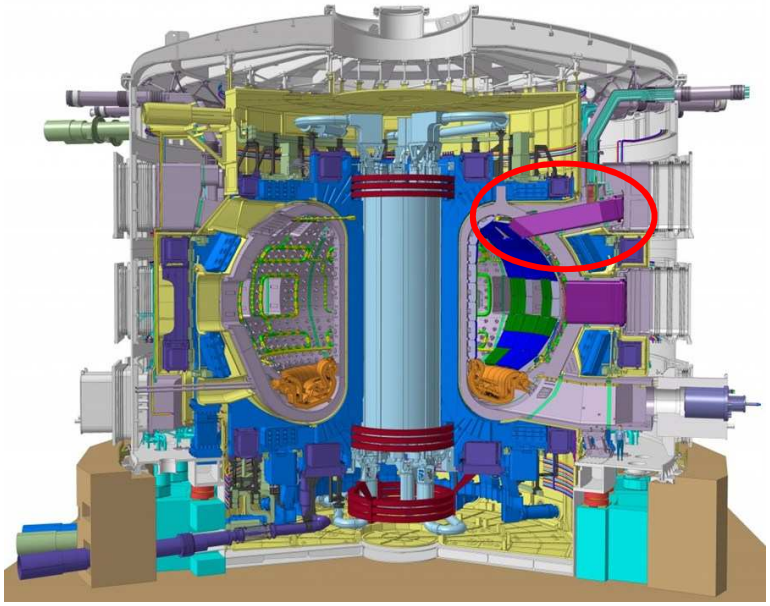
- Breaking news in CEA-Saclay
  - Nominal current reached last week
  - 25.7 [kA] with cryogenic shunt

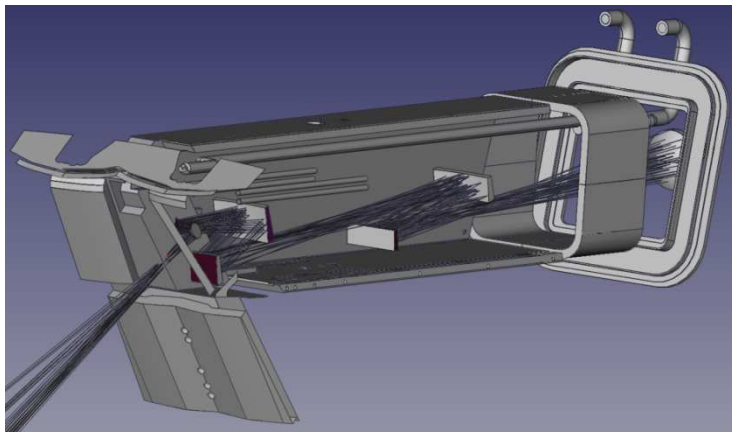


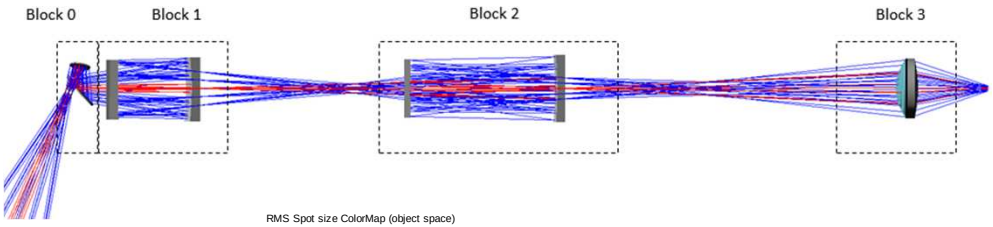


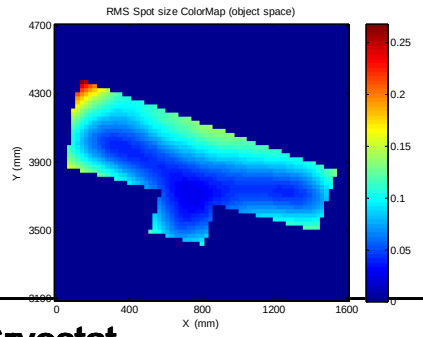
ITER CXRS

- ITER Endoscope CXRS
  - ✓ Plasma monitoring
  - ✓ For ITER real time control
  - ✓ Sub-contract for Jülich
  - ✓ Optical system optimisation









Conclusion

- ✓ Development of large scientific instruments by ALM / AMOS / CSL
  - an old story
  - Tools and skills available and shared, mainly :
    - manufacturing / mechanics / nuclear / energy at ALM
    - mechanics / mechatronics / optics / applied at AMOS
    - space science / optics / thermal / cryogenics / vacuum at CSL
- ✓ Commonalities from Space science to Fusion research large
  - Requirements similar
  - Technical challenges and solutions
  - PA/QA, IF management, partnership and work sharing with large consortia
- ✓ Quality, Reliability and Flexibility are drivers for us
  - very important for scientific development

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