CSL BIENNIAL REPORT 2010 - 2011

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Université de Liège

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FOREWORD

T. Chantraine
General Manager

For CSL, the two former years were definitely transitional.
On the external side, CSL faces a profound mutation of its environment. Space exploration is not any more a reserved area for the lone scientists. Access to space became a strategic goal for the emerging nations and a commercial playground for big aerospace companies. Orders providers have changed and the role of the space agencies considerably evolved.
Remember. In the 90's, the European Space Agency was directly coordinating the design and the integration of satellites and payloads. Today, those works are globally contracted to the industry. In the same kind of logic, this is an industrial joint-venture which operates the historical ESTEC Test Centre since 2000. The participating companies are both CSL competitors.
Like it or not, space is now a market, still surrounded by several guides of geographical redistribution, but more and more led by profit, competition and risk reduction. CSL has to consider this situation very seriously, and it will.

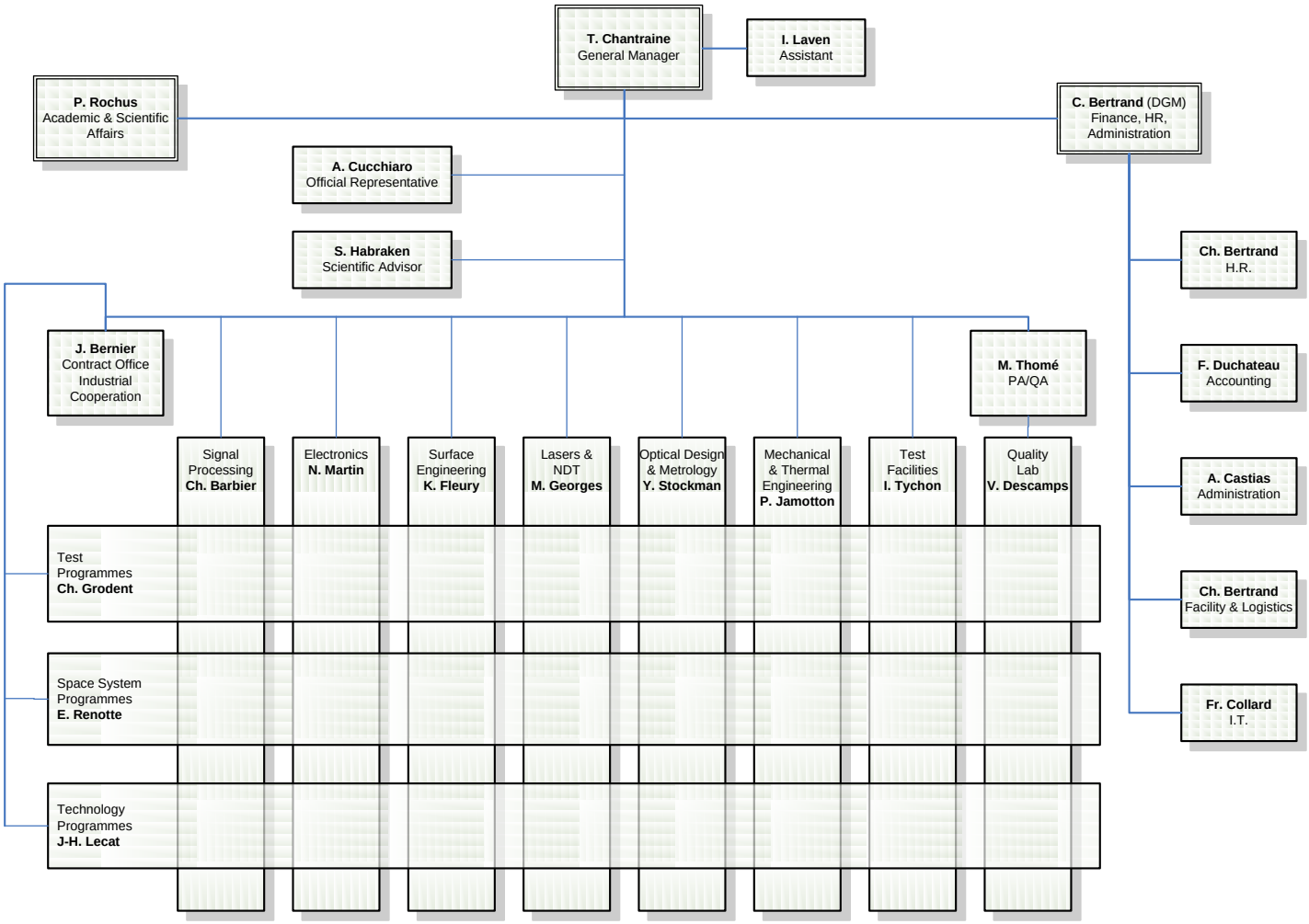
Internally, this biennial was quite turbulent too. During this period, CSL proceeded to a strong reengineering under the University supervision authority. The management processes and the global strategy were scrutinized through this work, which end up with the definition of a brand new organization headed by a straight vision:

- *CSL is a high level Research Center of the University of Liege devoted to applied research and managed as a "profit center".*
- *CSL performs Research Technology Development & Innovation (RTDI) activities mainly related to space.*
- *CSL commits to be a significant actor of the regional economical development.*
- *CSL nourishes a state of the art research related to space sciences within the University of Liege.*

This statement clearly beacons CSL missions on a route linking deep science to space system development and technology swarming (through applications, expertise and high level training for instance).
The inner matrix organization designed to support this activity also aims to yield a dual objective:

1. to provide a better visibility of the technological excellence areas of CSL and to clarify responsibilities as well as points of contact throughout the organization.

2. to reinforce and to improve our marketing activity.



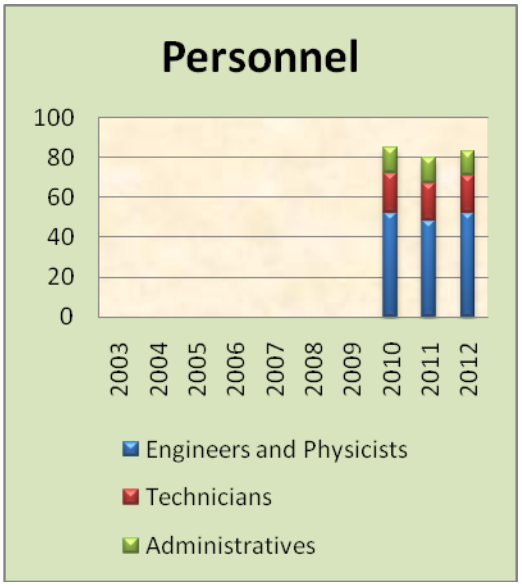
Note that this organization includes a specific academic and scientific director. This marks our strong anchorage to the Liege University and shows our willingness to keep a high level of scientific excellence using the enormous competence reservoir of the institution.

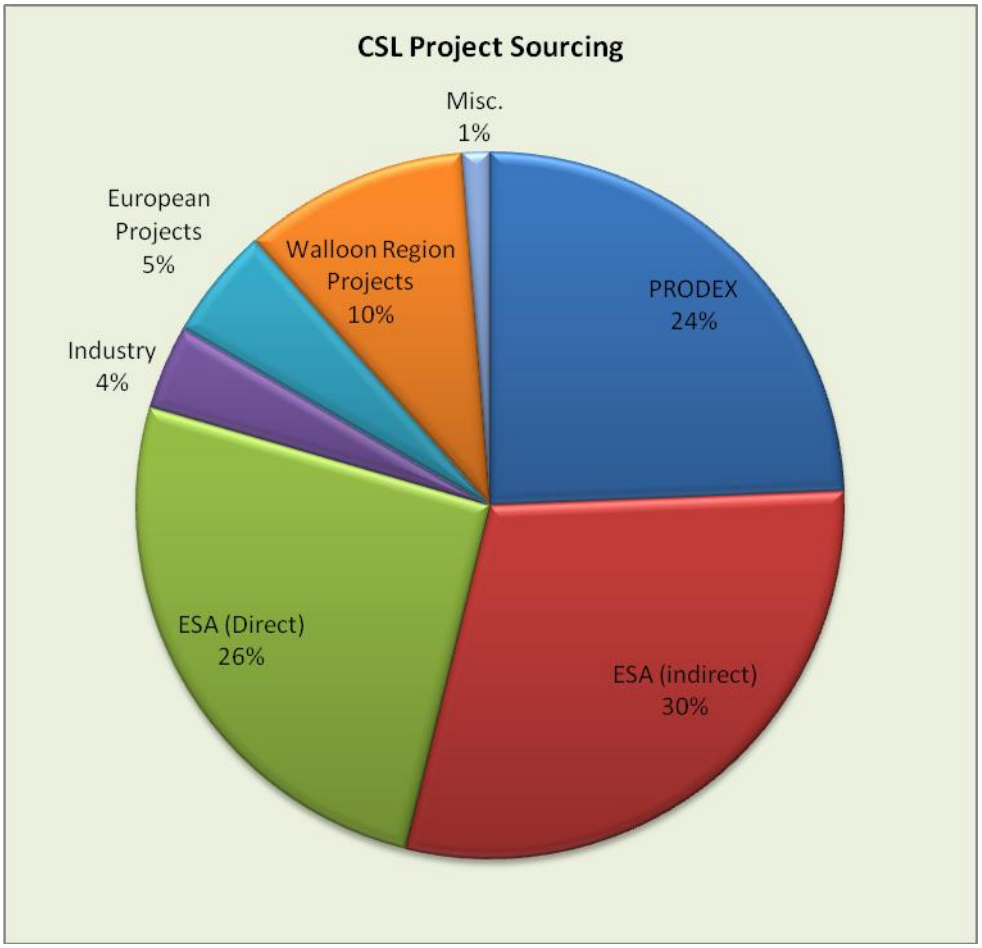
You will find many traces of this excellence all along those pages as CSL carried out complex and innovative projects within the 2010-2011 period. Those works allowed CSL to maintain an international reputation and to join prestigious consortium preparing the future of the space exploration. From that prospective, the announcement in October 2011 of the Solar Orbiter selection for the M1 slot of the ESA Cosmic Vision program was a major event for us.

Solar Orbiter is an extremely challenging mission crafted to stare closely at the sun. In this project, CSL owns the PIship of the Extreme Ultra-Violet Imager (EUI) and participates to the design and integration of the HI instrument. With this program, CSL consolidates a leading position in scientific system development and secures a substantial workload for the five coming years.
This success combined to the dynamic we expect from the new organization allows us to get a real ambition of growth. This report will show you that this ambition stands on robust foundations.

Thierry Chantraine

CSL in a FEW FIGURES




CSL Project Sourcing
Misc.
1%
European
Projects
5%
Walloon Region
Projects
10%
PRODEX
24%
Industry
4%
ESA (Direct)
26%
ESA (indirect)
30%

LABORATORIES

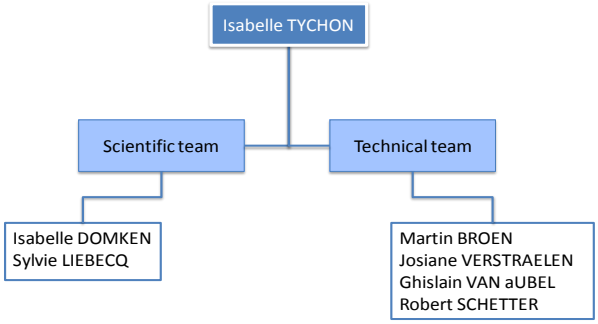
1. Tests Facilities Laboratory *(Resp. I.Tychon)*

6 vacuum chambers from 0.25m to 6.5m diameter, capable of extended vacuum and thermal cycling, equipped with optical bench laying on seismic device (vibration decoupling).

Vibration shakers (5 – 3000Hz , 80 -200KN)
Possibility of cryovibrations.

The team

The team consists in 7 persons who are presented in the following organization chart.



The CSL performs various qualifications on space instruments or equipments by submitting them to environmental space conditions.

The two main types of test campaigns are :

- thermal vacuum qualification,
- vibration qualification.

A specific facility has also been developed at CSL to allow a mixed full validation : vibration under vacuum at cryogenic temperature. This facility is called 'Cryovibration Test Facility'.
Generally, when thermal vacuum conditions (hot or cold cases) are imposed on an optical instrument, optical stimuli are simultaneously injected in order to validate the global optical performance in space conditions.
Some specific instruments require a cryogenic environment (4.2K – 20K). This can be achieved with cryogenic techniques involving liquid Helium.
The key specific CSL competencies in the test laboratory are : thermal and vibration control, cryogeny and optics.

Thermal Vacuum campaigns

CSL performs various qualification thermal vacuum test campaigns using its own thermal vacuum chambers with associated thermal systems.
Gaseous nitrogen (GN2) is generally used to feed thermal panels with an automatically adjusted temperature in the [-150°C, +100°C] range. For specific colder temperatures, liquid nitrogen (LN2) is also used.

Three types of campaigns are generally proposed:

- Bake-out and outgassing tests: a controllable warm up is imposed in a specimen during a specified period under vacuum to evaporate contaminants and to obtain a perfectly clean instrument. Any contamination risk must be indeed eliminated to avoid any optical performance degradation.
- Thermal cycles : this kind of test simulates the "in-orbit" extreme conditions with a succession of cold and hot temperatures. The instrument under test should survive to non-operating temperatures while performance should comply within the operating temperature range.
- Thermal balance tests : Specific radiative / conductive thermal conditions are imposed on the test specimen to simulate a stable environment as it will be seen in orbit during the operational phases. Artificial thermal gradients can be introduced in the instrument and the subsequent performance degradation is measured. Additionally the measured temperature cartography is compared with the corresponding thermal predictions.

All the parameters (pressure, temperature, LN2 level) are monitored and recorded during the test campaigns. All these key data can also be analyzed in real time via a dedicated secure web connection.
The CSL chambers are all equipped with a perfectly stable optical bench, fully decoupled from external parasitic vibration perturbations. All benches are connected to massive seismic blocks. Microvibration levels can be measured in real-time with specific seismic accelerometers.
For specific test campaigns of space instruments working in the millimeter or sub-millimeter wavelength range, a cryogenic environment is mandatory to reduce the own radiation of the tested instrument itself.
Two Helium liquefiers / refrigerators can dispatch the cold fluid to obtain environmental temperatures below 20K (4.2K for liquid Helium bath).

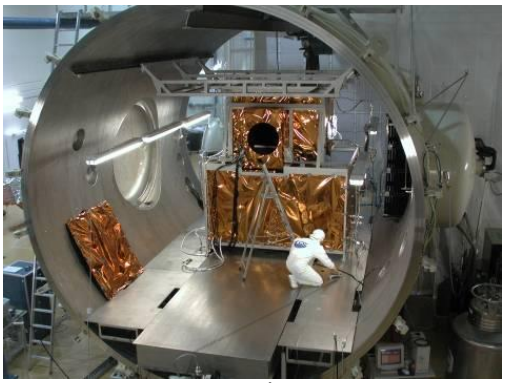
Finally, a global test campaign must always be conducted in a perfectly clean environment from the preparation phase to the final packing. This is managed by the cleanliness control section. The assembly and integration are realized in one of the two CSL clean rooms (ISO 7 as a baseline and ISO 5 cleanliness upon request).
The level of cleanliness is permanently controlled via dedicated equipments like particle contamination samples (PFO), molecular contamination samples (FTIR), Airborne Particle Counter, etc….Under vacuum, the level of contaminants is monitored in real time via RGA (Residual Gas Analyzer) or TQCM (Temperature Quartz Controlled Microbalance) while a LN2 cold panel (cold trap) is permanently activated.

CSL vacuum chambers and cryovibration facility


Focal 1.5


Focal 2


Focal 3


Focal 5


Focal 6.5


Cryovibration chamber connected to the shaker

CSL Helium Liquefiers / Refrigerators

KOCH 1630 Helium Liquefier/Refrigerator


LINDE TCF20 Helium Liquefier/Refrigerator

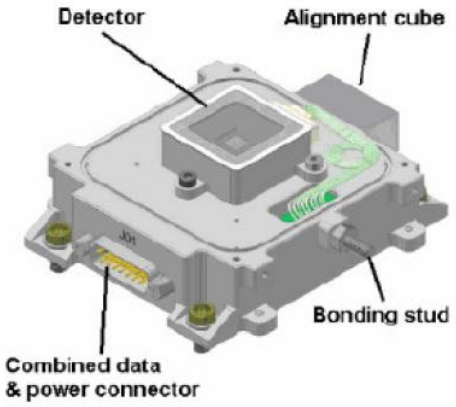
Works performed during the period 2010-2011

Focal 1.5 chamber

Several small thermal tests have been performed in the chamber Focal 1.5 in 2010-2011 among which :

Solar Orbiter Sun Sensor (ESA)

The goal of the project is to select, adapt and qualify the sun sensor for the Solar Orbiter platform. CSL will demonstrate that it will be operational under the extreme environmental conditions due to the close proximity of the satellite with the Sun (0,25 AU).
The extreme solar flux encountered during the mission lifetime required to develop sophisticated thermal protections for the complete satellite, such as front heat shield, thermal baffles and cooling radiators. The sun sensor is a crucial element for ensuring the pointing of the platform which is essential for the overall thermal control of the mission. This project is run for ESA with the Lambda-X company as prime. CSL is involved in the thermal aspect and the qualification of the system.



TNO-TPD sensor

The modified Sun Sensor from TNO has been tested in Focal 1.5 under 13 solar constants.

Solar Orbiter EUI
(started in 2006)

See a more detailed presentation on page 39

The aim of the tests in Focal 1.5 performed in 2011 concerned the thermo optical characterization of the entrance filters.

<u>List of Vacuum tests in Focal 1.5 – 2010/2011</u>

CLS Blank tests
- June to September 2010
- Customer : ESA

Sunsensor
- October to November 2010
- Customer : CSL (end customer: ESA)

VINCI Valve
- September 2011
- Customer : Techspace Aero

Solar Orbiter filters
- November to December 2011
- Customer : CSL (end customer: ESA)

Focal 2 chamber

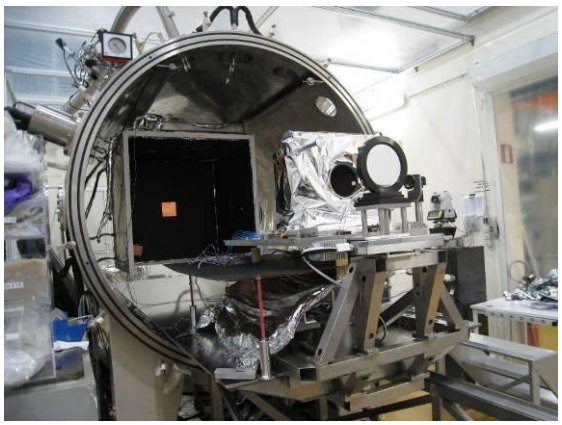
The main activities in the 2010-2011 period of time are related to the optical validation of the TanDEM X_TLA.

TanDEM-X_TLA

A blank test campaign for the Tandem-X telescope has been performed in March 2010. The purpose was to measure its optical performance via interferometric method at various operating temperature.

The Telescope Assembly (TLA) is a small telescope used as the optical antenna of an optical terminal. It can be used for transmission and for reception.
It has been asked to CSL to perform the thermal cycling test of the TLA (QM and FM model) and to measure its optical performances under vacuum for different thermal cases.

TLA overview



Set up integration in the chamber

<u>List of Vacuum tests in Focal 2 – 2010/2011</u>

TANDEM-X Blank test
- March 10
- Customer: RUAG Switzerland

TANDEM-X _TLA QM
- October 10
- Customer: RUAG Switzerland

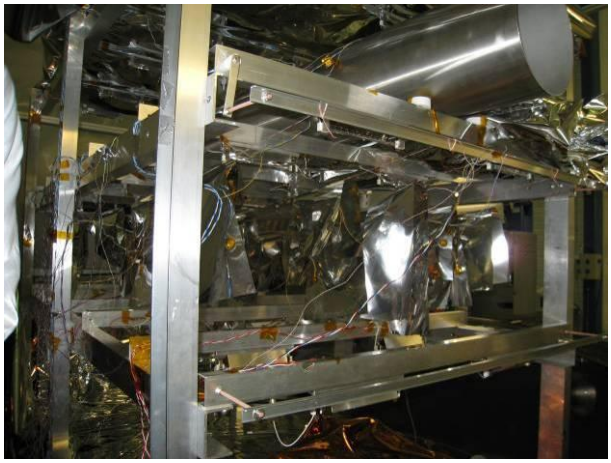
TANDEM-X _TLA_FM
- November 10
- Customer: RUAG Switzerland

Focal 3 chamber

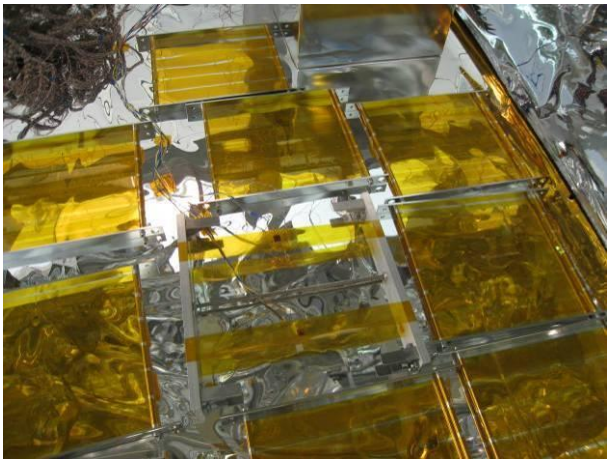
2010

ALADIN-Bakeout tests on permacell, MLI, STRO, tedlar for EADS Astrium SAS
February – June 2010

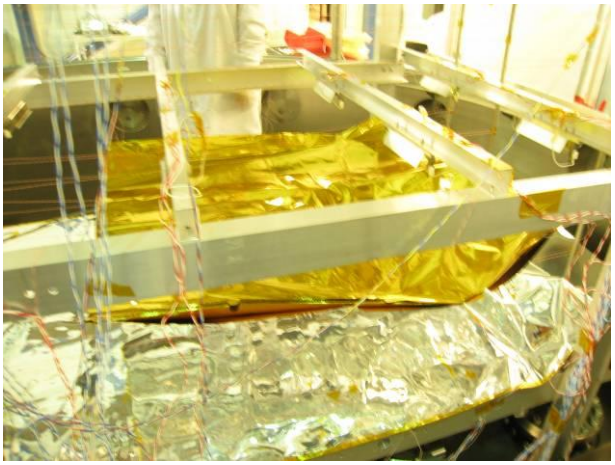
Aladin is an instrument containing a UV high fluence laser
The laser beam when crossing outgassing product can produce Laser Induced Contamination (LIC) on the optics, especially in vacuum.
The materials identified from the beginning (from literature) as being the most dangerous for the LIC problem are the silicone and the aromatics. A test campaign on materials behavior with respect to LIC has been conducted by ESA to identify those not to be used. It has shown that a large number of materials cause LIC at 355nm
The telescope is the last part of Aladin where the emitting path of the UV laser is crossing optical parts under vacuum.
Some individual parts have already been baked (MLI, structure) but not all of them and the telescope integration has added some other material which outgassed. It is why in order to reduce as far as possible, the amount of outgassing material in the vicinity of the M2 and the TRO window, it has been agreed to perform a bake out at telescope level.



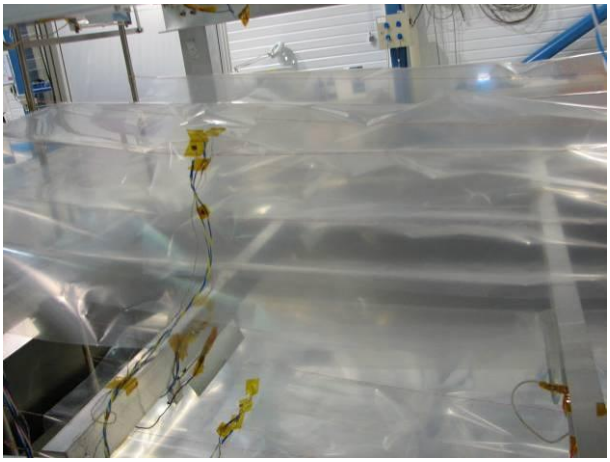
Metalic parts bakeout



Permacel bakeout



Kapton bakeout



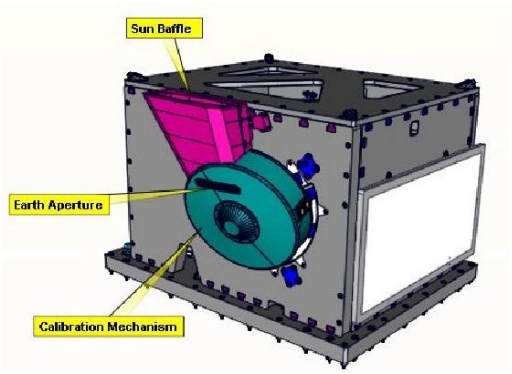
Tedlar bakeout

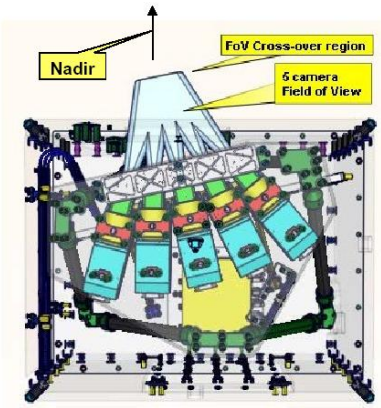
OLCI-Wheel bakeout tests & cycling on calibration wheel FM For Thales
September 2010 – November 2010

Within the Sentinel 3 components, there is a multi-spectral optical imager for Ocean and Land Colour operational applications (with equivalent ENVISAT MERIS baseline performance), named OLCI (Ocean and Land Colour Imager).

The OLCI instrument embarks a Calibration Assembly, made of a positioning mechanism and the appropriate reference diffusers which is the purpose of the current project. The overall OLCI is composed of the structure equipped with the units necessary for all functions and with the thermal hardware. All optical elements are supported on a stable flat panel (optical bench). Other equipments are distributed on the other panels. Five identical cameras point to the Earth, Eastwards and Westwards from the sub-satellite point. The Calibration Mechanism is mounted on the Instrument Earth side.
In this project, CSL is responsible for the design, manufacturing, verification, calibration and delivery of the Calibration Assembly that is composed of the Calibration Mechanism and the Calibration Hardware. This work is performed in collaboration with CSEM that acts as a sub-contractor of CSL.

The work of CSL is divided in two units: the calibration mechanism and the calibration hardware.



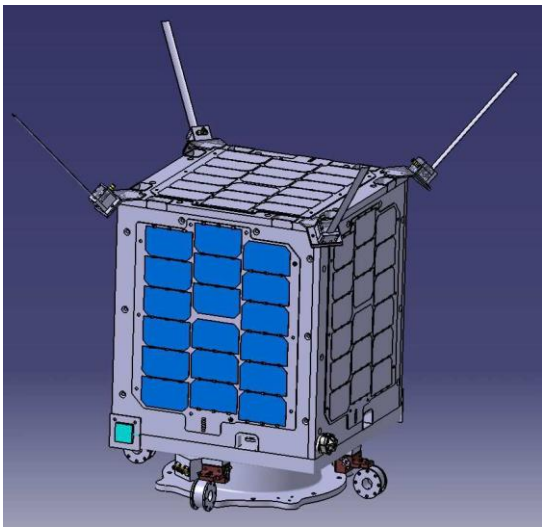


OLCI wheel bakeout

OLCI calibration wheel cycling test

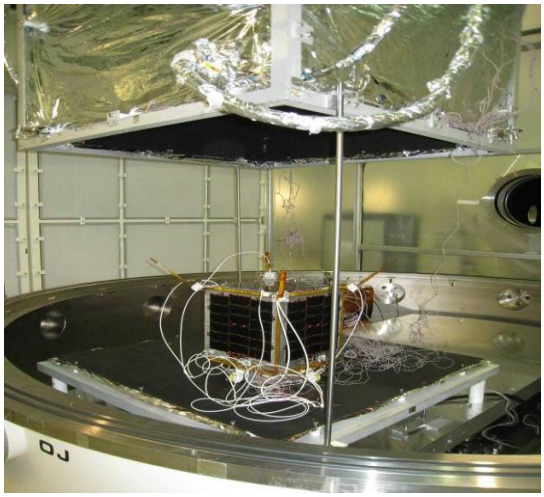
2011

AIS Gapfiller Vesselsat-1 for Luxspace
August 2011

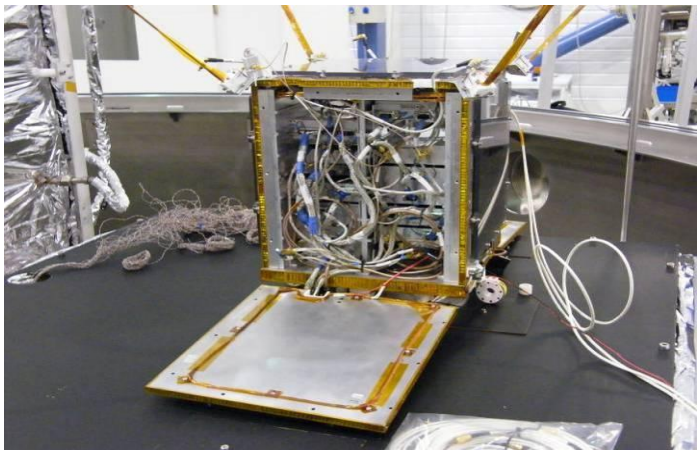


AIS, or the "Automatic Identification System" is a technology embarked on all vessels above 299 GRT, which is used as anti-collision system. Many coastal countries have established shore based receiving stations to monitor the vessel traffic. However, the reach of these stations is limited to more or less 100 nautical miles.
Satellite AIS is a new emerging technology that provides a cost effective solution for monitoring vessel traffic and the individual positions of ships around the world. Such vessel monitoring information is of particular interest to ship owners and port authorities but raises also expectations to be useful for supporting maritime policy and the creation of maritime awareness information.

Satellite AIS is considered as an add-on to the coastal stations that extends the vessel monitoring capability for safety and security aspects to a global scale for both the institutional and private sector.
The microsatellite has been cycled between 0 and +60 °C in August 2011



AIS Gapfiller Vesselsat in the cycling test configuration



Codechamps : bakeout of three encoders
October 2011

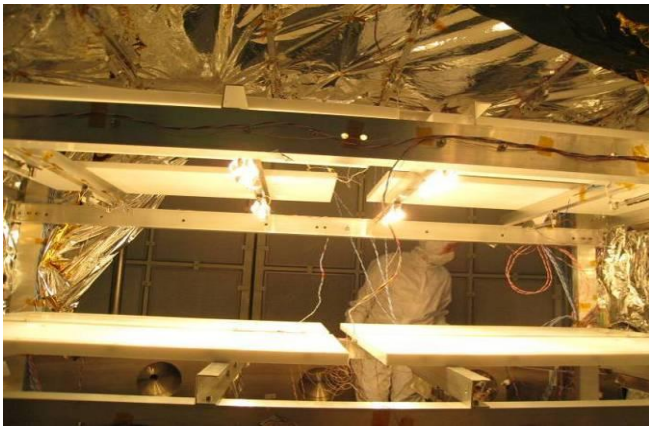
Bake-out of 3 encoders at +85 °C

MSI Diffuser (Multi Spectral Instrument) for CSL (end customer EADS ASTRIUM SAS)
October 2011

In the framework of the Global Monitoring for Environment and Security program (GMES), ESA develops Sentinel-2, a multispectral optical imaging system for Earth Remote Sensing with terrestrial applications providing continuity and enhancement to Landsat and SPOT type missions.

The diffuser is a sun-light diffuser used for absolute radiometric calibration of all spectral channels. The calibration is typically performed once a month when flying over the North Pole. During calibration phase, a mechanism deploys the diffuser in front of the instrument.
The sun diffuser covers the full field of view.

All the diffusers have been baked till 80 °C during 72 hours in a dedicated set up



MSI diffusers integration for bakeout

View of diffusers

<u>List of Vacuum tests in Focal 3 – 2010/2011</u>

Baking Aladin permacell, MLI, tedlar, STRO
- February – July 10
- Customer: CSL (end customer: Astrium)

OLCI – wheel bakeout
- September 10
- Customer: CSL (end customer: TAS-F)

OLCI calibration mechanism cycling
- November 10
- Customer: CSL (end customer: TAS-F)

Luxspace – AIS Gaspfiller -cycling
- Augustus 11
- Customer : Luxspace

CODECHAMP – Bakeout 3 encoders
- September-October 11
- Customer: Codechamp

GAIA RVS – blank test for cycling test
- October 11
- Customer : Astrium SAS(France)

MSI diffusers – Blank test & bakeout tests
- October 11
- Customer : CSL (end customer: Astrium)

Focal 5 chamber

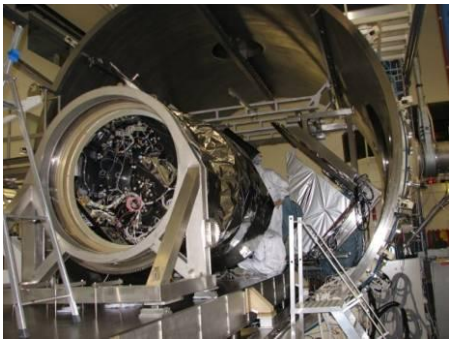
2010

ALADIN For EADS Astrium SAS
February - June 2010

In 2010, the activities in Focal 5 were principally based on the ALADIN project.
Four tests have occurred for the ALADIN: a blank test of the thermal tent, a blank test for the LIC test, a bakeout of the Aladin telescope and the LIC test, between January and July 2010.

The ALADIN Telescope has been installed inside the Focal 5 chamber and, once the vacuum is obtained, the high powered laser is activated by EADS and LIC measurements are performed on optical samples.
Various trials have been done to finally obtain an acceptable and compliant test set-up

Integration of the Telescope on Focal 5 bench (ISO5 cleanliness)



Preparation Phase

All the bake-out tests were permanently controlled with TQCM

All the suspected contaminants like metallic staples, Kapton scotch and glue, Aluminium parts, Kapton foils, Mechanical items not perfectly cleaned have been previously baked in the Focal 3 chamber before their integration in the ALADIN configuration.

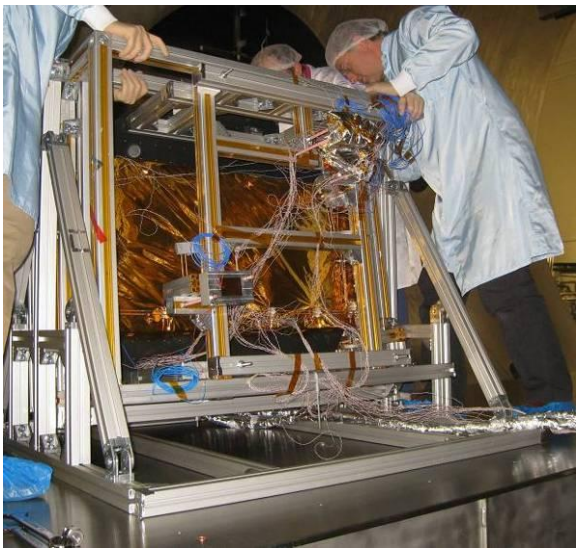
OME STRUCTURE SENTINEL 3 for Carbo FibreTec GmbH
November-December 2010

Additionally to the ALADIN activities, a bakeout test has been performed on the Sentinel 3 SLSTR OME structure, for the company CarbiFibertec GmbH

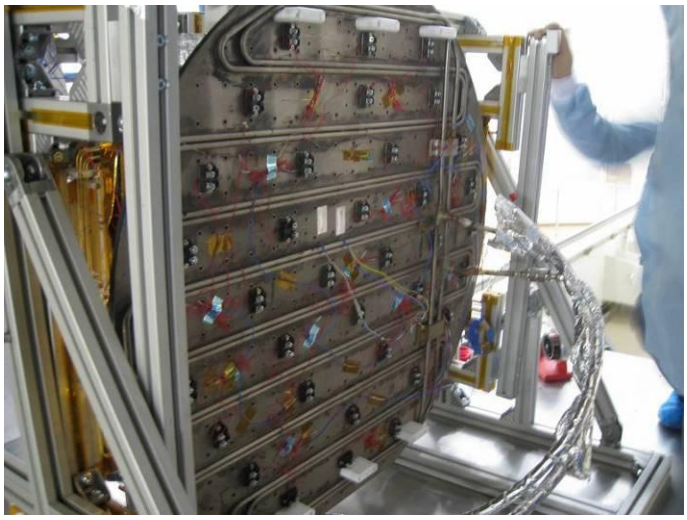
2011

EHP ENMAP for EHP (EuroheatPipes), Belgium –end customer Astrium SAS-France
February-March 2011

A cycling test on LHP (Loop Heat Pipes) of the satellite ENMAP instrument (Environment Mapping and Analysis Program).



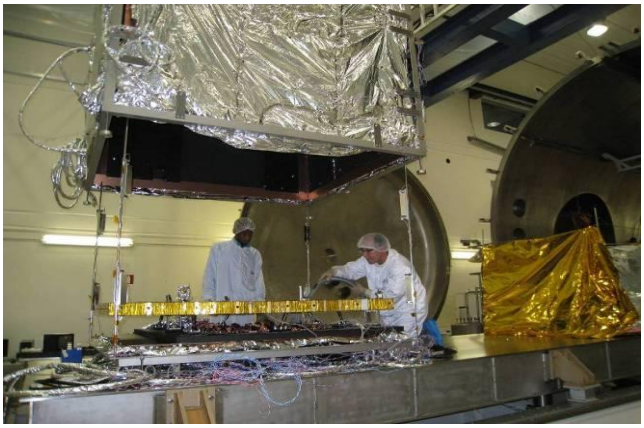
LHP integration in Focal 5



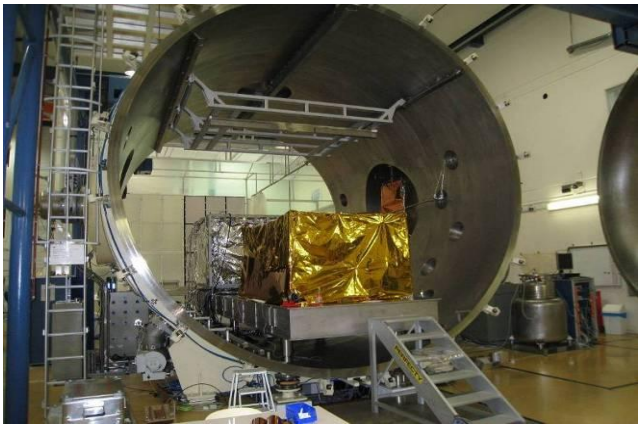
Rear face of the LHP

MSI STRUCTURE for APCO
June - September 2011

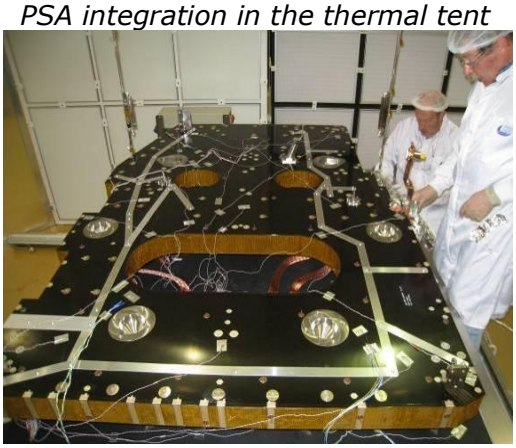
In the summer 2011, three tests have been performed on the MSI project, for the APCO company, a bakeout of the Heat sink, the MSI structure Blank test and the MSI PSA (Primary Structure Assembly) coupled with a bakeout of several test MLI.



PSA integration in the thermal tent



MLI bakeout set up



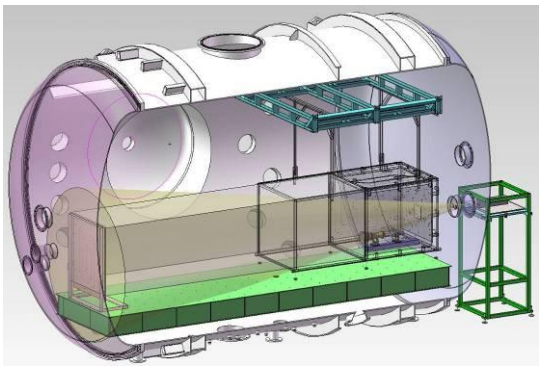
PSA overview

HOLODIR Thermal IR digital holography for non-contact surface metrology for ESA September-October 2011

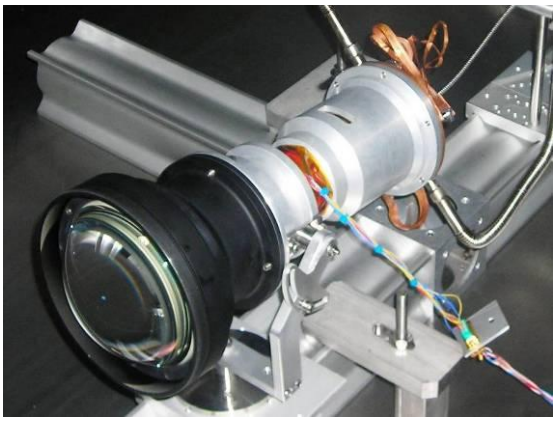
See a more detailed presentation on page 49.

TPV -Thermo-mechanical qualification of the Target Projector for Videogrammetry for ESA November-December 2011

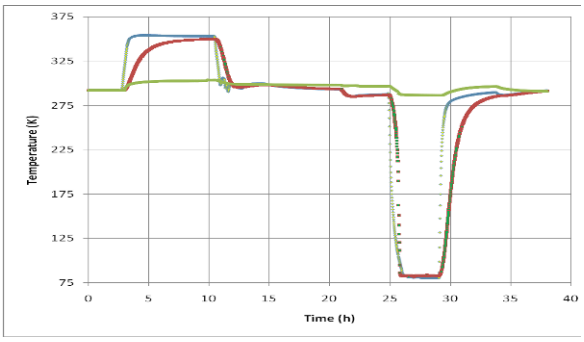
The thermo-mechanical qualification aimed to demonstrate the thermo-mechanical stability and design performance in the operating temperature range. The TPV system was tested in the thermal vacuum facility FOCAL5.The TPS was submitted to a varying temperature (hot and cold cycle) and viewing permanently an object at 5 m. As required by ESA the centroidisation was stable within 10 minute of recording and achieved a plane stability of better than 0.1 mm.



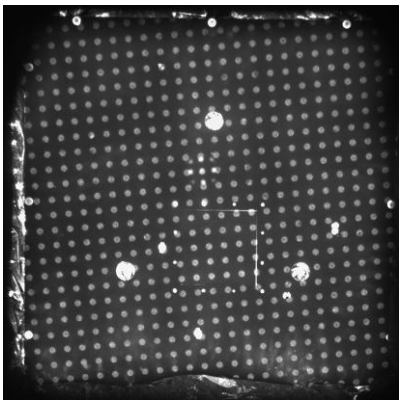
Isometric view of the thermal set up in FOCAL 5



Side view of the FFOV projector mounted on its X95 rail on the optical bench of Focal 5 (MLI not yet installed)



Shroud temperature of the SFOV projector head. Blue=>Front panel, Red=>Shroud around projector, Green=>Front lens temperature.



Dot pattern of the SFOV observed by the camera. The object is black coated radiative shroud. One notices some highly reflective areas which are due to the MLI. There are 3 apertures in the shroud covered with MLI. Some highly reflective points are due to screws. A strong loss of contrast is observed, due to reflections of the MLI tent on the shroud.

List of Vacuum tests in Focal 5 – 2010/2011

2010

ALADIN – BT Shroud
- January 2010
- Customer: EADS Astrium SAS

ALADIN – BT LIC test
- February 2010
- Customer: EADS Astrium SAS

ALADIN – Telescope bakeout
- March 2010
- Customer: EADS Astrium SAS

ALADIN – LIC test
- May-June 2010
- Customer: EADS Astrium SAS

Baking OME structure
- November-December 2010
- Customer: Carbo fibreTec, GmbH

2011

GAIA RVS – baking thermal tent
- January 2011
- Customer: EADS Astrium SAS

MSI – Structure Blank Test
- June 2011
- Customer: APCO, Switzerland

EHP EnMAP – Cycling test
- February-March 2011
- Customer: EHP Belgium (final customer : EADS Astrium SAS)

MSI – Heat sink bakeout
- June 2011
- Customer: APCO, Switzerland

MSI – PSA cycling and Bakeout MLI
- Augustus-September 2011
- Customer: APCO, Switzerland

Holodir
- September-October 2011
- Customer: ESA

TPV
- November-December 2011
- Customer: ESA

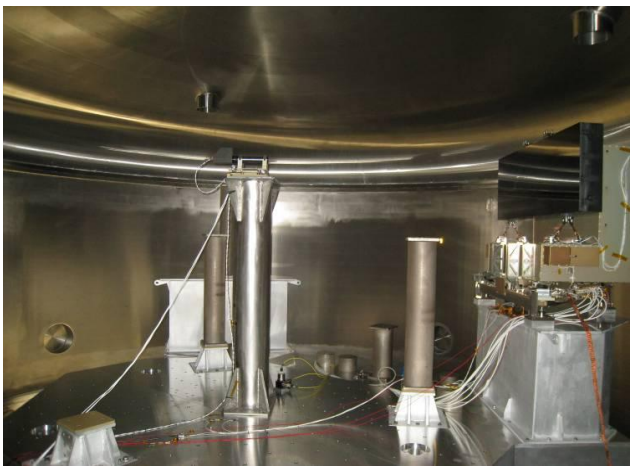
Focal 6.5 chamber

GAIA PLM- AC FLAT Stabilisation for EADS – Astrium SAS
June 2011

Another test for the GAIA programme was the stabilisation measurement under vacuum of the AC Flat (for the GAIA PLM configuration foreseen in the summer 2012).
The optical stability requirements of the GAIA PLM was so stringent that an additional bench, called TVIS (Thermal Vacuum Interface Structure) has been designed and manufactured under the CSL responsabilities, coupled with 3 isolator's with their own damping elements.
The GAIA AC Flat test campaign has been divided in two parts: the isolator's final acceptance test and the GAIA AC Flat vacuum test.

The goal of this GAIA test campaign was to :

- For Astrium :
  - Validate the simulation model
  - Find the different contributors in the perturbation environment
  - Validate the transport of one AC Flat fixed on its mechanism AFMA
  - Validate the AC Flat control loop in the configuration at CSL
- For CSL :
  - Validate the procedure for the isolators and the TVIS handling

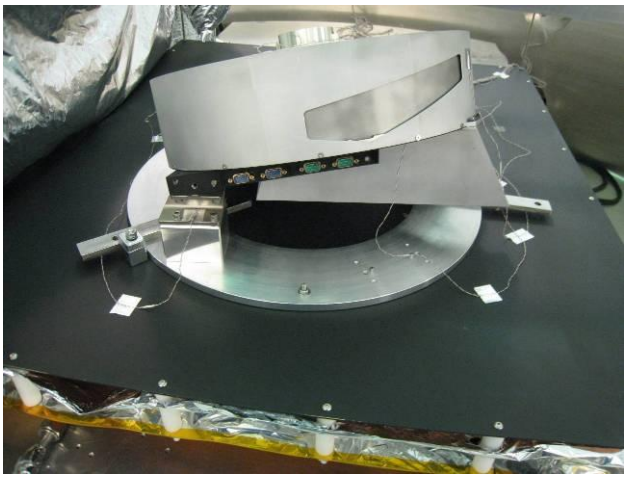

TVIS preparation with dummy masses and one AC Flat


GAIA AC FLAT integration

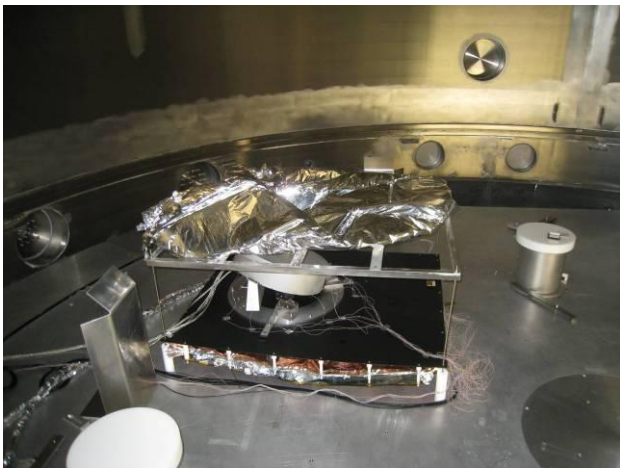
View of an isolator with its damping element

Compressed Isolator with seismic measurement system

Additionally to these GAIA campaigns (DSA and AC Flat), the Focal 6.5 was also used in 2011 to cycle the OLCI mechanism QM model and to perform a bakeout of the thermal tent dedicated to the cycling test on GAIA RVS.



OLCI mechanism preparation for cycling test



OLCI mechanism preparation for cycling test

<u>List of Vacuum tests in Focal 6.5 – 2010/2011</u>

GAIA DSA
- November-December 2011- Jan & March 2012
- Customer: Sener- Spain

GAIA PLM – AC FLAT stabilisation measurements
- June 2011
- Customer: EADS Astrium SAS

GAIA DSA pre and post vibration thermal test
- November 2012
- Customer: Sener – Spain

OLCI QM Mechanism- cycling test
- Augustus 2011
- Customer: Thales

GAIA RVS- thermal tent for cycling test bakeout
- October 2011
- Customer: EADS Astrium SAS

Vibration Facilities

The qualification vibration campaigns simulate the mechanical environmental constraints observed by an instrument during launch conditions. Simulating Sine, Random or Shock levels can be imposed on any structure with one of the two CSL shakers.

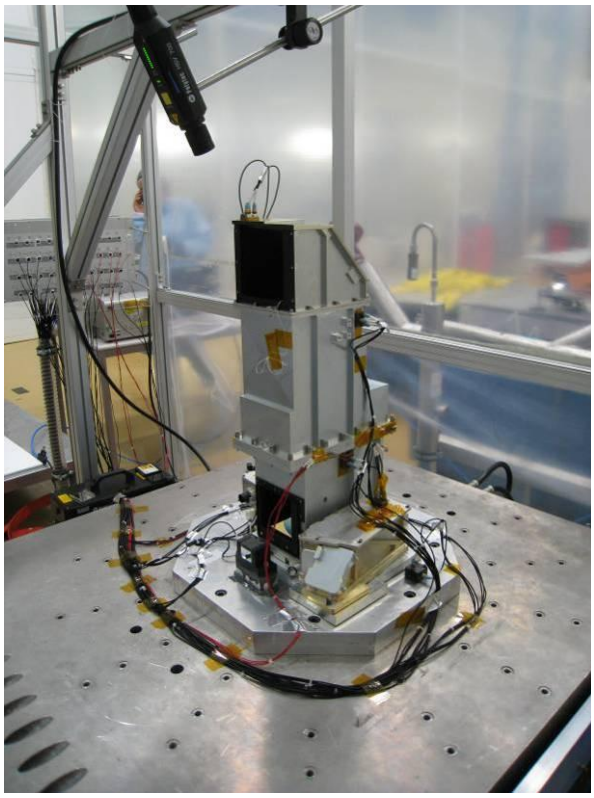
2016U 88kN CSL shaker

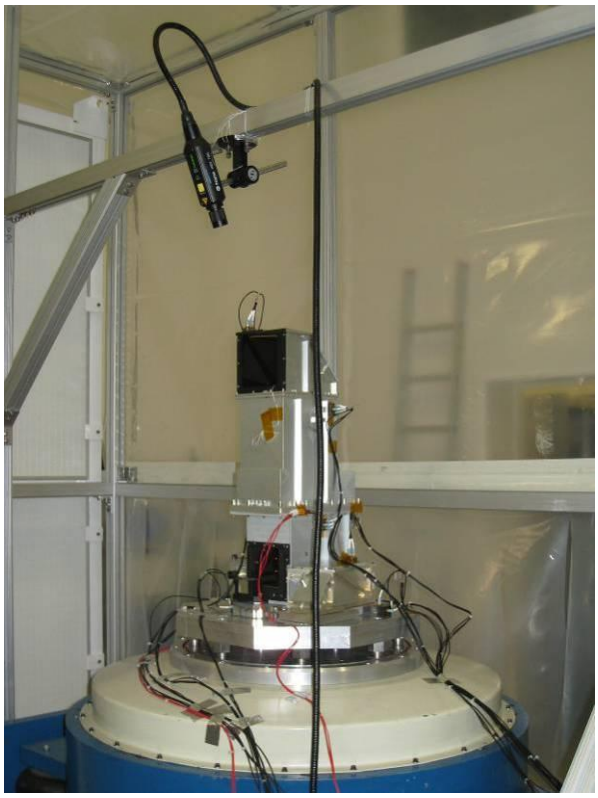
4522LX 200kN CSL shaker

2010 :

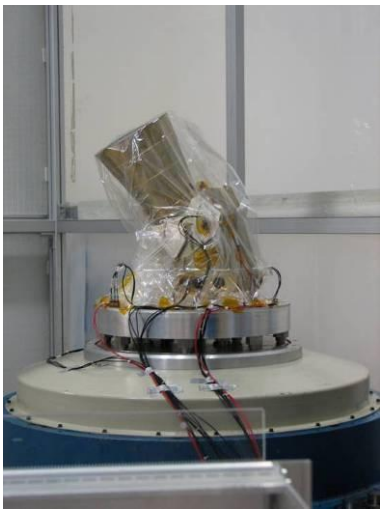
2016 U only

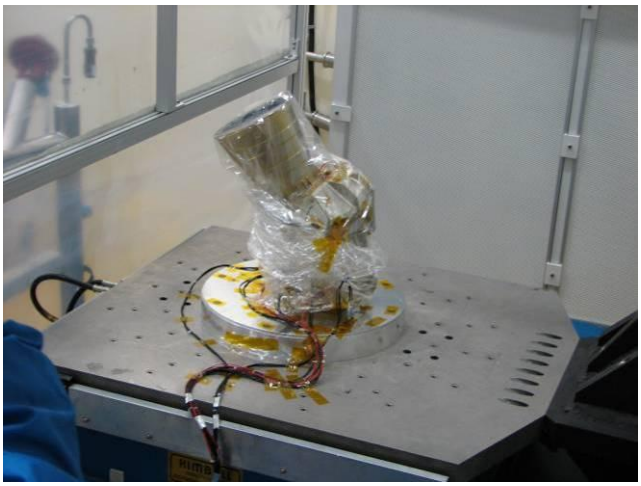
MIRI IOC For OIP - March 2010



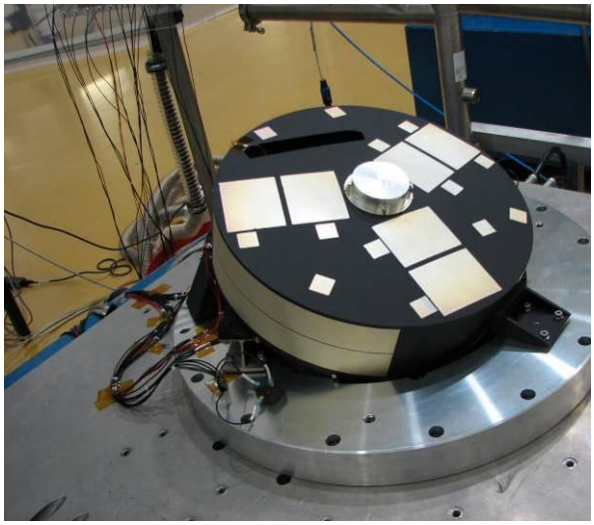


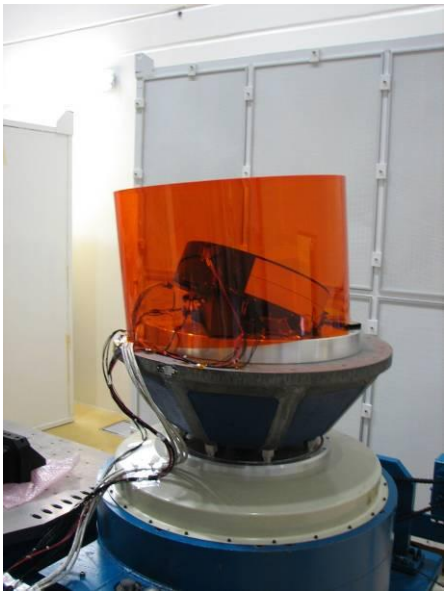
VISCAL for TNO October 2010





OLCI CA QM for CSL (end customer Thales) - December 2010 – June 2011

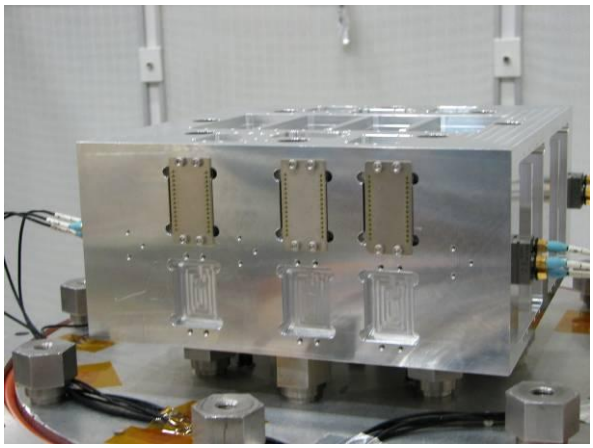


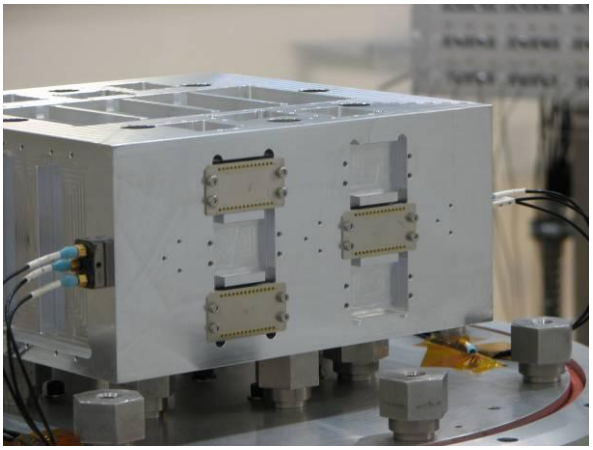


2011

2016 U

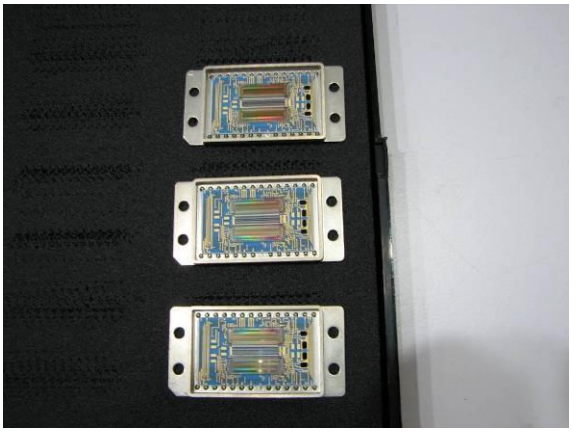
MSI_VNS Detectors for XENICS - April 2011

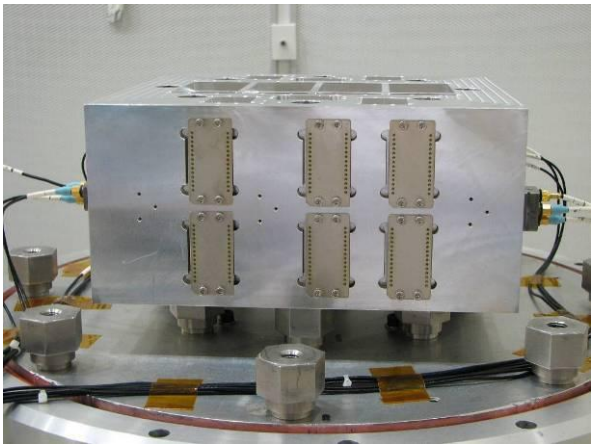




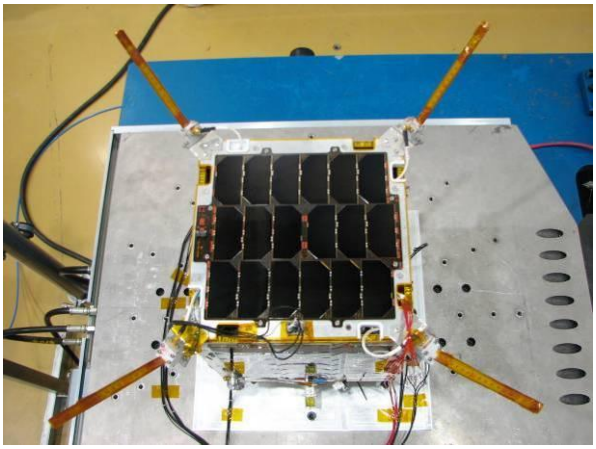
PROBA-V Detectors for XENICS - August 2011

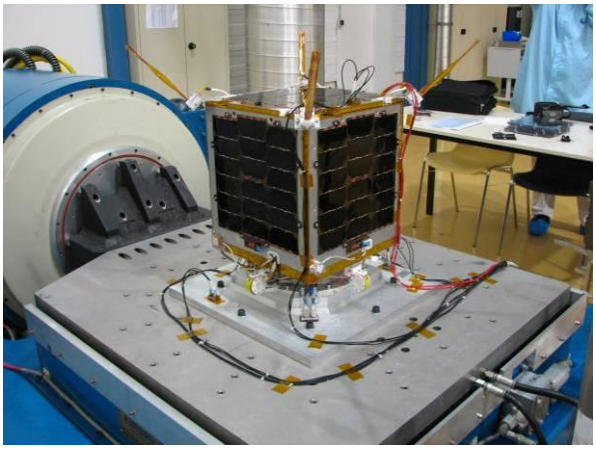
MSI SWIR2 and VISNIR Detectors for XENICS - October 2011

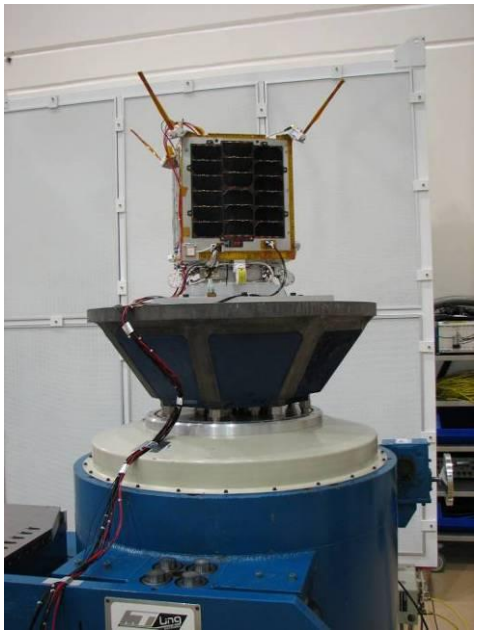




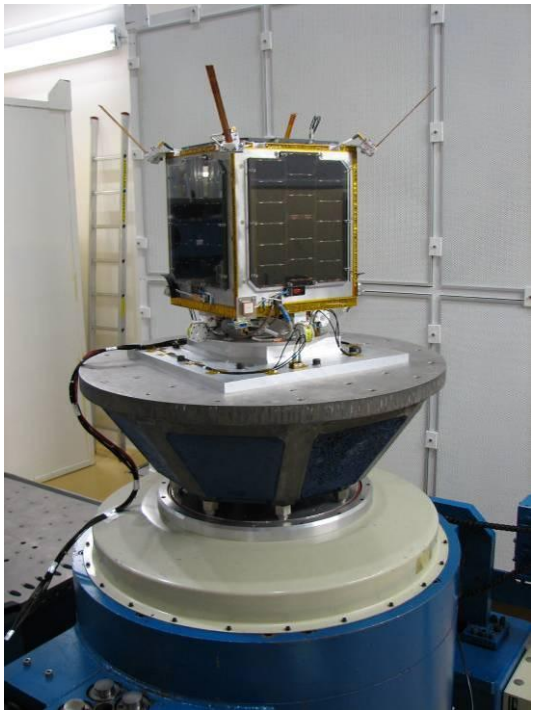
Vesselsat-1 for LUXSPACE - July 2011

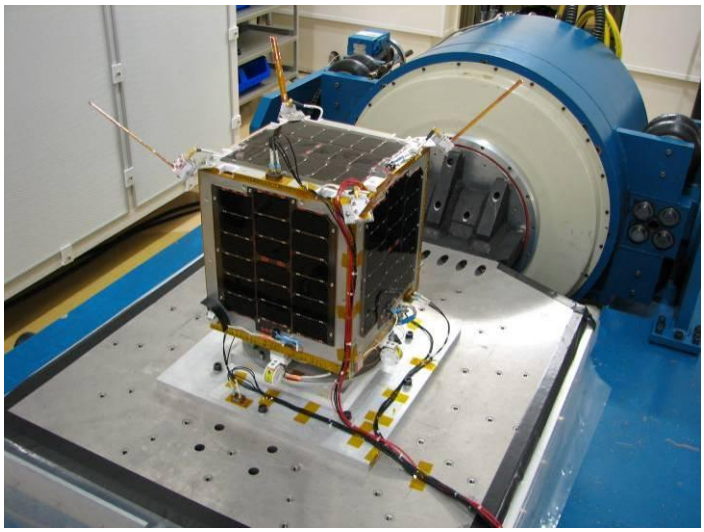




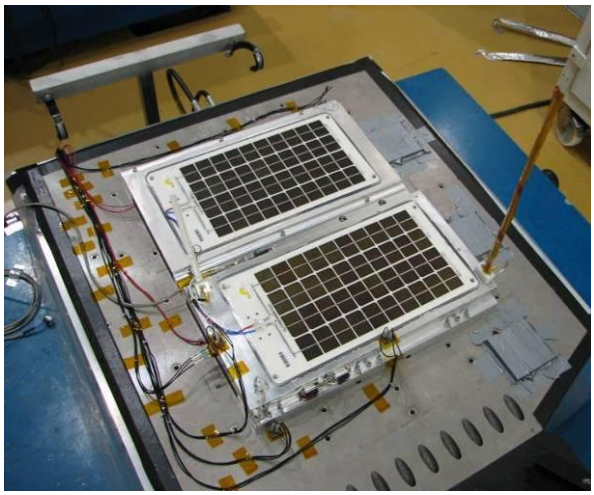


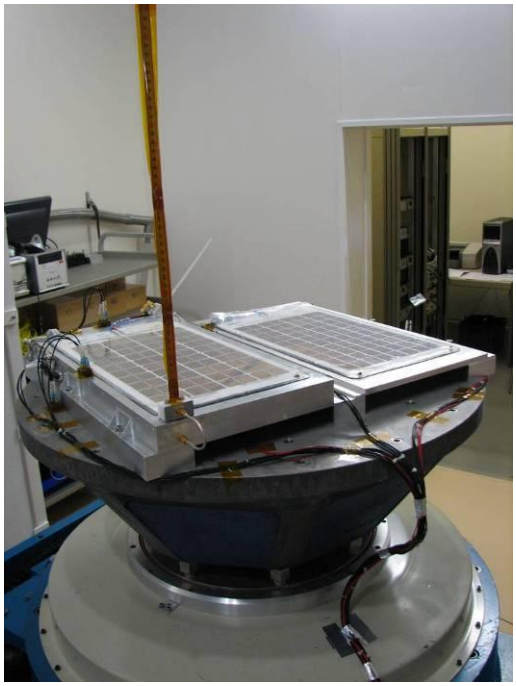
Vesselsat-2 for Luxspace - November 2011



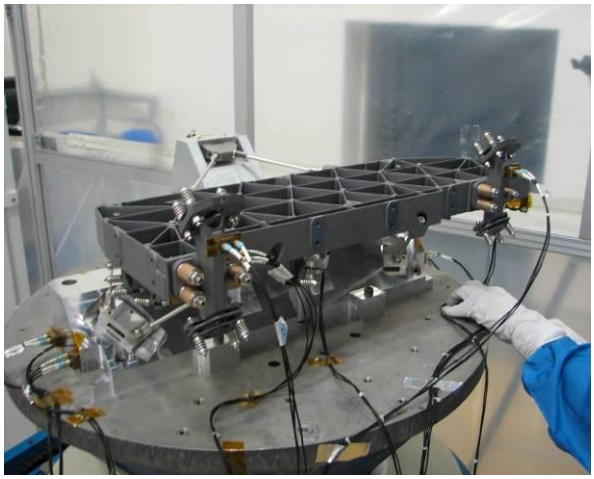


Pathfinder-3 for Luxspace - December 2011

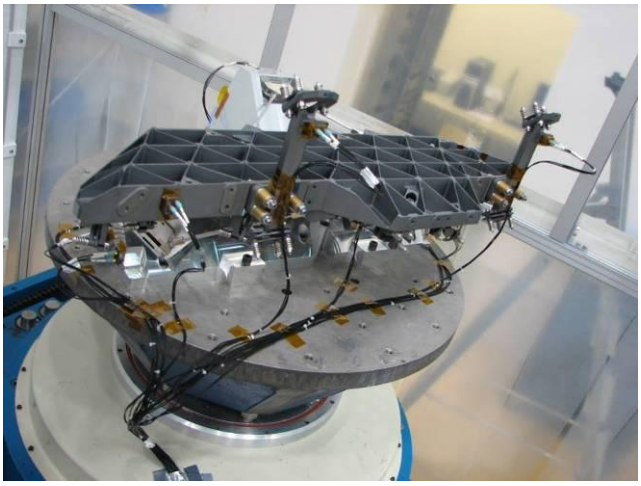




GAIA BAM OMA PFM Bar#1 and Bar#2 for TNO August 2011 – September 2011



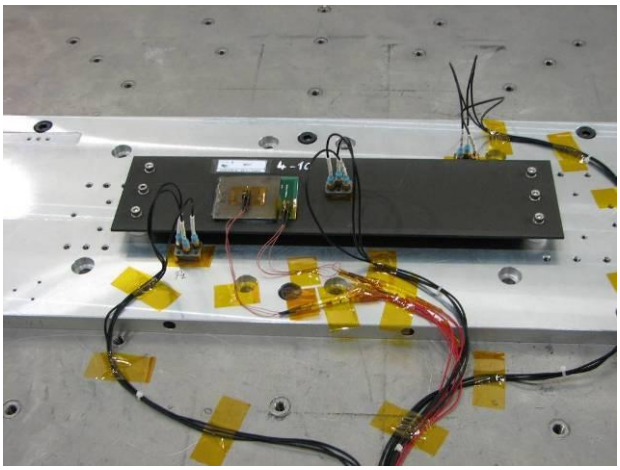
Bar #1



Bar #2

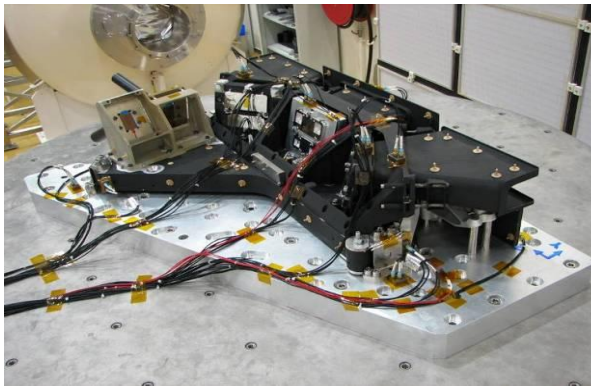
CENAERO : Triade
November 2011

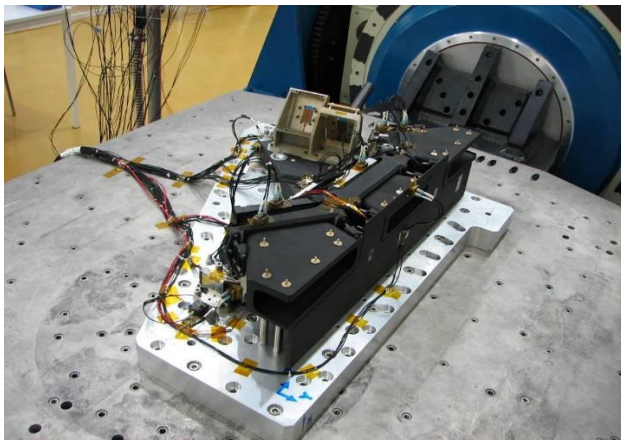
The aim of these tests is to check and measure the impact of the smart tag gluing on the structural integrity, under thermal and vibration aeronautic conditions, in order to validate and update the CENEARO simulation results.
The article to be tested is a dummy smart tag: (a structural model of the smart tag) glued on a structure sample.
Material is Prepreg UD; 8552 IM7 (Supplier HEXCEL); Approximative composition is: 60% CFC Fibre and 40% Epoxy Resin.



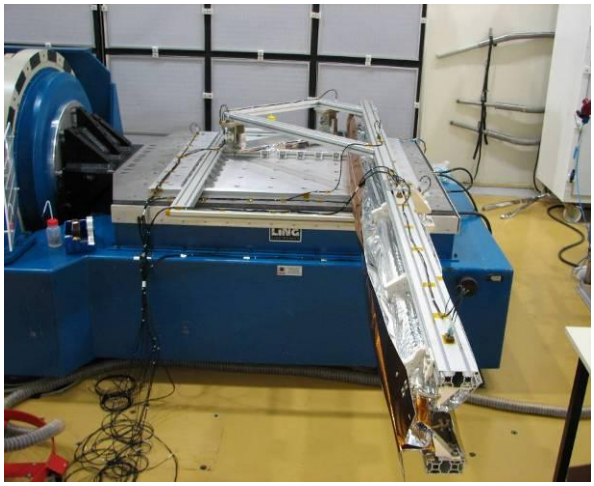
4522 LX

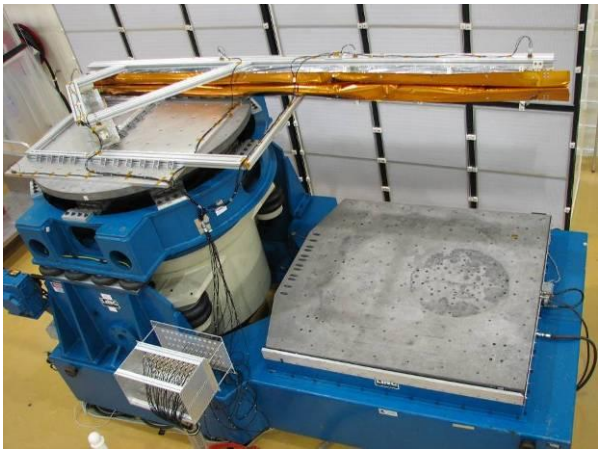
PROBA-V STM3 for OIP - October 2011





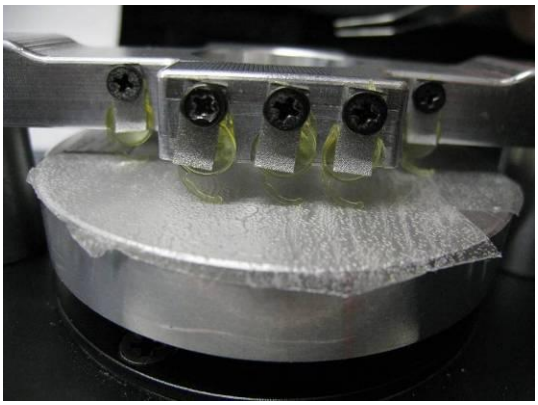
GAIA DSA for SENER - November 2011





Extra test

Physiol – Sirris : Fatigue test on intraocular lenses

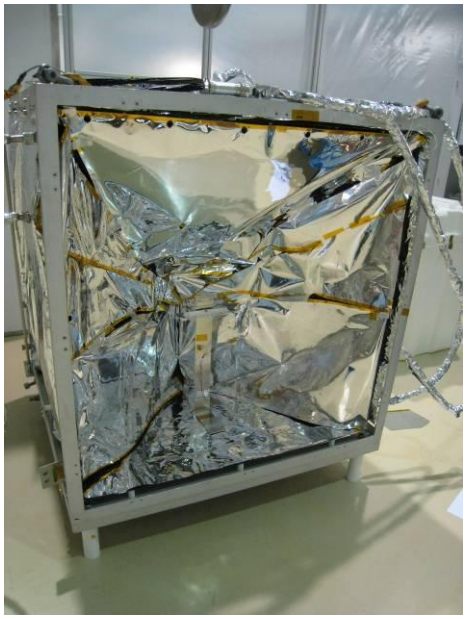


Maintenance and Facility Upgrade

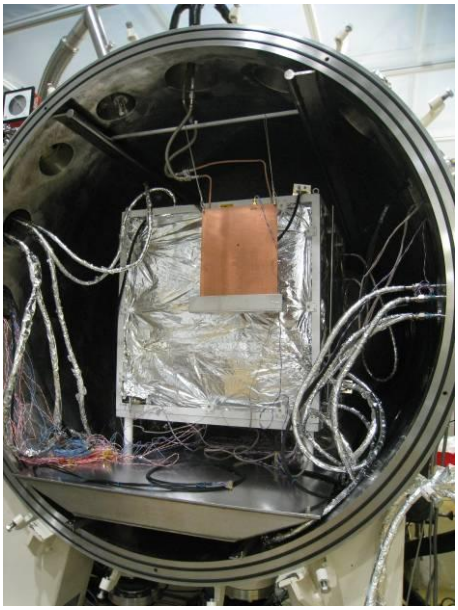
Apart from periodic planned maintenance activities, CSL proceeded to two specific main significant replacements during the 2010-2011 period.

Automatisation Test in Focal 2

After the installation of the new thermal system in Focal 2 by the CSL team (ended in 2010), an automatisation blank test has been performed in the chamber (April 2011) with 5 independent lines controlled at different temperatures. The bakeout mode has also been tested.
After this test, all the thermal systems of the other CSL facilities have been upgraded to allow future automatisation tests (end of this upgrading in 2012).



Thermal tent preparation for the automation blank test



Thermal tent in Focal 2

External activities

MSI FPA

For the MSI FPA (Focal Plane Assembly), CSL has been in charge to provide new thermal panels and electrical flanges with Sub D feedthroughs. The panels have been baked and instrumented at CSL before delivery at EADS Astrium.

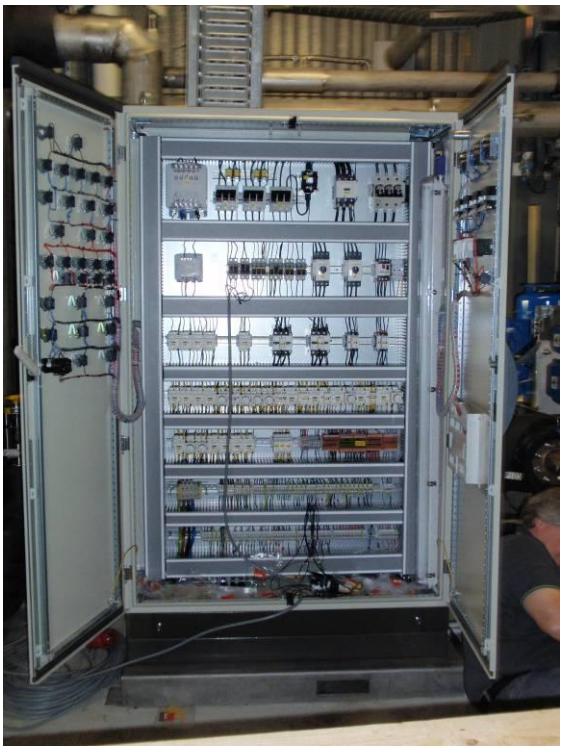
LSS LN2 pumps control cabinet design and manufacturing

The test department has developed all the CSL internal facilities and related equipments. This competence in thermal and vacuum engineering techniques is now proposed for external customers as well.

ESA has asked CSL to design and install a new control cabinet of the LSS (Large Space Simulator facility at ESTEC) LN2 pumps .

Additionally to this cabinet, CSL has also replaced the thermal system valves , the pumps and a new insulation of the thermal system.
The installation has been done in the summer 2010.

Control cabinet


Control cabinet

General overview of the new installation

CSL team during installation

- 

  CSL team during installation

2. Optical Design & Metrology Laboratory *(Resp. Y. Stockman)*

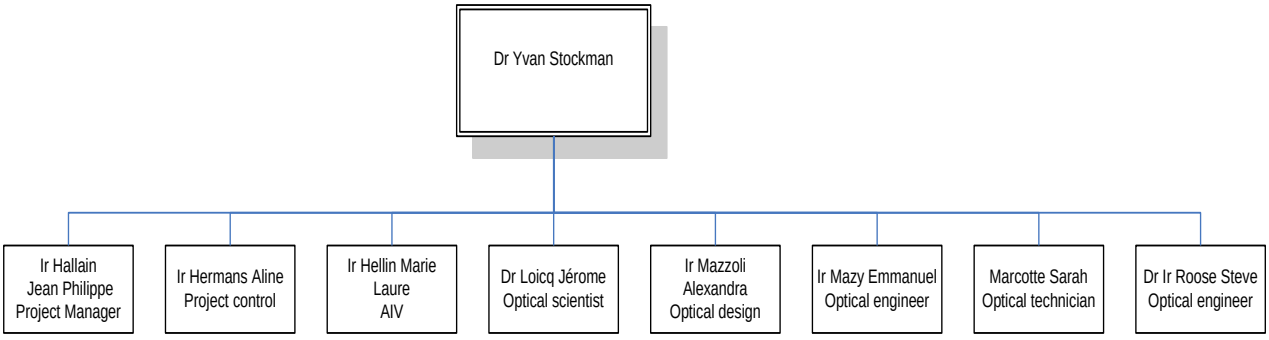
Innovative optical and spectral payloads (up to 15 CSL instruments in space).

Optical system calibration in space condition (including cryo). Optical metrology. BRDF calibration.

Optical instrument and assembly models and design.

The Team

The team consists in 9 people who are presented in the following organization chart.



The competences

Metrology is a key activity for all what concerns optical payload testing. Since the 70's, CSL develops Optical Ground System Equipments (OGSE) for testing scientific payloads operating from the X-rays until the sub-mm wavelengths. To provide efficient and up-to-date technology, the group develops new instruments and new metrology methods to face the upcoming demands. The knowhow and expertise acquired on these developments are now exploited for in-flight metrology to on-ground industrial metrology support.
The optical design activities support all CSL projects involving optical simulations as well as optical design and optical simulation for external customers.

The "Optical design and metrology" group activities cover the following:

- Development of Optical Ground Support Equipment
- Development of new metrology tools
- Development of flight metrology instrumentation
- Support to industry in metrology problems
- Perform optical design and analysis

The labs

The following S/W are available: CODE V, ASAP, FRED, IDL, Intelliwave.
Several labs are available and dedicated for different purposes:

- One lab for WFE measurement,
- Two labs with optical table for the development of optical experiment
- One optical table in a class 100 for OGSE integration
- One BRDF bench in class 100

The next table lists available metrology tools that are managed by the team.

H/W
Wave Front Sensors
MiniFiz Phase temporal shifting visible interferometer
HS 2000 interferometer simultaneous phase shifting
IR high spatial resolution interferometer
Hartman WF sensor + beam expander
Topology instruments
3D topology profilometer
Wyko profilometer
Metrology instruments
T5000, T3000A & TC2002 (+ T2 and T3) theodolites with ECDS3 software
2 * HP Interferometer
GOMfringe projection and Digital image correlation
Thermometry instruments
FLIR S45 and Infratec Thermographic cameras
Pyrometre
Collimators
F/10 Newton 300 mm diameter WFE 63 nm
F/5 Off axis 400 mm WFE 63 nm
Monochromators and spectrometer
Mc Pherson Rowland 1 m
Mc Pherson Czerny Turner 0.3 m
Optotronics
Spectometre Hamanatsu

Basic tools & S/W
Cameras
Optical tables
Softwares : IDL, ASAP, CODE V, INTELLIWAVE, FRED
Other tools
BRDF bench
Imaging
AC flat 700 mm on 2 axis
Parbolic mirror
400 mm of axis parabola from Athol
2 * 400 mm flat mirror from Athol
2 * 300 mm flat mirror (Hipparcos & XMM)
2 Autocollimator /µRadian + 1 Nikon
X-rays source
EUV collimator 800 mm
EUV collimator 440 mm
X-ray off axis parabola collimator

Major events in 2010 and 2011

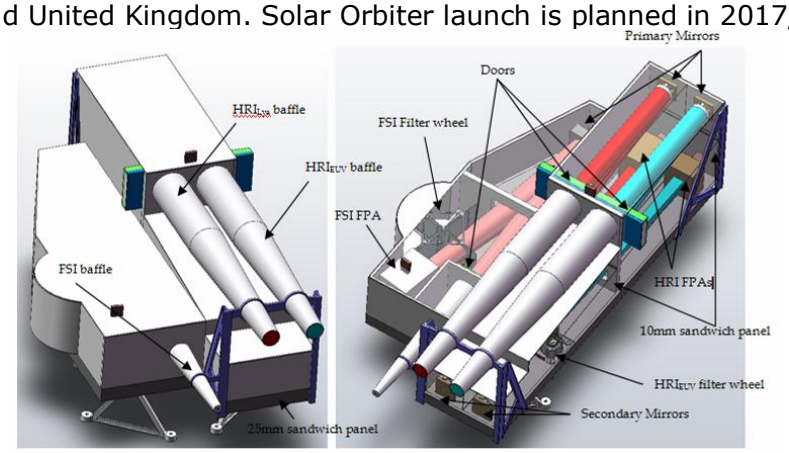
These activities are illustrated in the next table listing the major events of the years 2010-2011. A next paragraph presents a small description of the major events.

2010 events	2011 events
<u>End of</u> PROBA III Startiger	<u>End of</u> PROBA V straylight analysis
<u>Projects running</u> Space & ground imaging in astronomy Tip Top Lam Multiphy Target for videogrammetry Coarse Lateral Sensor (CLS) Large deployable telescope Optical consultancy BRDF characterisation of solar diffusers for Sentinel-2 & Sentinel-3 PROBA V straylight analysis	<u>Projects running</u> Space & ground imaging in astronomy Tip Top Lam Multiphy Target for videogrammetry Coarse Lateral Sensor (CLS) Large deployable telescope Optical consultancy BRDF characterisation of solar diffusers for Sentinel-2 & Sentinel-3 ACTIO
<u>Start of</u> ACTIO SOLO EUI	<u>Start of</u> PROBA V GSE SOLO HI/WSPR

Major events

Solar Orbiter EUI
(started in 2006 and has been selected in 2010 in the ESA Comic Vision program)

The EUI (Extreme Ultraviolet Imagers) instrument suite onboard the ESA Cosmic Vision Class-M Solar Orbiter candidate mission is composed of two high resolution imagers (HRI), one at Lyman α and one dual band at the two 17,4 and 33,5 nm EUV pass bands in the extreme UV, and one dual band full-sun imager (FSI) working alternatively at the two 17,4 and 30,4 nm EUV pass bands. In all the units, the image is produced by a mirror-telescope, working in nearly normal incidence. The EUV reflectivity of the optical surfaces is obtained with specific EUV multilayered coatings, providing also the spectral selection of the EUV units. The spectral selection is complemented with very thin filters rejecting the visible and IR radiation. Due to its orbit, EUI / Solar Orbiter will be irradiated to 20 solar constants and an entrance baffle to limit the solar heat input into EUI is needed. The CSL is the PI Institute of the EUI Consortium including members from Belgium, France, Germany and United Kingdom. Solar Orbiter launch is planned in 2017/2018.



Solar Orbiter EUI instrument suite (Dec. 2009)

The optical design of the High Resolution Imager is performed by the CSL optical design workshop. This telescope makes an image of a portion of the sun. One pixel sees a surface of sun equal to 85 x 85 km².The main activity was a tradeoff between different designs depending on the minimum distance to the sun; between 0.2 and 0.3 AU :

- modification of the focal length,
- increase of the entrance pupil diameter.

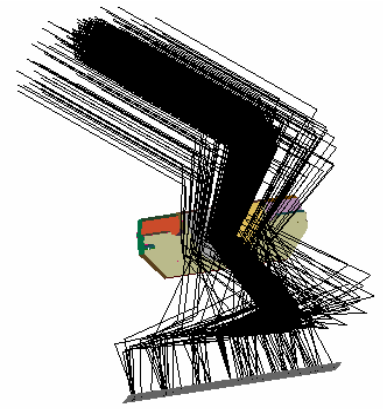
Solar Orbiter HRI optical design

SOLO HI and WSPR
Started 2011 – end 2013 Prodex

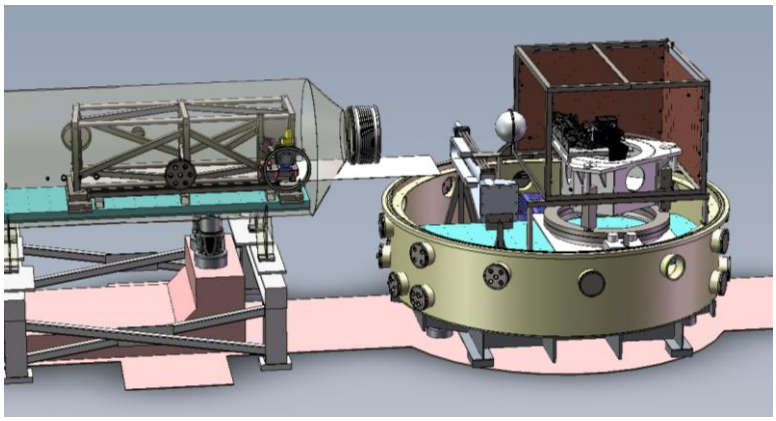
SOLO HI is an instrument on board of the SOLO solar mission proposed by R. Howard from NRL (US). The CSL activities consist in the optical design, BRDF measurement on samples and straylight evaluation on a demo and on the FM.

PROBA V ESA via Industry
Started 04-07-2011 – end 2012

Proba Vegetation is a platform embarking a multispectral instrument for Earth Observation. It shall fill the gap between the Spot 5 and the Pleiades missions, with the major constraints that it can be flown on a PROBA type satellite.
CSL has been involved in the straylight analysis and the performance and environment test definition of PROBA V. CSL is the subcontractor of OIP
The straylight is performed by the CSL optical design workshop group. The study allows to define the baffle design. A dedicated straylight analysis on the SWIR channel identified the best chamber orientation to avoid a scattering towards the SWIR detector.



PROBA V stray light analysis



CSL FOCAL 3 general implementation drawing

CSL contributed to the on-ground calibration study of PROBA V. The aims of the study were to define the overall calibration strategy. This on-ground characterization must address all the instrumental effects that will affect the final in-flight measurements. A complete calibration process covers a lot of parameters: radiometric, spectral, geometrical, dark signal, effects that can contribute to the instrumental response.
The year 2012 will be dedicated to the realization of the proposed work.

<u>The following projects have run during 2010 and 2011</u>

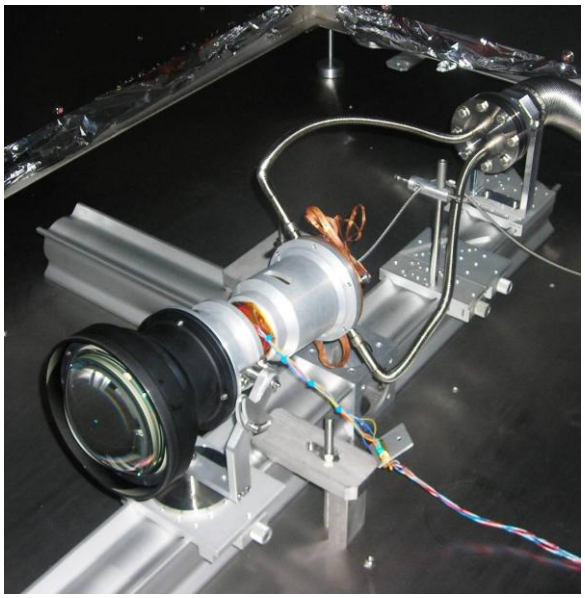
Target Projector System
ESA GSTP 2008-2012

The objective of this activity is to design, develop, manufacture, install, qualify, test and deliver to ESA an operational prototype videogrammetry target projector system (TPS) for use under thermal vacuum conditions. The TPS to be developed in the frame of this activity had to be compatible and usable with the existing ESTEC videogrammetry systems (listed here in order of importance for critical design decisions) :

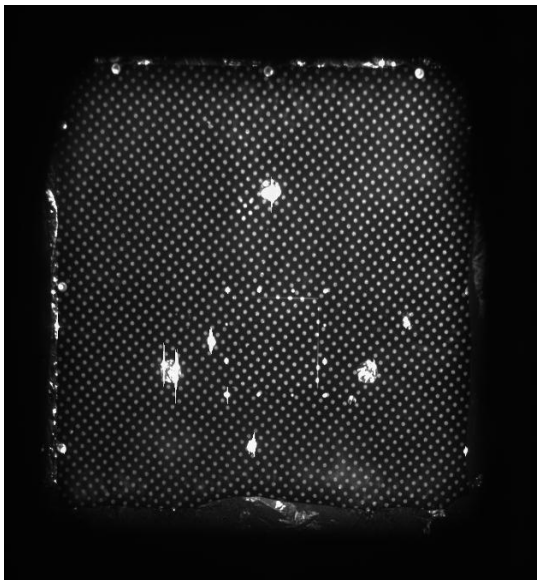
- ESA miniaturized system (Space-X cameras, space-qualified) and for further operational application information,
- ESA canister based videogrammetry system (Rollei 6008 cameras enclosed in a canister for thermal control and environmental conditioning).

The TPS shall be designed to be usable in the ESA Large Space Simulator (LSS) without any thermal impact on the test item. It will maintain operational stability and precision under typical thermal-vacuum test environments to which the system will be subjected.

In 2011 final functional and performance tests have been successfully carried out. The final delivery will be completed beginning 2012.



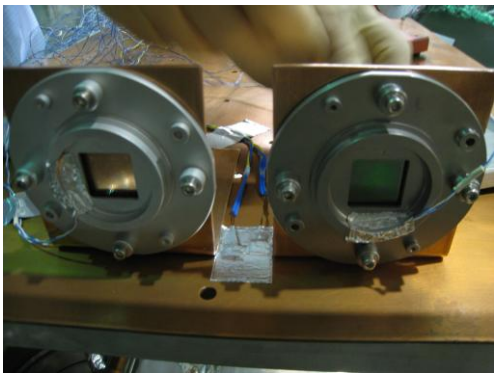
TPV projector



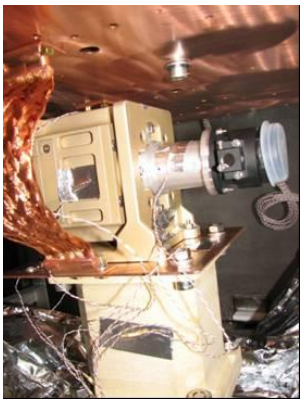
Dot pattern observed by the camera.
The object is black coated radiative shroud.

Coarse Lateral Sensor
ESA GSTP 2009 – 2012

The objective of this activity is to develop an engineering qualification model (EQM) of a coarse lateral sensor (CLS) for the PROBA-3 formation flight with two satellites to form a giant solar coronagraph. As a goal requirement CSL will base the CLS on the heritage of existing space hardware, where only delta developments are required. The complete CLS system (optics, mechanics, electronics) will be developed and brought to a technology readiness level of 6 (i.e. System/subsystem model or prototype demonstration in a relevant environment (ground or space).



CLS opto mechanical design



CLS optical design elaborated by the optical design workshop

The coarse lateral sensor developed at CSL is based on a camera (CMOS detector), a telecentric lens, a fiber-coupled laser-diode bar, and a corner cube. The fiber-coupled laser-diode bar emits a diverging beam, from the coronagraph satellite. A corner cube located on the occulter satellite sends the light back. This light is captured by the telecentric lens and camera, located on the

other satellite. A lateral shift of the PROBA-3 Occulter S/C is seen on the camera as an image displacement. Pseudo real time centroidisation algorithms, allow tracking the image position and feed the on-board computer with this information, allowing position stabilization.
In 2010 the system has been build and all the required performances have been demonstrated. Nevertheless, its operation at high temperature 60°C needs to modify the CMOS support structure. These activities have been started end of 2011.

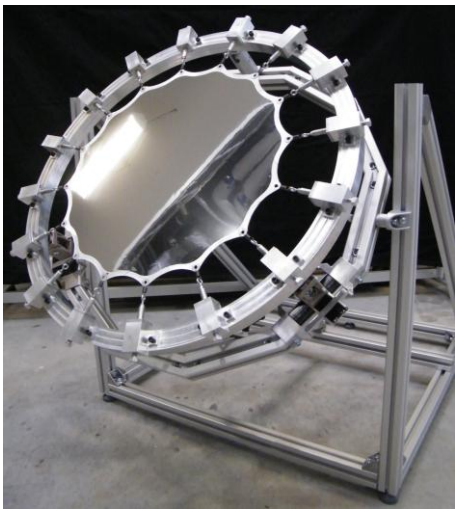
Large Deployable Telescopes
ESA TRP2009 – 2012

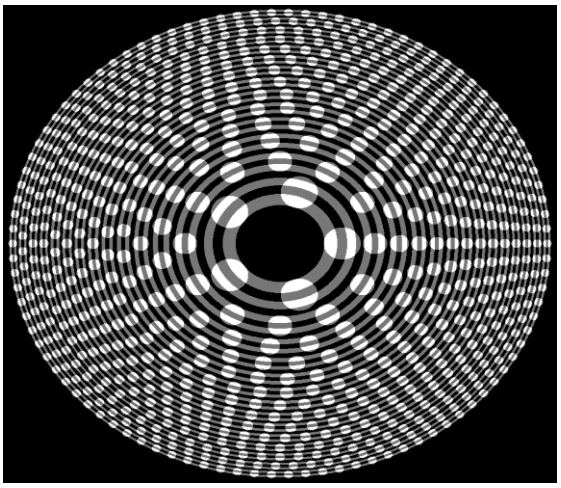
Large light-weight telescopes in space are considered as key elements enabling future Earth observation and space science. They will be needed for imaging as well as non-imaging (photon bucket) applications. The first large space telescope, "Hubble", has an area density of about 180 kg/m2, the current generation space telescope, 'James Webb Space Telescope' has an area density below 20 kg/m2.

However, continued demand for new science and observation from space will drive the need for even larger telescope apertures. For achieving from GEO a ground spatial resolution of a few meters, telescope aperture diameters of the order of 20 m need to be achieved. This requires completely new concepts of deployable space telescopes with primary mirror area densities below 3 kg/m2.
Many interesting ideas and concepts of very large and lightweight telescopes can be found in the literature. They often fall into one of the three following telescope concept groups:

- 3D-shaped membrane
- Flat membrane
- Light-weight plates

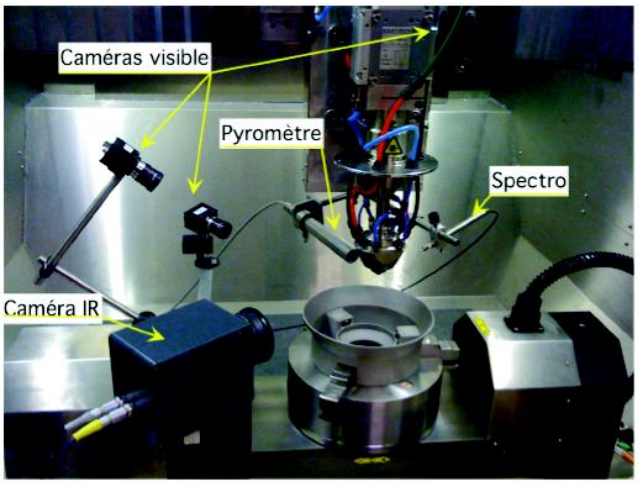
The objectives of the activity are firstly the study of various advanced concepts of large deployable space telescopes and secondly the bread-boarding of the key element(s) or heart of the most promising telescope concept in form of a demonstrator. The aim of the demonstrator will be to demonstrate (at full or reduced but representative scale) the feasibility and applicability of the selected concept and technologies for future large deployable telescopes in space. CSL is prime, with TUM (D) and ULB (B) as subcontractors.
Detailed design of the demonstrator has been accomplished during 2010, while the year 2011 was dedicated to the manufacturing of these demonstrators.


Demonstrator prototype build by MUL and TUM


Example of photon sieve achieved with the CSL simulator

Tip Top Lam FEDER
2008 – 2013

The project is led by SIRRIS and can be considered as a natural continuation of our collaboration on the TAP project on "Rapid Prototyping". The laser cladding techniques started in the 90th.
The powder used in laser cladding is normally of metallic nature, and is injected into the system by either coaxial or lateral nozzles. The interaction of the metallic powder stream and the laser causes melting to occur, and is known as the melt pool. This is deposited onto a substrate; moving the substrate allows the melt pool to solidify and thus produces a track of solid metal. This is the most common technique; however some processes involve moving the laser/nozzle assembly over a stationary substrate to produce solidified tracks. The motion of the substrate is guided by a CAD system which interpolates solid objects into a set of tracks, thus producing the desired part at the end of the trajectory. This technique reduced considerably the manufacturing time and cost. The technique takes advantage of the 3D definition of an object to manufacture layer per layer in a few hours. The CSL contributes to the selection and procurement of equipments for the real time dimensional and thermal control.
The real time dimensional control is obtained by a stereo correlation technique, that indicates the thermal stresses during the cooling down, while the thermal control is ensured by a pyrometer and a IR camera. Contamination issues are also monitored through a spectrometer.
2010 and 2011 were dedicated to the integration and optimization of the metrology tools in the cladding machine.



Tip Top Lam FEDER with industries in Wallonia

MULTIPHY

Walloon Region project in the frame of the aerospace cluster Skywin 2008-2012
This project is led by OPEN ENGINEERING and aims to develop new CAE tools that integrates in a coupled way methods and simulation in different field: aerodynamic, thermal, structural, optical, electrical and acoustical fields.
CAE is presently used in all the industries for analysis and prediction of their own products. The goal of these simulations techniques are :

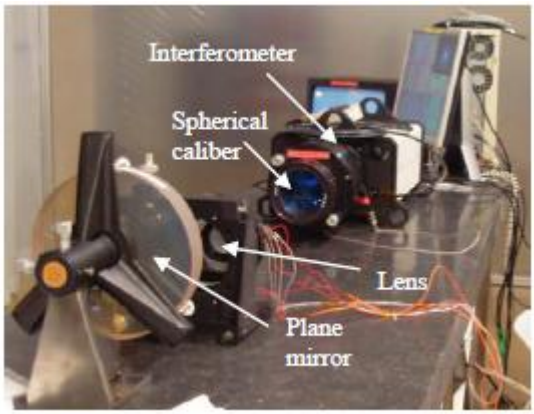
- Reduction of the optimization time (time to market)
- Increase the liability of the predicted models
- Use of design optimization methods on parametric model to increase the performances.

Due to the increase power capacities of the computer, there is a demand from the industry to produce simulations as close as possible from the reality.

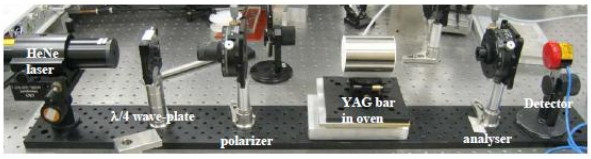
This implies:

- Increase in the geometrical details implies a lot of nodes
- Interactions between fluid mechanics and other physical phenomena as mechanical, thermal, vibro and aero acoustical
- Other electromagnetic interactions, optics, radiation, …

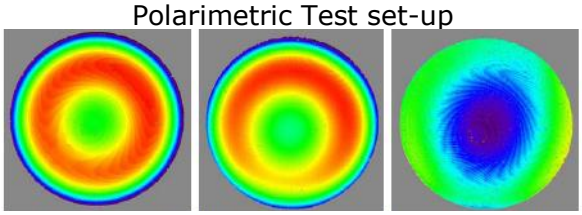
The goal of the project is to reply to the need of the industry based on the necessity to use a new generation of S/W based on problem of large dimension integrating new multiphysics coupling.
The major contributions of CSL in this project are to handle the optical problems and models, and to demonstrate experimentally the multiphysics coupling announced by the model.
To achieve this, CSL developed several test benches, one opto-thermo-mechanical case with a spherical lens fixed in an aluminium barrel, which is the simplest structure found in an opto-mechanical system. In this study, material characteristics are assumed to be well known: BK7 and aluminium have been retained. Temperature variations between 0 and +60°C from ambient have been applied to the samples.
The second system is an opto-thermal bench consisting in a YAG laser rod heated by means of a dedicated oven. The thermo-elastic distortions impact on the optical performances has been measured using a Fizeau interferometer.
For the YAG bar, birefringence and polarization measurements have also been performed using a polarimetric bench. The tests results have been compared to the predictions obtained by OOFELIE Multiphysics which is a simulation software dedicated to multiphysics coupled problems involving optics, mechanics, thermal physics, electricity, electromagnetism, acoustics and hydrodynamics. From this comparison modeling guidelines have been issued with the aim of improving the accuracy of computed thermo-elastic distortions and their impact on the optical performances.



Spherical lens test bench

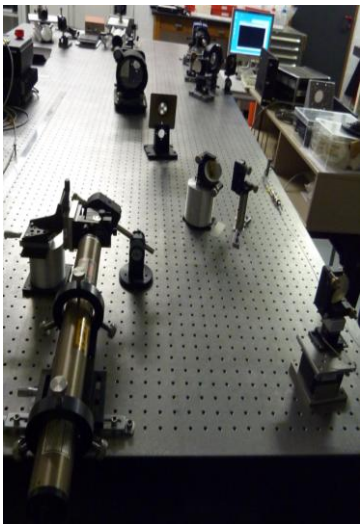


Polarimetric Test set-up

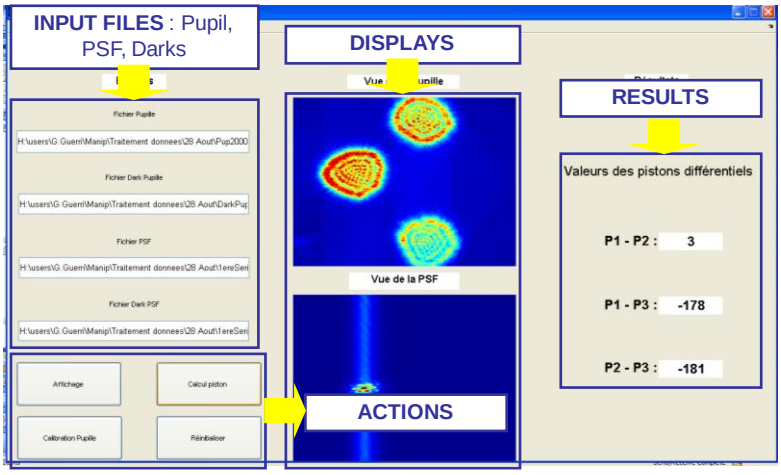

Measured WFE at T=20.5°C and 57.2°C at lens center and remainder from their subtraction

Space and ground-based imaging in astrophysics (2007 2012)

CSL participates to this ARC (Action de Recherche Concertée) as specialist in optics and space instruments. The target of this project is to merge different teams specialized in astrophysics, optics and instrumentation in order to be prepared for the forthcoming astrophysical and space research programs.
This project is run with 3 other research groups of ULg : AGO-AEOS, AGO-GAPHE and Hololab. CSL develops a compact co-phasing sensor to phase segmented mirrors space telescopes.
During 2010 and 2011, a post Doc developed and tested a co-phasing Piston sensor based on phase retrieval algorithm.



Test bench



S/W interface

ACTIO

Walloon Region project in the frame of the aerospace cluster SKYWIN 2009 – 2014
The project goal is to follow and even anticipate the general trend in EO :

- increase of the spatial resolution within the dimensional limitations of a microsatellite,
- develop acceptable and space qualified solutions with commercial components.

To improve the commercial attractivity of the Walloon space industry in this content, CSL will study the development of qualification and calibration of small multi- and hyper-spectral instruments. Concerning the increase in spatial resolution, new breakthrough technology will be proposed.
This project started in 2009 and will be finished in February 2014.

During the years 2010 and 2011, participation to the high level specification for EO has been carried out and the way to verify and calibrate these requirements has been performed.

Solar Orbiter Sun Sensor
(Started in 2009, ended 2011)

See description page 14.

Optical Design Workshop

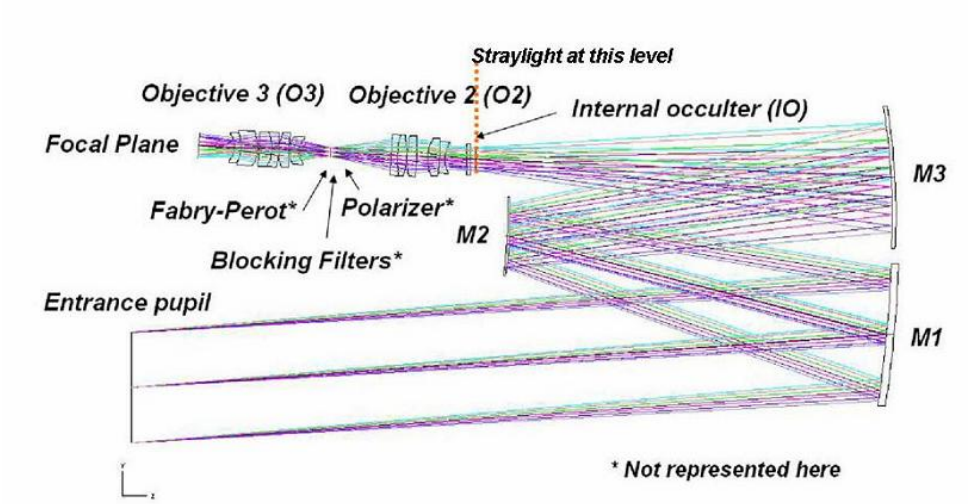
Introduction

The optical design section supports all CSL projects involving optical simulations as well as optical design and optical simulation for external customers.
A large part of the workshop activity was already presented here above in the different activity group reports (E.g. EUI, CLS, TPV, PROBA V, SCID). Nevertheless, the workshop deals also with project concerning only optical design generally for industry. Major examples are given hereafter.

Project descriptions

ASPIICS StarTiger ESA
(2009 – 2010)

This study concerns the PROBA-3 mission, which is dedicated to the demonstration of Formation Flying (FF) technologies for future European scientific and application missions like DARWIN. The success of the envisaged missions depends on understanding and correctly implementing all the aspects of FF.
The STARTIGER program addresses the study of a new generation externally-occulted solar coronagraph operating in flight formation. The instrument is distributed over two platforms separated by about 150m, and forming a giant externally-occulted coronagraph: the imaging part is hosted by one spacecraft and remains in the shadow of the external occulter hosted by the other spacecraft. This basic configuration corresponds to a "rigid" long base instrument, and in this case the formation can be considered as the instrument.
This study will focus on the optical design of the coronagraph and the formation flight metrology. CSL is working with LAM as prime contractor.



PROBA III Coronograph design

Other studies for industrial customers

Most of these studies are protected by NDA. These studies use the optical skill of the team for straylight analysis in remote systems, flux homogenisation for solar panel applications or illumination devices.
Dedicated optical benches are set-up for measurements on industry demand as detector spectral response, BRDF.

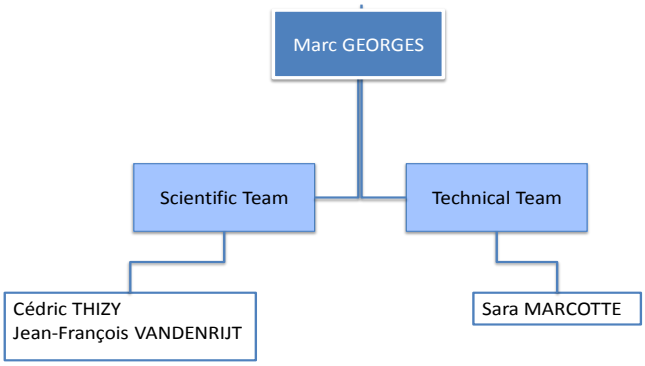
3. Lasers & NDT Laboratory *(Resp. M. Georges)*

Non DestructiveTesting for space system, instrument, material (holography, interferometer, IR, …)

Composite non destructive characterization

The team

The team consists in 3 persons who are presented in the following organization chart.



The competences

The competences of the group are historically centered on laser metrology system developments, from research to pre-industrial prototyping and applications. Typical systems developed in the past are a high resolution holographic camera for non destructive testing and full-field deformation metrology, laser distance-meter, and so on. The group is also highly active in

applying such techniques in relationship with needs of aerospace industries: metrology for comparison with finite element analysis, flaw detection in composites, etc.
Recently the group started development of innovative techniques, mainly based on speckle and holography in the Long Wave InfraRed spectrum. Basic studies were first performed and followed by laboratory breadboarding and development of portable sensor. In order to reach this high level of achievement, the group is composed of experts, highly skilled in physics, and especially in optics, and in measurement science.
The group is now involved in various projects for characterizing the behavior of composite structures undergoing different kind of stresses, measurement of expansion up to 150°C and detection of flaws in composites. The group is currently studying various non destructive methods like shearography, thermography and laser ultrasounds.

Major equipment

1. Three laboratories with various optical tables

2. Lasers :

   - YAG DPSS Coherent Verdi 532 nm, 5 Watts
   - YAG DPSS Coherent 532 nm, 500 mWatts
   - YAG DPSS Coherent 1064 nm, 80 mWatts
   - Ar3+ Coherent Sabre 488 nm, 5 Watts
   - YAG Q-Switch Coherent Infinity 1064 nm (600 mJ/pulse) & 532 nm (300 mJ/pulse)
   - YAG Q-Switch Quantel Brilliant Easy, 1064 nm (350 mJ/pulse) & 532 nm (165 mJ/pulse)
   - Tunable diode laser New Focus, Velocity 6308, central wavelength 673 nm ± 10 nm, 2 mWatts
   - CO2 VM-TIM, 9.5 µm & 10.6 µm, 10 Watts
   - CO2 Access Laser Co Merit-S, 10.6 µm, 8 Watts
   - Various He-Ne lasers for alignment

3. Vacuum chamber : 55 cm diameter, 55 cm long, with various optical windows in glass for visible applications and ZnSe for thermography.

4. Photorefractive holographic cameras for high resolution displacement measurement (CSL own development) :

   - Optional 4 illumination for full-vector measurement
   - Vacuum compatibility

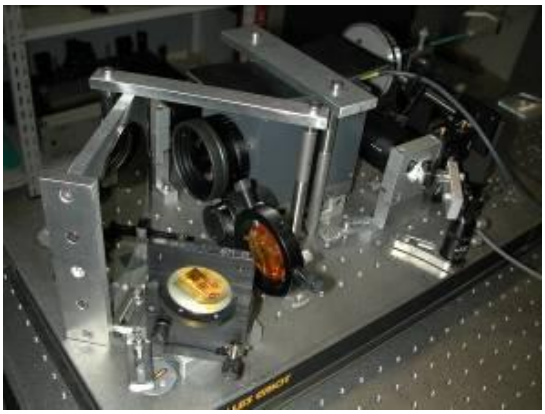
5. Shearographic camera for flaw detection (CSL own development)

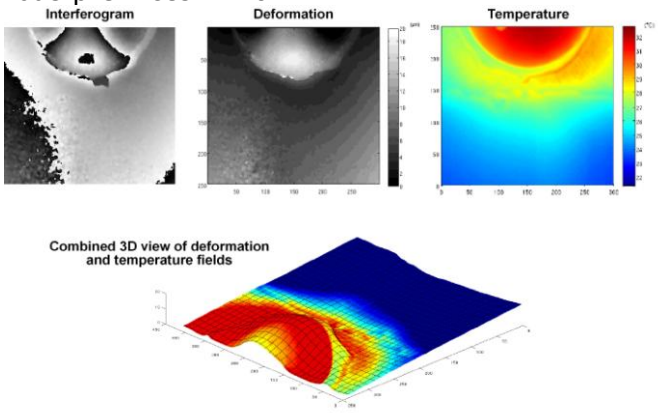
6. Thermographic cameras

7. Various excitation methods (Infrared lamps, flash lamps, etc…)

FANTOM : Full-Field Advanced Non Destructive Testing Technique for Online Thermo-Mechanical Measurement on Aeronautical Structures (2009-2012)
Funded by European Union - FP7

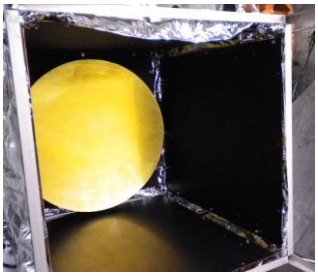
CSL coordinates the FANTOM project, with a total of 6 partners. The FANTOM project aims at developing an innovative non destructive testing based on association of thermography and holographic techniques, using lasers in the thermal infrared spectrum (around 10 µm). The applications are mainly the thermomechanical behaviour assessment of aeronautical composite structures but also the flaw detection in such structures.
The project has proven so far that it was possible to combine holography and thermography in a single sensor. A transportable set-up is currently under investigation for various non destructive testing applications. Tests are scheduled at Airbus premices in 2012.

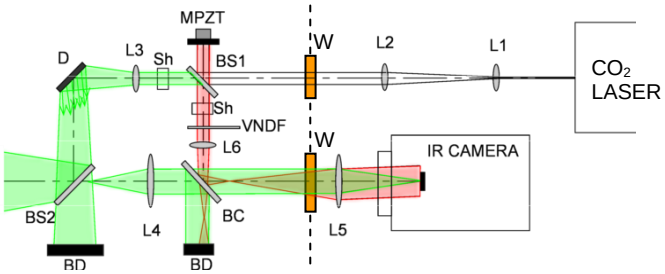




HOLODIR (Thermal Infrared Digital Holography for Non Contact Surface Metrology) (2009-2012) Funded by ESA - GSTP

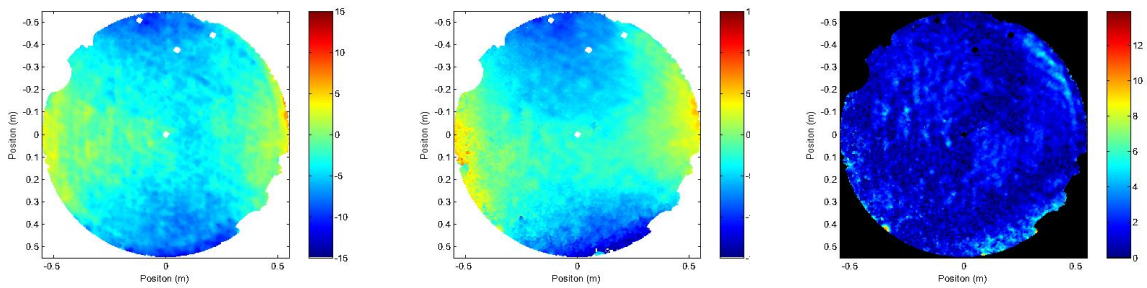
The goal of the project is to develop a novel digital holographic technique targeted at space reflector deformation measurement. It consists of a long wave infrared (LWIR) digital holographic interferometer (DHI) to measure relatively large displacements, typically 250 µm, of complex surfaces, shapes and structures under both ambient and thermal vacuum condition with a measurement uncertainty of 0.25 µm. This LWIR digital holographic interferometer provides a new measurement technique to fill the gap between holography/interferometry in the visible and techniques based on structured light illumination. The former provides a very good measurement uncertainty but requires a very stable environment, while the latter provide large measurement range but with higher measurement uncertainties. The performances of the developed instrument have first been verified in the lab by measuring tilts of a 1.1 m diameter parabolic reflector, shown in a vacuum chamber surrounded by a thermal shroud (figure (a)). The optical set-up is depicted in figure (b). The tested object is not shown but is placed on the left of the BS2 element. The set-up was designed to be partly incorporated into a vacuum chamber. Only the CO2 laser and the thermographic camera are out of the chamber of which limits are indicated by windows W. One particularity of our technique is that is makes use of a diffuser D for illuminating the tested specular objects. This allows imaging object with unusual shapes or to avoid optical components such as null-lenses, specifically designed for the reflector under test, when conventional interferometry is applied.

(a) 

(b) 

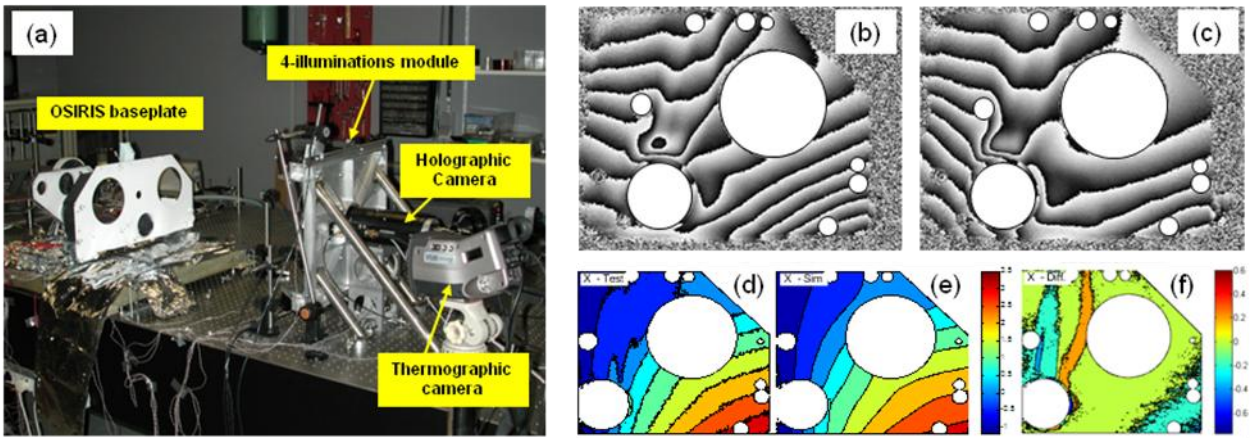
The following figures show the deformation measured by LWIR Digital Holography between 288K and 113K on the parabolic reflector. These are compared to measurements that were obtained with a High Resolution InfraRed Interferometer (HRIRI) developed by CSL in the past and making use of null-lens. The results show an excellent consistency between both measurements. The next tasks are to consider more complex shapes of reflectors which cannot be measured by classical interferometry.

LWIR DH measurement HIRI measurement Difference ~ 1,6 µm RMS



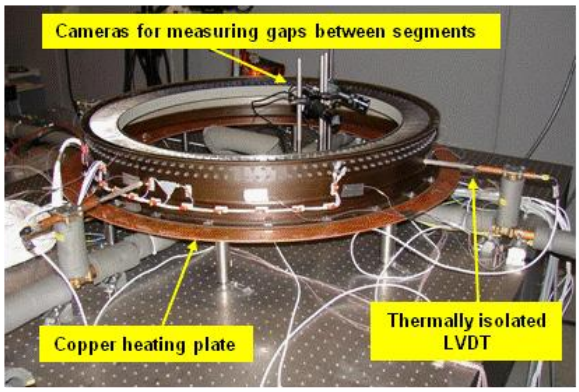
Thermoelastic distortion verification methods for spacecraft structures (2009-2012)
Funded by ESA - TRP

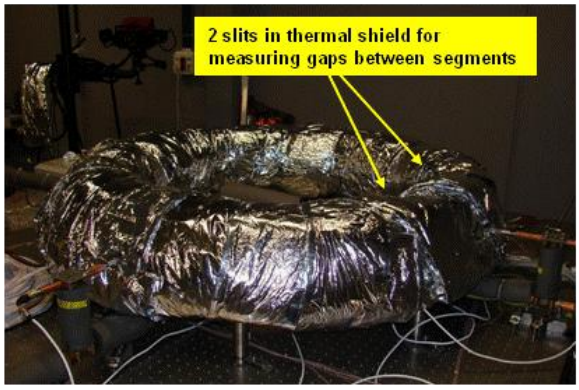
The project aims at verifying simulation methods by finite element modeling of thermoelastic distortions which appear on spacecraft structures. Our partner EADS Astrium has selected the STM of the OSIRIS telescope, part of the current Rosetta mission. The following figure (a) shows the set-up which includes a holographic camera equipped with a device splitting the laser illumination in 4 beams which allows the measurement of full vector displacement of the specimen. This device was developed by CSL. On the upper right images (b) and (c) show typical high resolution interferograms obtained with the holographic camera developed by CSL and 2 illuminations of the 4-illumination module. The 4 interferograms obtained with each one are combined to retrieve the 3 components of displacement-vector in every pixel of the image. The lower right images show the result of the X-component of full-field displacement. Image (d) is the result of the measurement, (e) the simulated one and (f) the difference between the model and the measurement.

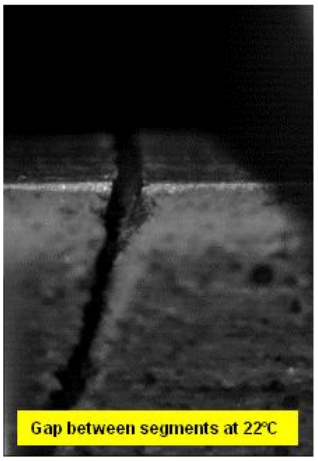


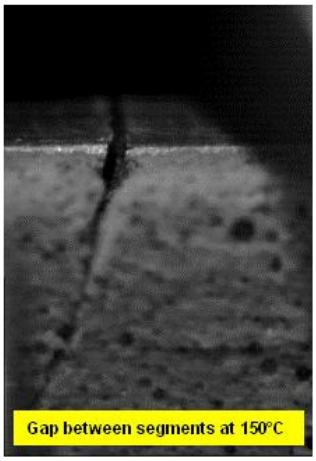
E_COM : Engine Composite (2009-2012)
Funded by Wallonia – DG06 (Marshall Plan)

The project is led by Techspace Aero and aims at developing engine elements in composite. CSL has the task to perform various Non Destructive Testing methods for assessing the behavior of components under thermal loads. CSL developed various set-ups for measuring expansion of elements developed by Techspace. The following figures show facility used for heating an assembly which incorporates various materials and whose differential expansion had to be assessed in various points. The temperature of 150°C was obtained by heating the specimen (visible on the left) and temperature homogeneity was insured by insulating the whole set-up. The expansion was measured by LVDTs in 4 points distributed around the specimen. The gap (in the range of a few microns) between various segments was also measured by cameras and is also shown hereafter.



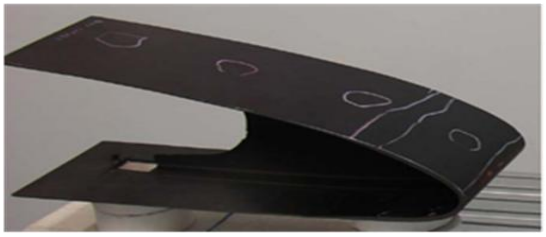


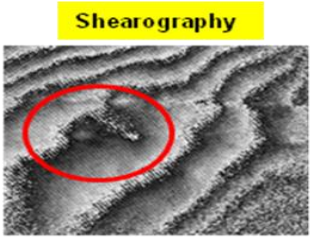


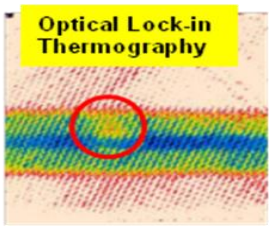


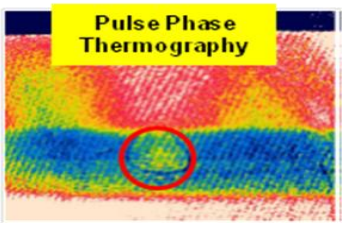
ECOTAC : Efficient COmposites Technologies for Aircraft Components (2011-2014)
Funded by Wallonia – DG06 (Marshall Plan)

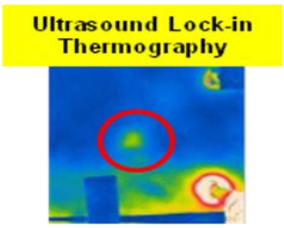
The project is led by the 3 main aerospace industries present in Wallonia: Sonaca, Sabca and Techspace Aero. It aims at developing composite structures for various aeronautics applications. CSL leads the non destructive inspection task, benchmarking different emerging non contact techniques for aeronautics, such as shearography, thermography and laser ultrasonics. Following figures present a defect present in the composite slat and which is visualized by shearography and various thermography techniques. Laser ultrasonics will be considered later. In the next phase of the project, CSL will develop further these NDT techniques.




Shearography


Optical Lock-in
Thermography


Pulse Phase
Thermography


Ultrasound Lock-in
Thermography

4. Signal Processing Laboratory *(Resp. C. Barbier)*

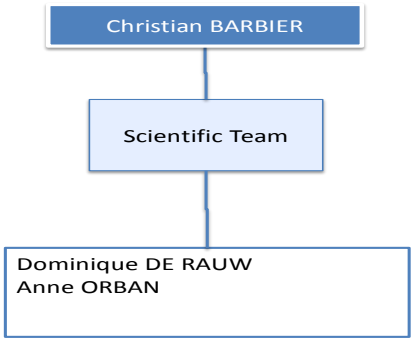
OpticaSAR (Synthetic Aperture Radar) image processing.

Optical and spectral data processing

Training

The Team

The team consists in 3 persons who are presented in the following organization chart.



Introduction

CSL activities on radar imagery processing have begun for twenty years and resulted in the creation of the "Space Environment and Remote Sensing Group". The projects are articulated onto three principal themes :

- SAR PRE-PROCESSING,
- SAR POST-PROCESSING,
- GEOMATIC APPLICATIONS.

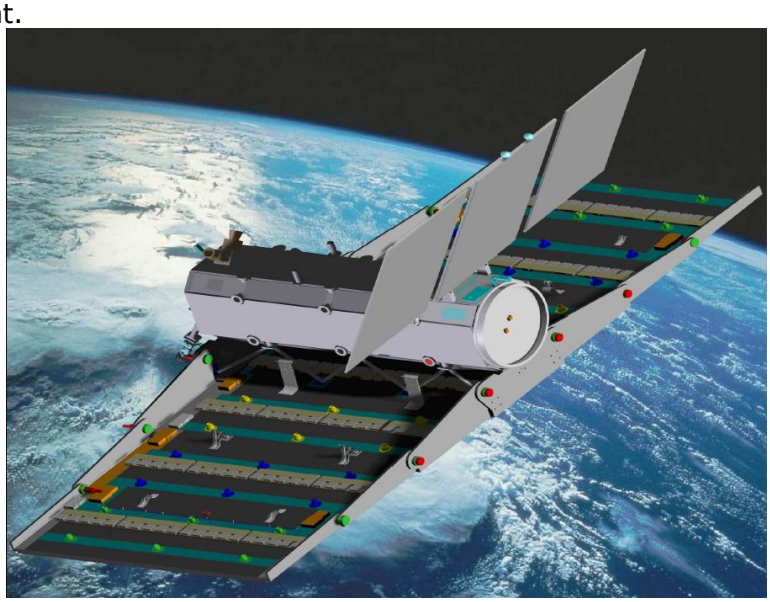
The Space Environment and Remote Sensing group has acquired an international reputation in the field of SAR data processing; however, for various reasons independent of the quality of the team, funding has become insufficient to sustain the ambitions of the past years. Accordingly, new or refocused activities are gradually integrated in the group's workplan :

- Keep up with SAR projects with limited budgets (WISIP, MUSAR, WIMCA)
- Consolidate the existing partnership with the Royal Military Academy
- Introduce new ideas in the SAR activity, e.g., bistatic and opportunistic SAR, processing.
- Develop projects in the VIS / NIR / TIR (hyperspectral) instrumentation and calibration.
- Develop machine vision activities based on UAV's for infrastructure monitoring
- Space Weather, particularly in the field of Space Situation Awareness (SSA) is a new topic of research.

Majors events

Argentine-Belgium Cooperation : SAOCOM Project :

In 1997, Belgium and Argentina signed a cooperation agreement on space, which materialized with Belgium's participation to the SAOCOM project, in the framework of a specific agreement signed in 2000. The responsibility of the project was attributed to Centre Spatial de Liège (CSL) under Belspo financing.
SAOCOM is an Earth observation satellite system developed by CONAE (Comción Nacional de los Activitades Aerospaciales), the payload of which is a L-band full polarimetric Synthetic Aperture Radar(SAR). Two satellites are to be launched one year apart, starting end 2014. Together with the Italian Cosmo-Skymed satellites, they will constitute the X+L-band SIASGE system for disaster management.

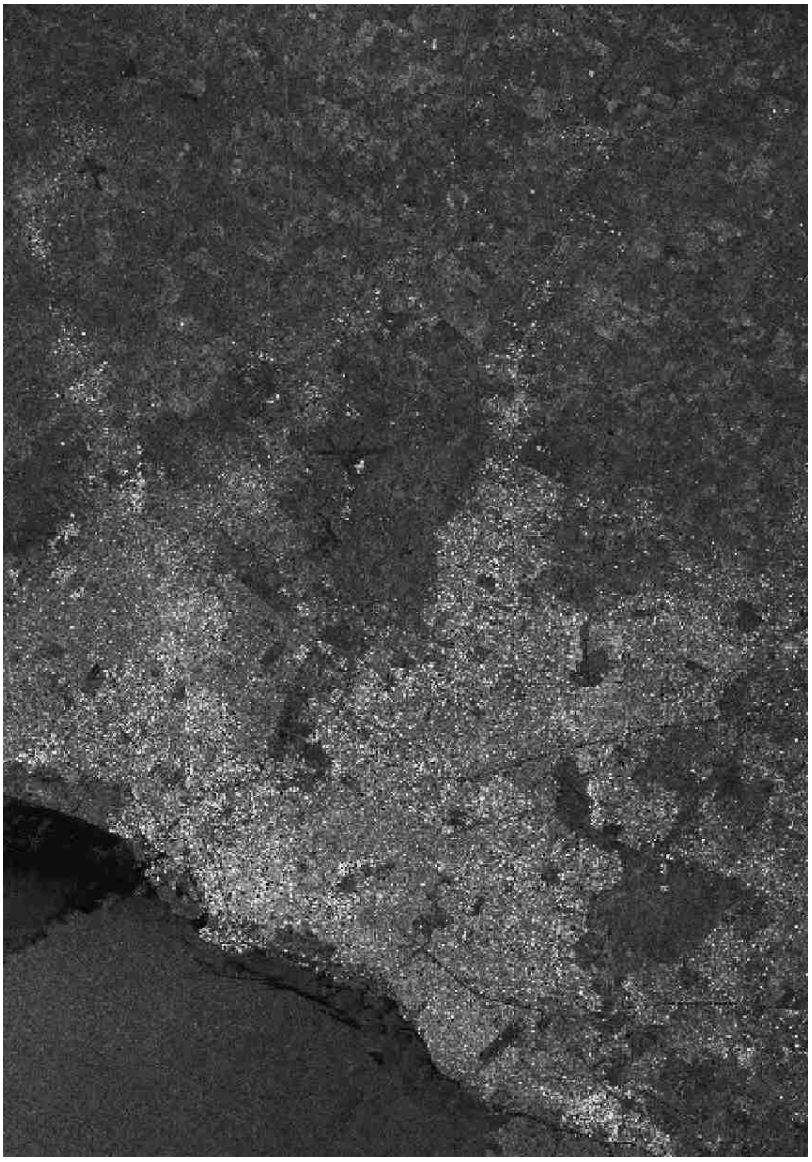


The CSL contribution to this project consist in :

1) The preparation and delivery to CONAE of the SAR interferometry (InSAR) and polarimetric SAR interferometry (PolInSAR) tools.
2) The development of a reference Stripmap/TOPSAR processor capable of handling a set of SAOCOM reference beams and imaging modes.
3) Participating in the various reviews (currently at CDR level) of the SAOCOM subsystem.

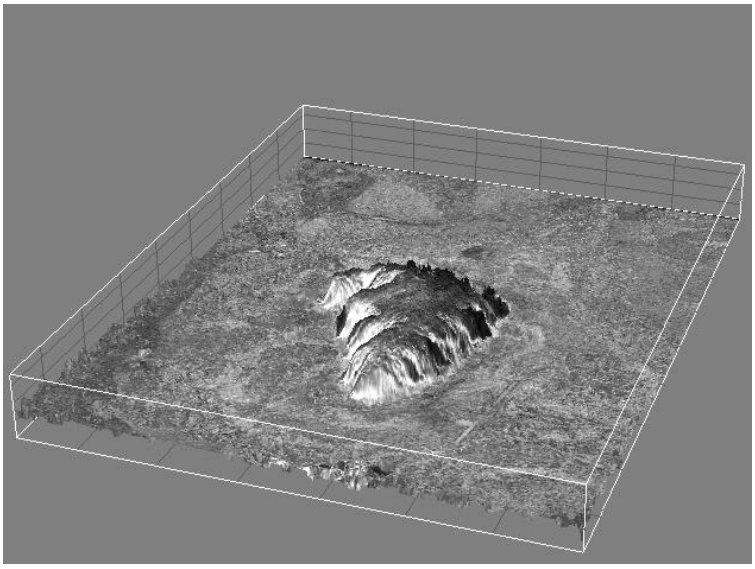
CSL attended the SAR instrument CDR at CONAE premises (Buenos Aires) in September 2011. The InSAR and PolInSAR tools were delivered at the end of 2011. The Stripmap SAR processor is due for end of 2012, while the TopSAR processor shall be delivered end of 2013.

An image of Buenos Aires focused by the current CSL SAR processor from ERS-1 raw data acquired at the Cordoba ground station is shown hereunder.



WIMCA :

WIMCA is an ESA project for which we are Sub-Contractor to the University of Bari. The objective is to study, experiment and validate a new radar interferometry technique that exploits the wide-band capabilities offerred by the new-generation SAR sensors (e.g., TerraSAR-X). As a sample illustration of the results, the figure hereunder shows a 3D view of an interferometric digital terrain model, generated by the new technique from TerraSAR-X images, over the region of Uluru in Australia. An aerial view of the same site is also shown for comparison purposes.
The project was completed in 2011. An extension is to be carried out in 2012.



MUSAR :

Passive radars use transmitters of opportunity as signal source and are necessarily bistatic. Passivity has many advantages:

- Built-in redundancy since any transmitter (subject to central frequency and bandwidth requirements) can be used as source;
- By exploiting several transmitters of opportunity, it is feasible to increase the revisit rate of a particular area;
- Lower cost than an active system since there is no need for a transmitter. Moreover since no signal is transmitted, there is no need for acquiring a license or obey transmit power regulations.

The MUSAR project was carried out in collaboration with the Royal Military Academy. The contribution of CSL was to provide a demonstrator of frequency-domain passive bistatic SAR processor. This processor was tested on both simulated (point target responses) and real (ENVISAT) raw data.

The final report was delivered in December 2011 and the final presentation took place at RMA premises in February 2012.

5. Thermal & Mechanical Design Laboratory
(Resp. P. Jamotton)

GSE facilities advanced thermal test environment designed upon requirement.

Extended capabilities for space condition simulation (from 5K to 400 K).

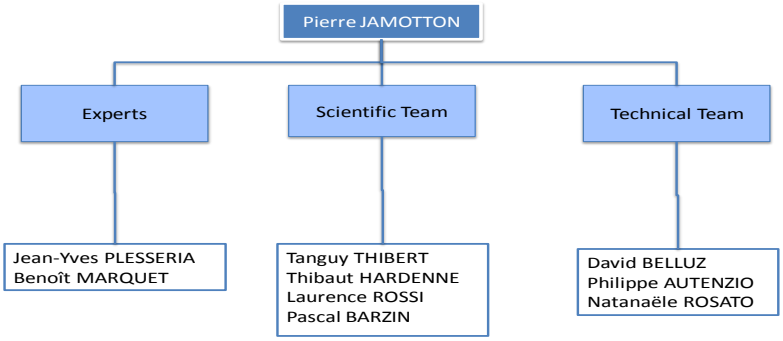
Cryogenic expertise.

Solar systems to increase energy concentration and spacecraft/payload thermal efficiency and autonomy

Space payload mechanism Design

The Team

The team consists in 10 persons who are represented in the following organization chart.



The thermal and mechanical competences of the CSL originally emerged to support our historical activities; design and integration of space instruments, as well as operation of our unique set of environmental test facilities.

As a consequence of the team excellence, CSL rapidly acquired a recognized expertise in thermal analyze from ESA which highly contribute to shape the team today.
But the lab is much more than "thermal analyses focused" and has developed a range of specific skills allowing the lab to participate to international technological project as a key player and to become a reference in thermal control for space environment simulators. Amongst this wide spectrum of world class competences, we want to highlight:

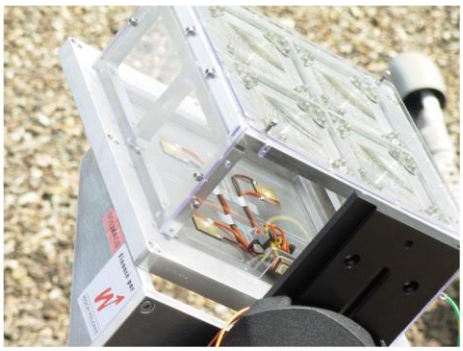
- Cryogenics
- Space mechanisms for optical instruments (working under harsh environment)
- Solar concentration
- Thermal control

You may discover stringent applications of this expertise in the projects below.

- Solar Orbiter EUI
- Proba V
- Multiphy
  and in particular

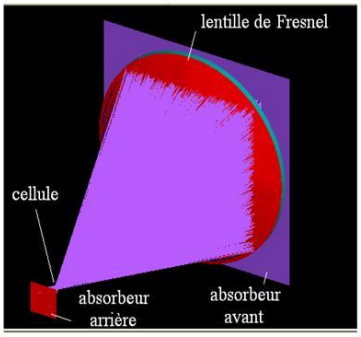
SOLMACS

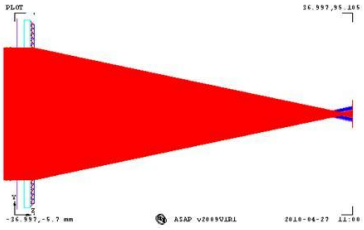
SOLMACS is research project obtained in the frame of Future Energy call, launched by the Walloon Region. Project objective is to develop a new type of solar panel based on high concentration technology. It provides the advantage to reduce the amount of active solar cell materials, and is optimized for sites of small and medium scale electricity production where solar conditions are favorable.

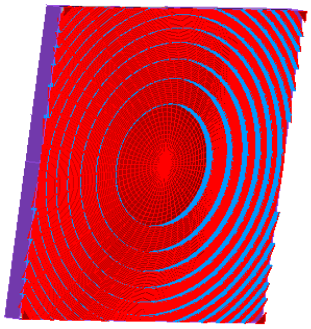


In collaboration with ATHOL and SIRRIS, a demonstration prototype has been manufactured using Fresnel lens realized by plastic injection to highly concentrate (more of 500 times) sunlight on high efficiency small cells (1.7mm x 1.7mm).
The global efficiency of the module is 28 %, knowing that the used photovoltaic cells have an intrinsic efficiency of 35 %.

This level of performance has been obtained by optimization of optical and thermal design, performed by CSL team.

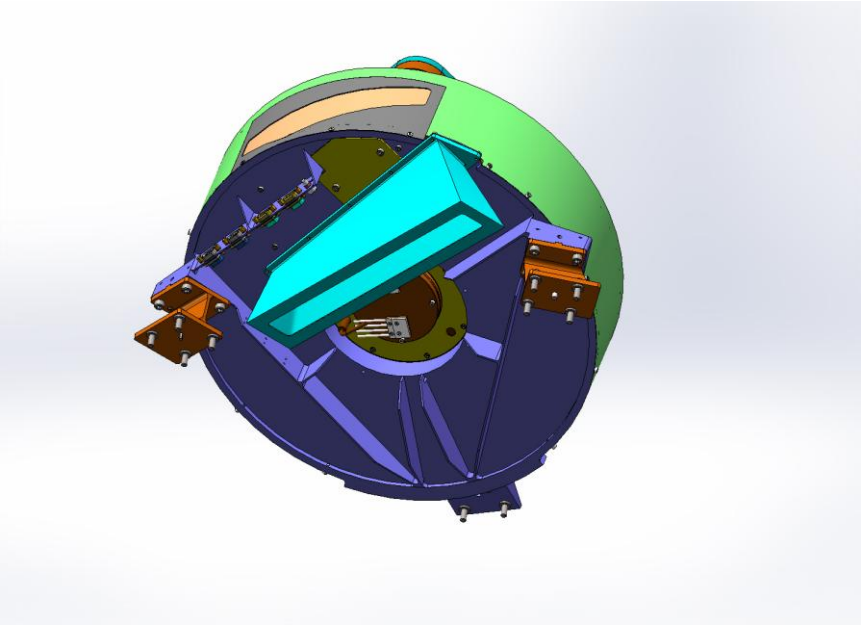




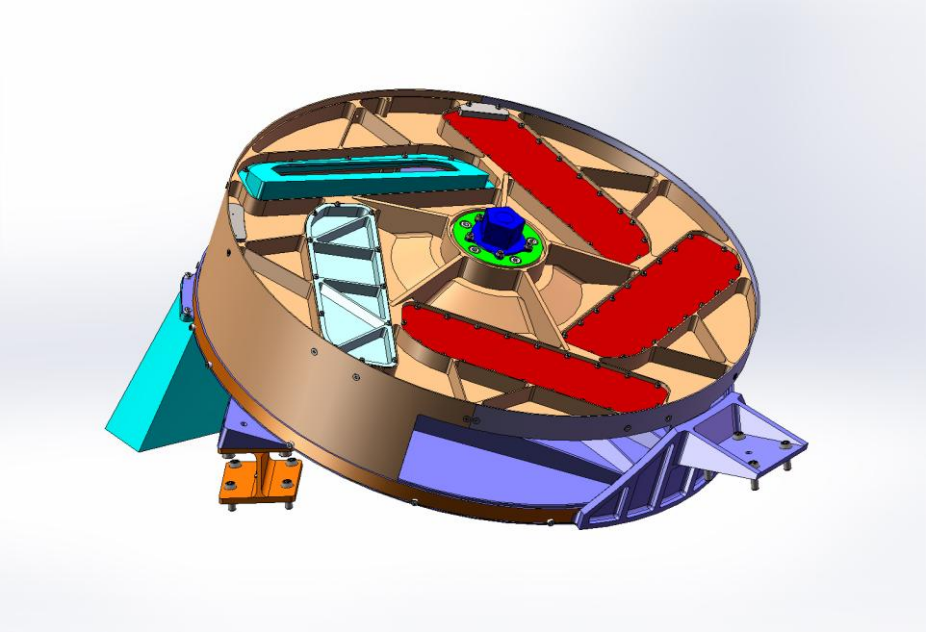


MAJOR EQUIPMENT AND MATERIAL

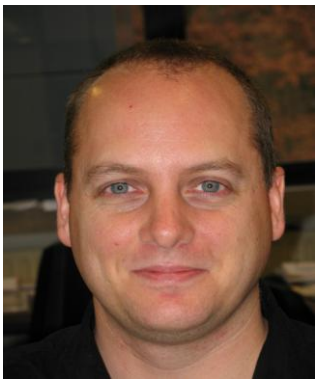
- Cryogenic test benches
- ESATAN-ESARAD stations
- Thermal and Mechanical workshop (illustration of some productions hereunder).



OLCI Calibration assembly with and without protection



6. Surface Engineering Laboratory *(Resp. K. Fleury)*



Surface coating for space applications

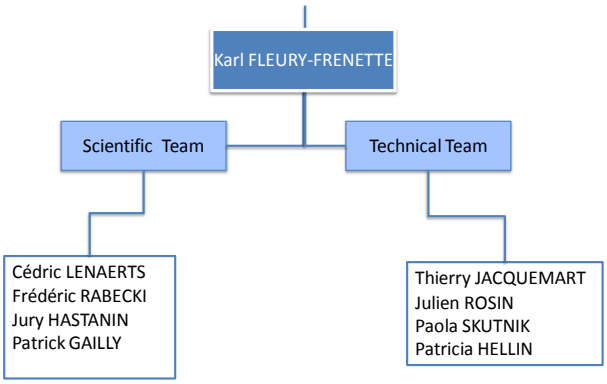
Surface micro texturing

Laser ablation process

Ion Beam Polishing

The Team

The team consists in 9 persons who are presented in the following organization chart.



This activity came as the answer to a very simple question: how to get a perfect shape and quality for our space instrument optics?
Working on mirror or lens surfaces at the sub structural level was the answer. And very quickly, you discover that the surfacing techniques you imagine to make this happen have thousands of other applications, widely over passing the initial field of optics to spread on light management, solar energy, sensors or connectics, just to mention the most recent experiences.
Today, our lab mastered surface treatments based on deposit coatings, ion beam figuring, reactive plasma etching, surface micro texturing and related metrology. Some of the techniques or applications developed at CSL are extensively used by the industry.
This is the way we want to expand our expertise illustrated below through very significant achievements in projects like:

- Solar Orbiter EUI
- Multiphy
- Microbiomed

and in particular

PLASMOBIO [Advanced microtechnologies for biological instrumentation]

Program Interreg IV FWVL

First France-Belgium consortium on this subject, PLASMOBIO is a multidisciplinary project grouping biologists, physico-chemists, physicists and micro-technology experts, investigating several scientific issues. To facilitate an efficient valorisation of the project results and communication, Eurasanté, economic development agency, will also be part of the consortium.

Chemistry and topography of sensing surfaces play a major role in SPR instruments performance. Therefore, one of the objectives of PLASMOBIO is to improve surfaces characterisation and functionalisation. Using micro-structures, micro-patterning techniques, localised SPR (LSPR), this research project aims to create new plasmonic sensitive interfaces adapted to clinical applications.

It is known that surface based binding analyses such as SPR are influenced by the transport of analytes to the sensing surface. Conventionally, pressure driven flows are used in SPR devices leading to high products and sample consumptions. Therefore, PLASMOBIO proposes to develop a droplet based SPR biosensor using microstreaming techniques (EWOD, SAW) coupled to Localised SPR biosensing.

Optical Integrated Circuits in SPR systems are investigated to create particular sensing arrangements and therefore enhance analysis performances. This project also proposes to design new microcantilever-based biosensors which can assay analytes in low concentrations.

By combining these technologies, PLASMOBIO aims to create fully integrated SPR-based biosensors dedicated to medical applications. Therefore, to demonstrate the efficiency of prototypes developed in PLASMOBIO, part of the project will consist in identifying relevant biological models.

Project partners :

1. Université des Sciences et Technologies de Lille (USTL), chef de file du projet (IEMN, l'Institut d'Electronique, de Microélectronique et de Nanotechnologie, "BioMEMS" et "Optoélectronique")

2. IRI, l'Institut de Recherche Interdisciplinaire ("Biointerfaces"),
3. PhLAM, Laboratoire de Physique des Lasers, Atomes et Molécules (groupe de recherche "Photonique")
4. Université de Mons Hainaut
5. Université de Liège (Centre Spatial de Liège et service d'optique de la Faculté des Sciences, Hololab)
6. Université de Lille 2 Droit et Santé, (IMPRT)
7. EURASANTE

MAJOR EQUIPMENT AND MATERIAL

Instruments of the Surface Micro & Nano Engineering Laboratory.

Thin films deposition facilities:
- Ion beam sputtering
- Magnetron sputtering
- Evaporation

Laser processes
- Laser-induced forward transfer (LIFT)
- Laser ablation
- Laser generation of nanoparticles

Ion and Plasma processes
- Ion beam figuring
- Dry etching

Photolithography
- Direct laser writing
- Soft-UV lithography

Micro & nanostructures replication
- Nickel electrolysis
- Hot embossing station
- Soft-UV embossing station

Characterization
- Ellispsometers (coating thickness and refractive index over 280nm-25µm)
- Spectrophotometers (reflectivity, absorption, solar absorptance and and transmission, 190nm-25µm)
- Refractometer (refractive index of liquid)
- Contact angle (surface wettability)
- Four-point probe (electrical resistivity)
- Flash thermoreflectance (thermal diffusivity of thin films and bulk materials)
- Surface plasmon resonance (liquid analysis)
- Scanning electron microscope (surface topology)
- Optical profiler (surface topology)
- Atomic force microscope (surface topology)

7. Electronics Laboratory *(Resp. N. Martin)*

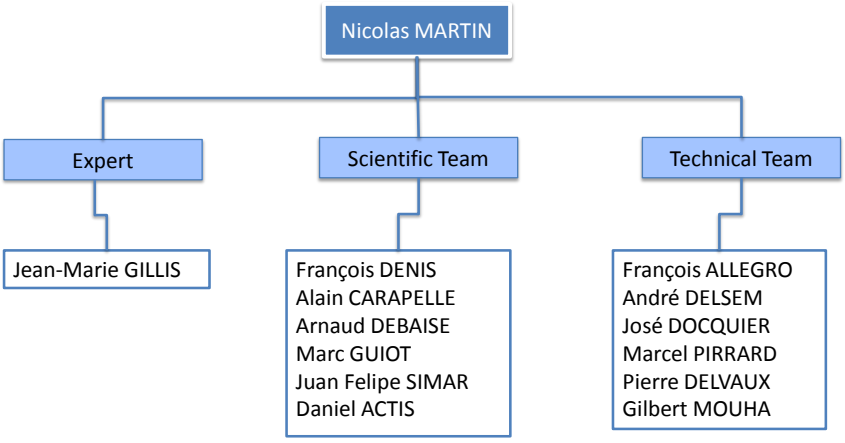
Embedded hardware and software dedicated to severe environment (vacuum, temperature, radiation).

Material sensors and transmission systems (wireless) for flight, or environmental monitoring under extreme conditions.

Design of ITAR free solutions

The Team

The team consists in 14 persons who are presented in the following organization chart.



Competencies

The competencies of the CSL laboratory of electronics are the following:

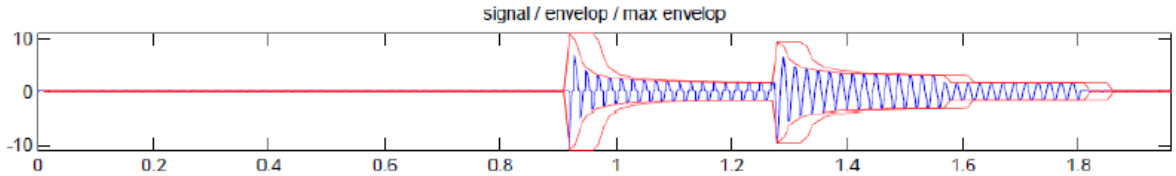
We have specialists in microcontrollers, in digital electronics and especially in analog circuits (low and high levels). Power electronics, high voltage and electromagnetism are also used. A lot of devices are conceived and designed every year. The design and construction of camera prototypes (star observation) is also part of the experience of the laboratory for over 30 years.
Our work is based on customer specifications (SABCA, Techspace Aero, ...).
Smart sensors are also designed and prototyped for RW and European projects. EGSE are developed and manufactured for private companies like ETCA in Charleroi.

Electrical control panels for thermal systems are also developed and manufactured for ESA-ESTEC (among others).

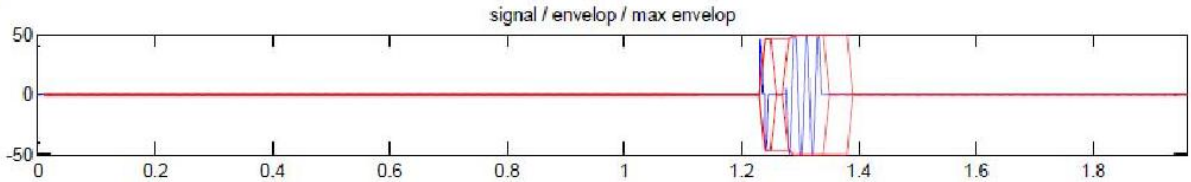
Major events

HM+ project (Health Monitoring),

The objective of this project is to decrease the maintenance cost, representing today around 25 % of total airplane ownership cost. This is achieved by development of predictive maintenance (health monitoring).
HM+ is funded by the Walloon Region in the frame of the SKYWIN aerospace cluster.
In this frame, in collaboration with THALES ALENIA SPACE ETCA, a bench test for electrical arc fault generation is operational at CSL, providing a useful tool for test and validation of algorithms for arc fault detection.



Exemple of serial arc



Exemple of parallel arc

Arc Fault Generation Bench Test at CSL - Position sensor working at cryogenic temperature.

In parallel, and following the technical requirements from TECHSPACE AERO, a rotational position sensor working through metallic wall under cryogenic environment has been studied and prototyped at CSL. Performance tests achieved in December 2009 showed an angular accuracy of 0,01° measured at 4K. 0.01° of accuracy is performed between 4K and 300 K. In this interval a very light drift of 0.01° is observed.

Materials for the same measurements at high temperature (600 °C) have been studied.

TRIADE

TRIADE is an FP7 project, whose objective is the development of technology building blocks for structural health monitoring sensing devices in aeronautics. The industrial coordinator is EADS France. The other partners are DASSAULT AVIATION, EUROCOPTER SAS, GOODRICH, PZL ZWIDNICK and some others. CSL is involved in different work packages, whose purposes are development of neural computation and study of mechanical and thermo-mechanical stresses.

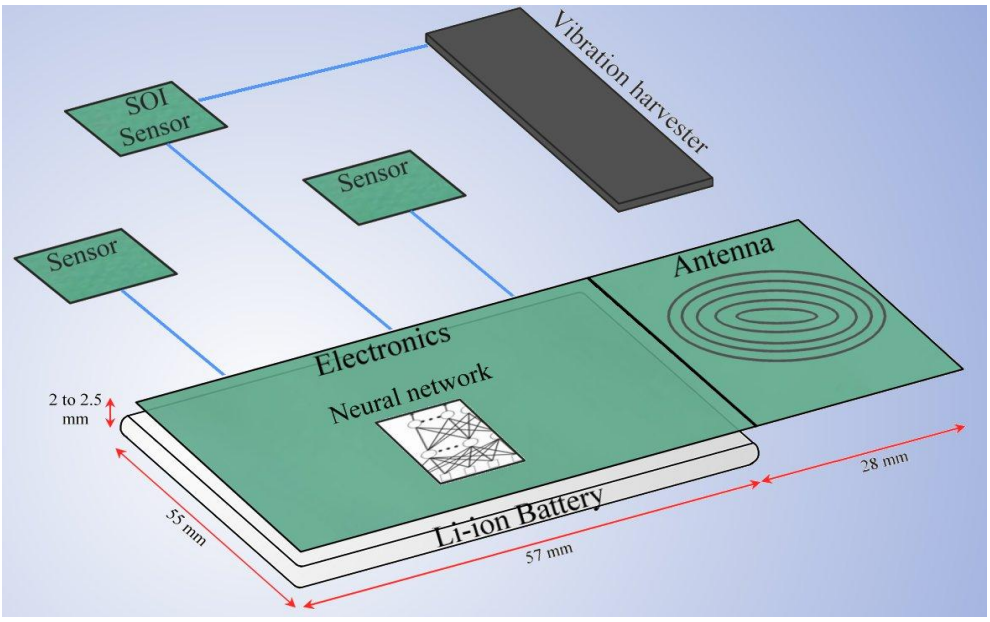
TRIADE will provide technology building blocks and fully integrated prototypes to achieve in-situ:

- power generation, power conservation
- embedded powerful intelligence-data processing/storage
- energy management

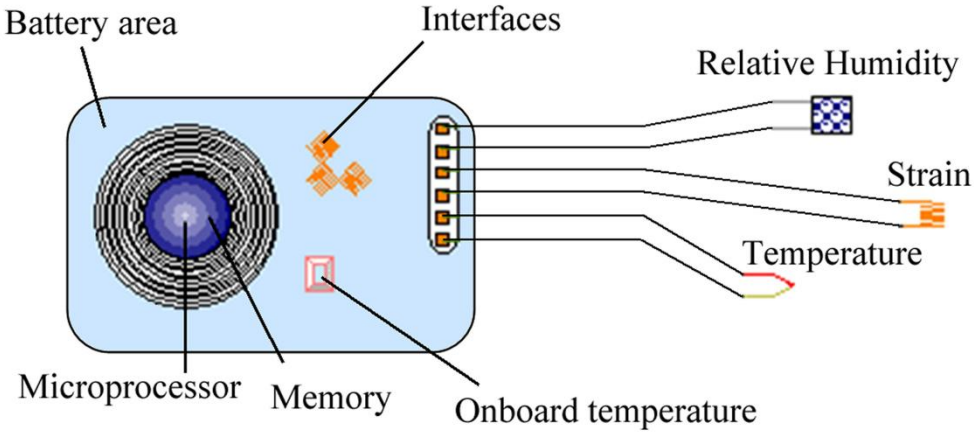
for structural health monitoring sensing devices in aeronautics.

The main characteristics are:

- size of a credit card,
- remote sensors,
- embedded under the last composite layer or similar,
- RF communications,
- expandable
- less than 100 €/unit,
- start/stop when the system starts/stops,
- monitor temperature, relative humidity, pressure, strain, vibration and acoustic emissions



Principle schematic 1



Principle schematic 2

1. Battery (high energy density and harsh environment),
2. Power management and energy harvester (vibrations and electromagnetic RF harvester),
3. Ultra low power sensors (design electronic blocks in SOI),
4. Neural network (for data recording and damage assessment).

- Memory storage capacity,
- RF link.

8. Quality Assurance Laboratory (*Resp. V. Descamps*)

Contamination check and expertise (Spectrometry)
Cleanliness control
Metrology

The main activities of the QA Laboratory are:

Detection of organic contamination by infrared spectroscopy

Organic contamination monitoring is performed to verify that the stringent contamination and cleanliness specifications applied to spacecraft materials and associated equipment are met.

The QA Laboratory realised quantitative analysis of organic contaminants by Fourier Transform InfaRred spectroscopy (FTIR) according to the indirect method defined in the ESA_ECSS-Q-ST-70-05C standard. Following this standard, three groups of contaminants are determined (hydrocarbons, esters and silicons). The results obtained for each group of contaminants (of an equivalent amount of the standard material) are reported in terms of mass per surface area in units of g cm^{-2}.

In 2010, the QA Laboratory performed 315 analyses with:

- 220 analyses for several space projects managed at CSL (i.e.: OLCI, MIRI (JWST), ALADIN, Solar Orbiter, etc) and including monitoring of the CSL's clean rooms and,
- 95 analyses for external customers (SODERN, AMOS, CNRS, EADS, XENICS, etc).

In 2011, the QA Laboratory performed 267 analyses with:

- 164 analyses for several space projects managed at CSL (i.e.: ProbaV, OLCI, MSI diffusers, GAIA TNO, GAIA RVS, Solar Orbiter EUI, etc) and including monitoring of the CSL's clean rooms and ,
- 103 analyses for external customers (SODERN, AMOS, CNRS, EADS, XENICS, etc).

FTIR laboratory equipments

Humidity tests in a climatic chamber

The QA laboratory is also equipped of a climatic chamber to performed reproducible tests with precise climatic conditions. Applications are various in all sectors of development and qualifications such as to demonstrate the ability of the equipment to withstand the humid environment, product shelf testing, stability testing, accelerated ageing test, etc

In 2010 and 2011, the QA Laboratory performed qualification tests for space projects such as Solar Orbiter EUI, MSI Diffusers, GAIA TNO, OLCI, etc

Monitoring of particle contamination

In the framework of the CSL programmes, it is committed to work with a strict contamination control program, depending of the specific payload requirements.
For the monitoring of particles contamination, the QA laboratory performed measurements with the following methods, which have been selected for their practicality and relevance thorough the different on-ground AIV/AIT phases:

- **Airborne contamination:** in each clean room, 3 airborn counters are running permanently with a 1 hour delay between each measurement. These instruments allow to qualify the working areas (class 10000 i.e. ISO7 and class 100 i.e. ISO5 according to ECSS.Q.20.07A.

- **Deposited particles (PFO system) :** The particle fall out system (ESA License) measures the particles that are deposited onto surfaces. Fall out witness sensors are exposed during at least 24 hours. The results (given in ppm [part per million – mm²/m²] per 24 hours) provide the level of particles contamination of the surface. A number of witness sensors are distributed over each CSL's clean room.
  This system is an easy counting system and may also be used for external needs. Some customer and/or sub-contractors are using it, by asking CSL to send one or more PFO witness sensors. They are safely and securely packed, send to the customer premises and returned back to CSL for measurement. Report is provided to the user.

PROGRAMMES

1. Test Programmes *(Resp. C. Grodent)*

1. Introduction

In the frame of the ESA ALADIN program, CSL is involved in the Space Environmental Testing of the complete instrument. Additionally, CSL will be responsible for the final thermal vacuum qualification of the complete Aeolus Spacecraft together with the instrument flight model to be carried out by end of 2013.
The OSTM (Optical, Structural and Thermal Model) has been tested in 2007 and some additional activities have been carried out in the 2010-2011. They are detailed here below.

2. Mission description

The ADM (Atmospheric Dynamics Mission) Aeolus is an ESA satellite developed to observe the global wind profile and aerosols and then improve the weather forecasting. The CSL Customer is EADS Astrium Toulouse. The main instrument is called ALADIN (Atmospheric Laser Doppler Instrument). It is a Space Based LIDAR (LIght Detection And Ranging) instrument.

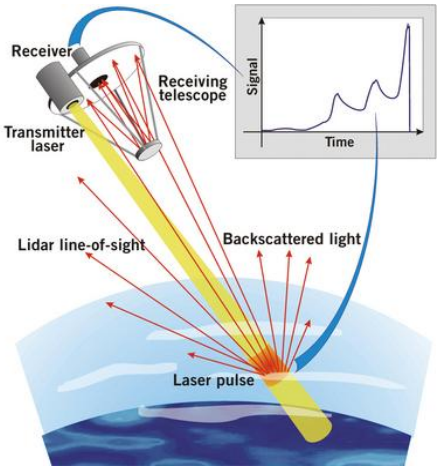
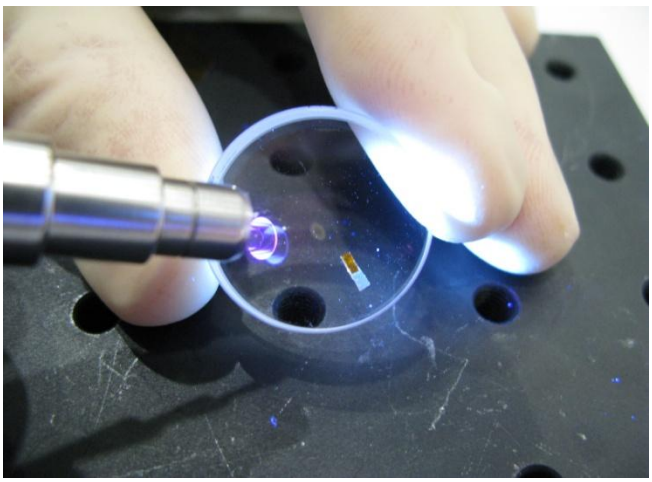


Figure 1, LIDAR instrument

These instruments are generally faced to LIC (Laser Induced Contamination) problematic due to the use of high powered laser together with optical components and potential contaminants.
As a consequence, the associated risks are some deposit on irradiated surfaces, the degradation of optical performances and some irreversible damage of optical components.

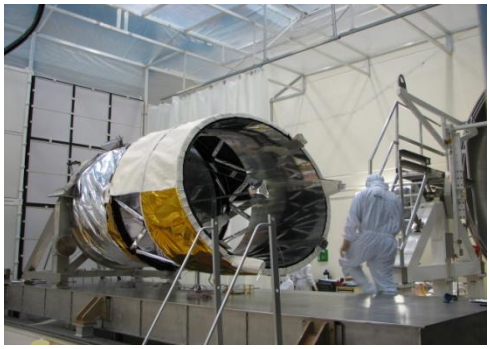


Observed LI Contamination on optical sample

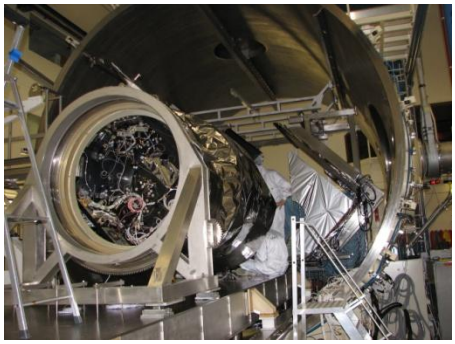
CSL has participated to the LIC measurement campaign for quantifying potential contaminants and to improve the final thermal vacuum test set-up to be installed for the final qualification of the complete instrument.

3. Test campaign description.

The ALADIN Telescope has been installed inside the Focal 5 chamber and, once the vacuum is obtained, the high powered laser is activated by EADS and LIC measurements are performed on optical samples.
Various trials have been done to finally obtain an acceptable and compliant test set-up



Integration of the Telescope on Focal 5 bench (ISO5 cleanliness)



Preparation Phase

Some contaminants have been identified like

- Metallic staples
- Kapton scotch and glue
- Aluminium parts
- Non baked Kapton foils
- Mechanical items not perfectly cleaned

Consequently, CSL has also been requested to perform various bake-out tests on MLI, thermal shrouds and the complete Telescope. Any bake-out test is permanently controlled with TQCM.

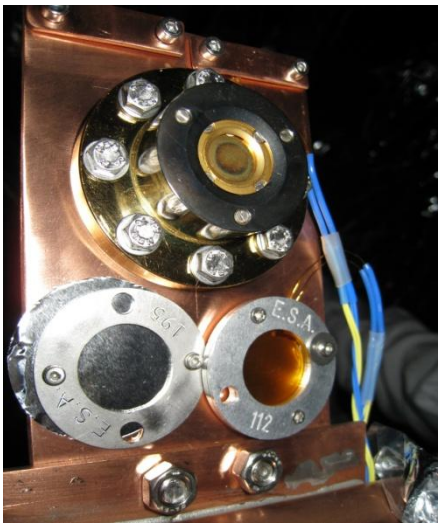


Figure 2, TQCM head

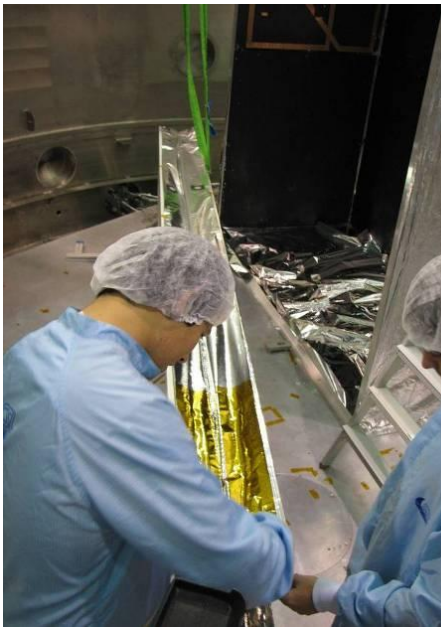
This successful campaign has involved many people with various competencies.
For the preparation phase, from the preliminary design to the final integration, thermal and mechanical competencies are mandatory. AIV operations are performed like cabling, instrumentation check, shrouds mounting, leak check, MLI covering, cleaning…
Additionally, the required cleanliness level (ISO5) induces a permanent monitoring and analysis from the PA/QA team.
The CSL optical experts contribute also to the project with their advices and recommendations.
Finally, during the vacuum tests, the facility is permanently under full survey thanks to the help of the whole technical CSL staff

Other Campaigns either in thermal vacuum or in vibrations

GAIA DSA for Sener, Spain

The GAIA project was present in most of the CSL facilities. In Focal 6.5, the DSA (Deployable Sunshield Assembly) has been tested in a dedicated thermal tent. The opening of the Sunshield was done at different temperatures and an ESA canister has controlled the deployment movement in live.

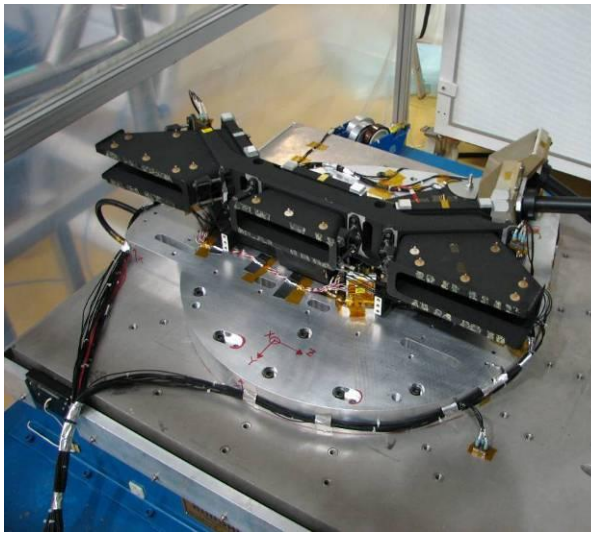
DSA integration in the thermal tent with the ESA canister

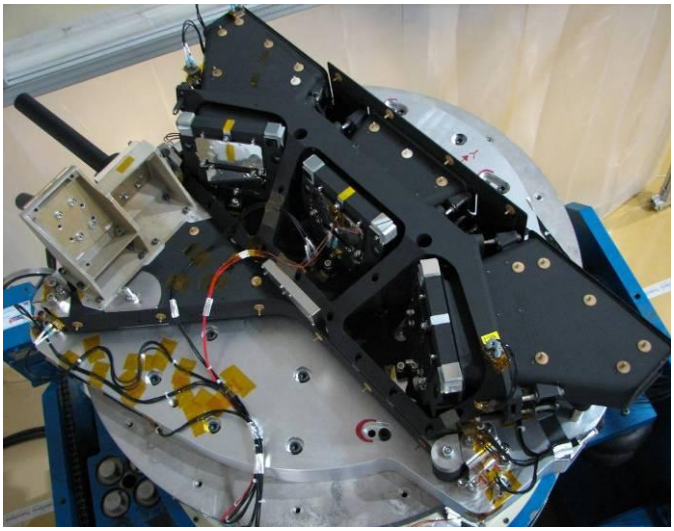


DSA preparation by the Sener team

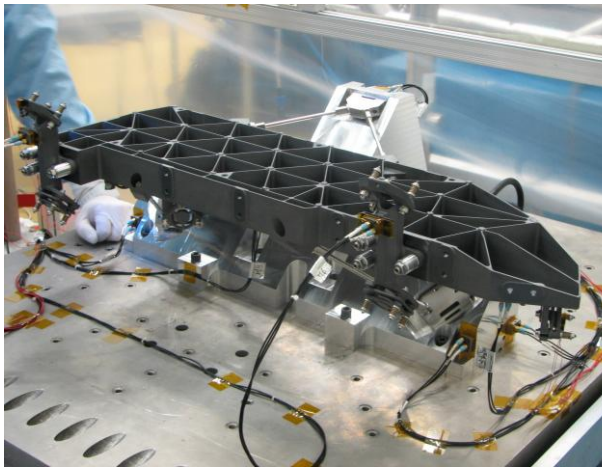
GAIA DSA team (Sener + CSL)

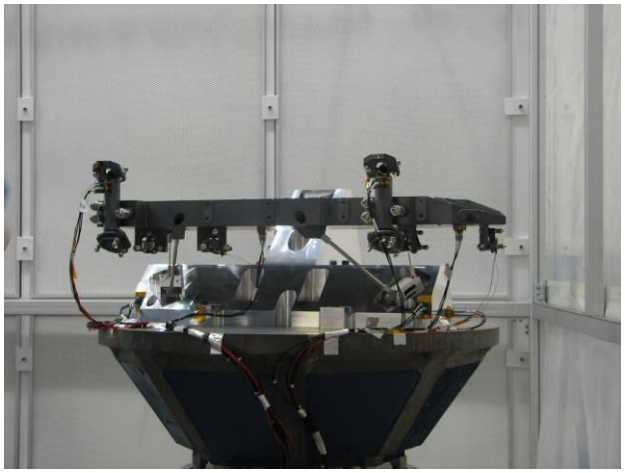
PROBA V STM for OIP - June 2010



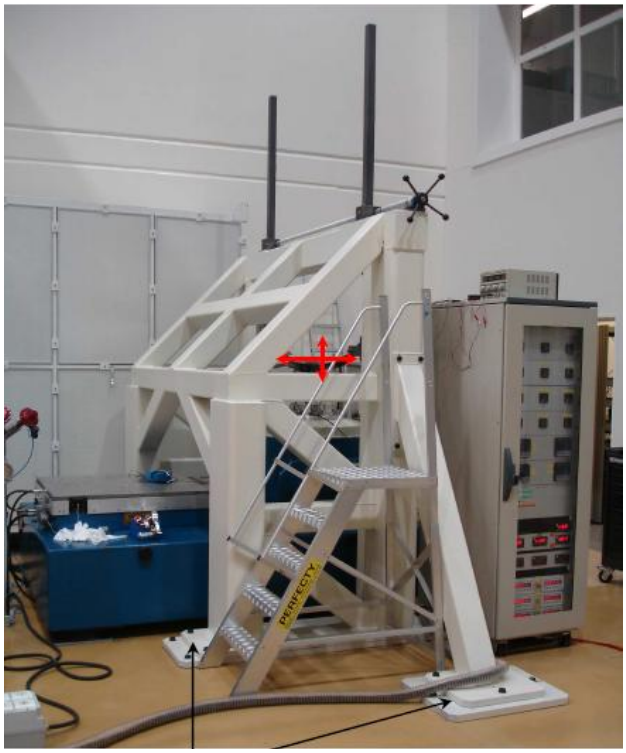


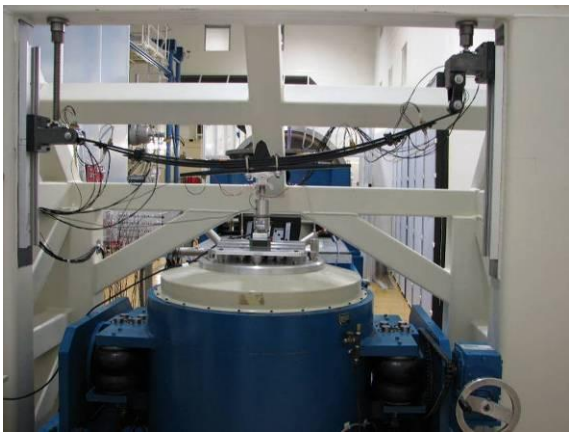
GAIA BAM OMA Bar#1 SM for TNO February 2010



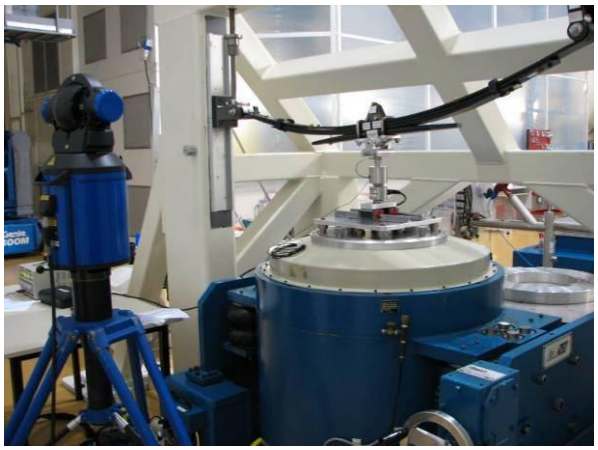


TOYOTA for Samtech (Belgium) – January 2011





Dynamic measurements at different Pre-loads [kN]



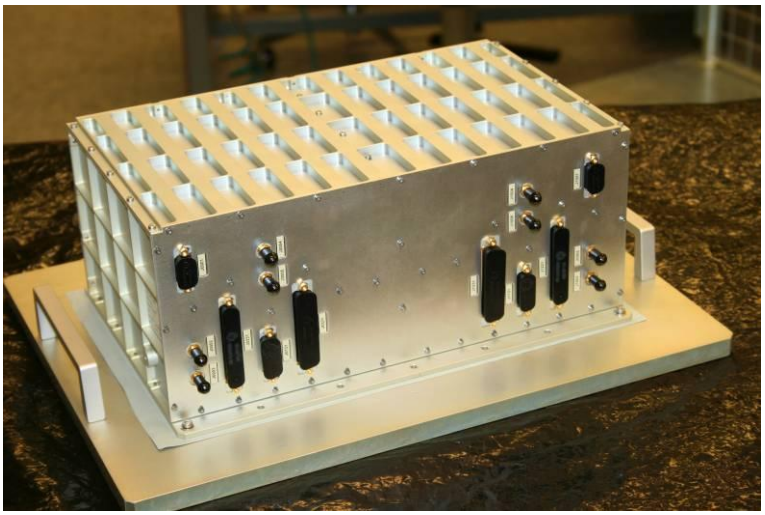
Static measurements (displacement vs Pre-load) with laser tracker

2. Space System Programmes *(Resp. E. Renotte)*

Major Programs

JWST MIRI (2004 – 2010)

MIRI is one of three instruments on the James Webb Space Telescope (JWST) and will provide imaging, spectroscopy and coronagraphy at wavelengths between 5 and 28 µm. The project is an international partnership (50 / 50) between JPL and a nationally funded consortium of European institutes, working with ESA and NASA. MIRI is designed to meet the science requirements of JWST for mid-IR capabilities. The European Consortium will design, build, integrate, and test the instrument "optical bench assembly" (consisting of an imager and two spectrometer modules, together with the focal planes and the associated electronics provided to us by JPL). It is led by Gillian Wright (UK), along with France, Germany, The Netherlands, Sweden, Ireland, Switzerland, Denmark, Spain and Belgium. The project is managed by EADS-Astrium, Ltd. The contributions of the CSL are the Input Optics and Calibration Unit (IOC), the Instrument Control Electronics (ICE) and various optics (mirrors and prisms) for the French Imager (MIRIM). MIRI is to be shipped to NASA in early 2012. JWST launch is scheduled in 2018.

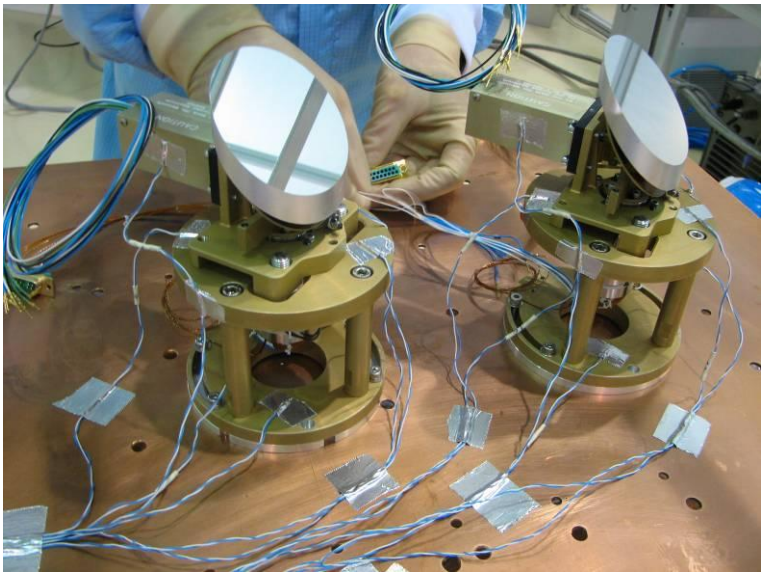


MIRI Instrument Control Electronics (ICE).

MIRI IOC integrated with MIRI deck.

JUNO UVS (2007 – 2010)

Juno, a NASA New Frontiers mission, has been launched in August 2011. JUNO plans for a 5-year cruise and 14 months around Jupiter after arriving in August 2016. Juno will study Jupiter from a highly elliptical orbit, in which the spacecraft dives down over the north pole, skims the outermost atmosphere, and rises back up over the south pole. Juno carries an Ultraviolet Spectrograph (UVS) to make spectral images of Jupiter's aurora. UVS is a UV imaging spectrograph sensitive to both extreme and far ultraviolet emissions in the 70-205 nm range that will characterize the morphology and spectral nature of Jupiter's auroral emissions. Juno UVS consists of two separate sections: a dedicated telescope/spectrograph assembly and a vault electronics box. The contributions of CSL to UVS are the scan mirror mechanism and its driver card.

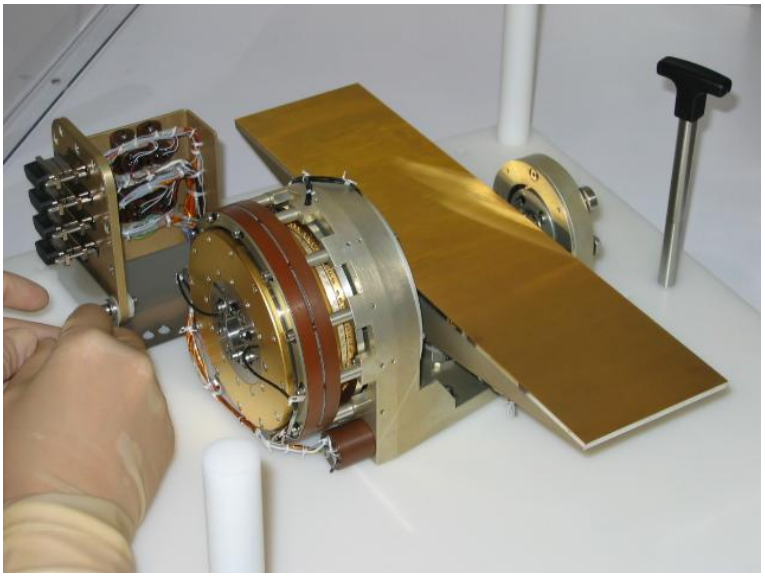


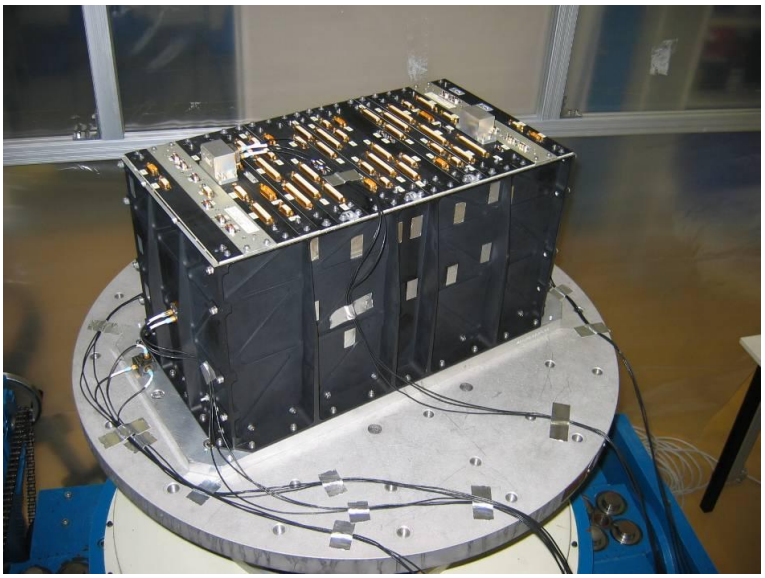
JUNO UVS Scan Mirrors being prepared for thermal-vacuum test at CSL.

JUNO launch, 5 Aug 2011, from Cape Canaveral.

Herschel PACS (1997 – 2009)

PACS is one of three science instruments for ESA's Herschel Space Observatory. It operates either as an imaging photometer or an integral field spectrometer over the spectral band from 57 to 210 µm. PACS is designed, built and operated by a consortium of institutes and university departments from across Europe under the leadership of Principal Investigator Albrecht Poglitsch located at Max-Planck-Institute for Extraterrestrial Physics, Garching, Germany. Consortium members are: Austria: UVIE; Belgium: IMEC, KUL, CSL; France: CEA, OAMP; Germany: MPE, MPIA; Italy: IFSI, OAP/OAT, OAA/CAISMI, LENS, SISSA; Spain: IAC. The contributions of the CSL are the diffraction grating mechanism, the detector and mechanism controllers and the warm interconnecting harness. The Herschel observatory has been successfully launched with an Ariane 5 from Kourou on 14 May 2009. PACS is now performing routine operations until February/March 2013 when Herschel will run out of helium, precluding any further observing.


PACS Grating Mechanism.

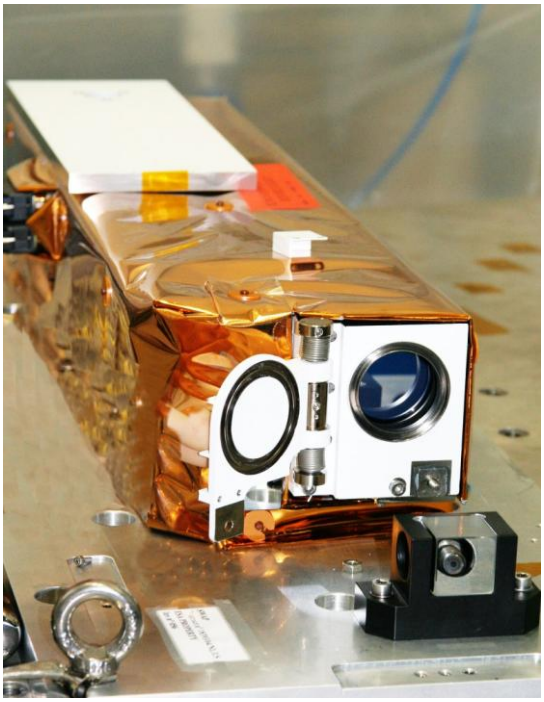


PACS Detector & Mechanism Controller (DEC/MEC) on CSL's shaker.

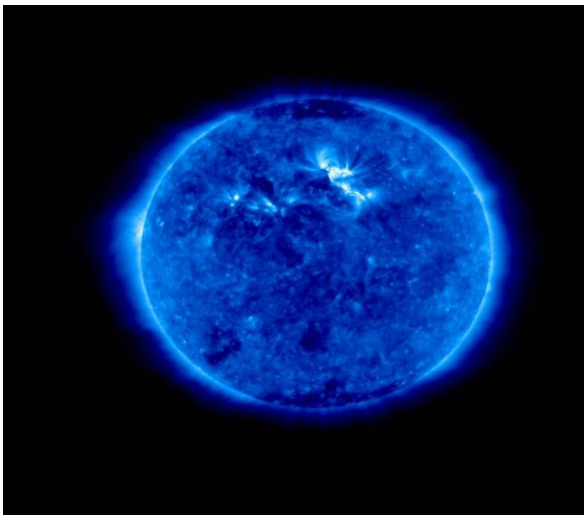
Herschel launch from CSG (14 May 2009).

PROBA-2 SWAP (2004 - 2009)

SWAP (Sun Watcher using Active Pixel system detector and image processing) is a solar imager in the extreme ultraviolet (EUV) on the PROBA 2 technological platform, an ESA program. SWAP uses an off-axis Ritchey Chrétien telescope equipped with an EUV enhanced active pixel sensor detector (coated APS). SWAP provides solar coronal images at a 1-min cadence in a bandpass centered on 17.5 nm. Observations with this specific wavelength allow detecting phenomena, such as solar flares or EIT-waves, associated with the early phases of coronal mass ejections.
PROBA-2 has been successfully launched with a Rockot launcher from the Plestesk Cosmodrome in Northern Russia on 2 Nov. 2009.



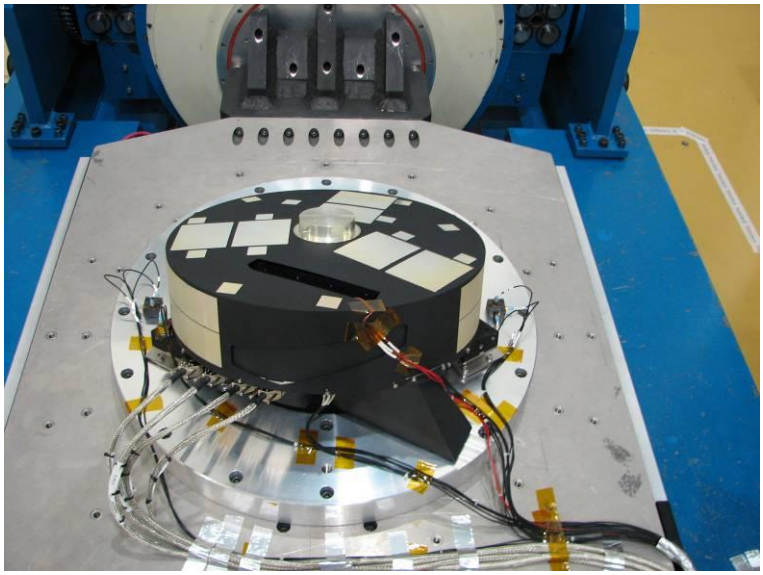
SWAP Instrument with front cover open.



An image of the Sun taken by SWAP.

Sentinel-3 OLCI (since 2008)

The Sentinel-3 mission of the ESA's GMES Space Component Programme is devoted to operational oceanography and global land application, thanks to its payload composed of a set of optical and microwave instruments. It requires the concurrent operations of two similar satellites in orbit; additional satellites are then required to provide the sustained operational services over a minimum period of twenty years following the first satellite launch. The Ocean and Land Colour Instrument (OLCI), based on Envisat's MERIS instrument, fulfils ocean colour and land-cover objectives. In this project, CSL has been selected by the OLCI Prime, TAS-F, for the provision of the Calibration Assembly and the ground characterisation of the calibration diffusers.

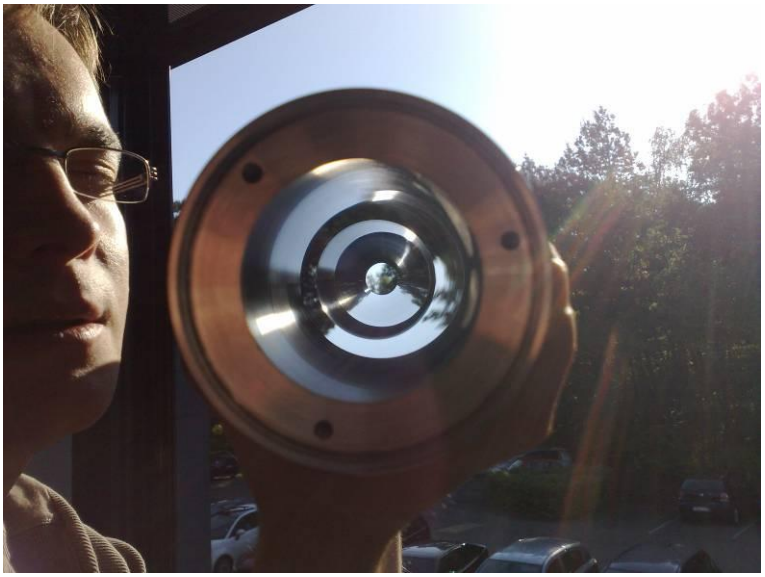


OLCI Calibration Mechanism on CSL's shaker table.

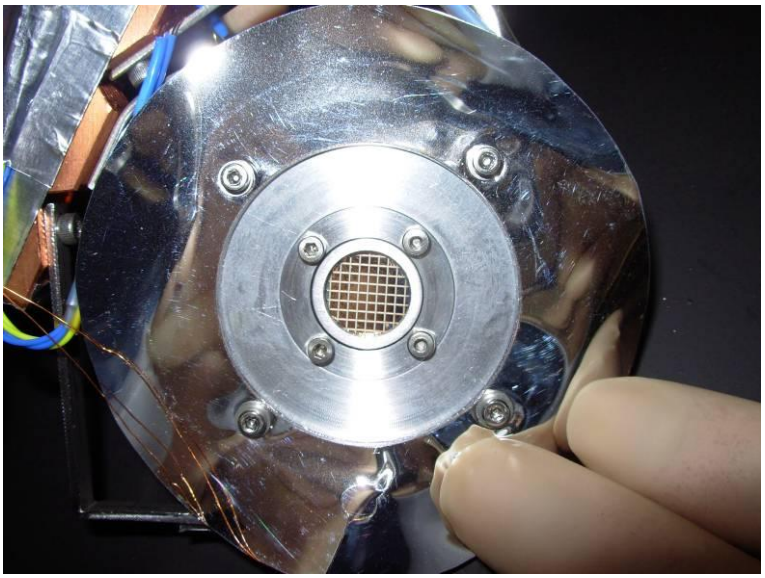
OLCI Calibration Diffusers (PTFE) mounted on their wheel disk.

Solar Orbiter EUI (since 2006)

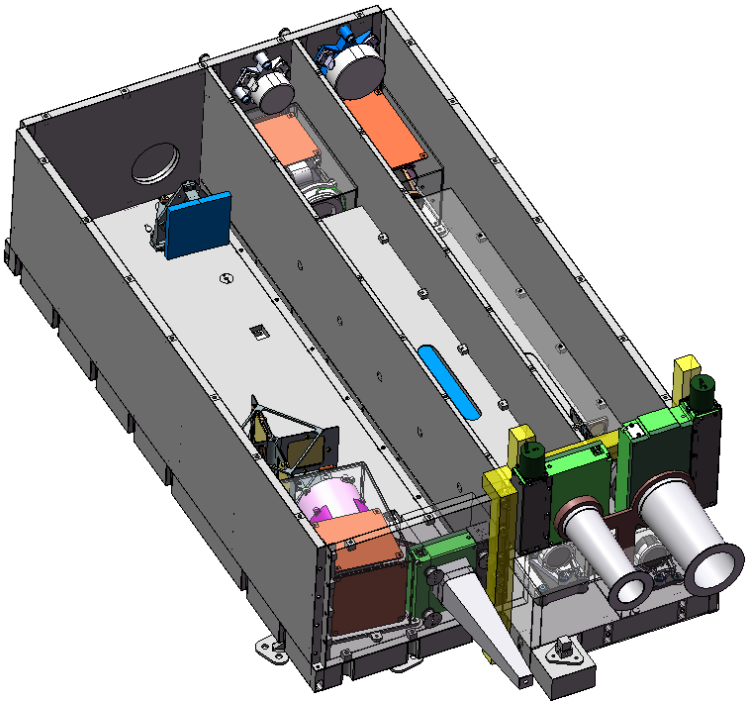
On the 4th of October 2011, Solar Orbiter has been selected by the ESA's Science Programme Committee (SPC) as the M1 mission of the Cosmic Vision programme, to be launched in 2017.
Solar Orbiter will provide the next major step forward in the exploration of the Sun and the heliosphere to investigate many of the fundamental problems remaining in solar and heliospheric science. It includes both a near-Sun and a high solar latitude phase. The near-Sun phase of the mission enables the spacecraft to approach the Sun as close as 0.28 Astronomical Unit (AU) during part of its orbit and thereby permitting observations from a quasi heliosynchronous vantage point. The satellite will co-rotate with the Sun, as at these distances the angular speed of a spacecraft near its perihelion approximately matches the rotation rate of the Sun. This characteristic enables the instruments to track a given point on the Sun surface for several days. According to this spacecraft configuration, several surfaces, components and subsystems shall be directly exposed to a solar flux profile ranging from 0.5 SC up to 13 SC.
The EUI instrument suite is composed of two high-resolution imagers (HRI), one operating at Lyman-α and one at 174Å, respectively named "$HRI_{Ly\text{-}\alpha}$" and "HRI_{EUV}", and one dual band full-sun imager (FSI) working alternatively at the 174 and 304 Å EUV passbands. The HRI and FSI images are produced by a two-mirror and a one-mirror telescope respectively, working in near normal incidence. The EUV reflectivity of the optical surfaces obtained with specific EUV multilayered coating provides the spectral selection, complemented by filters rejecting the visible and IR radiation. The UV photons reach the detectors (back-thinned APS of 10µm 2k x 2k for the HRI channels and 10µm 3k x 3k for the FSI channel) where they are converted into electrical signal in a front-end electronic (FEE), before being compressed and stored in the CEB (common electronic box).
The CSL is the PI Institute of the EUI Consortium including members from Belgium, France, Germany, Switzerland and United Kingdom.



Solar Orbiter EUI heat rejection baffle prototype.



Solar Orbiter EUI entrance filter prototype under test at CSL.



Solar Orbiter EUI instrument CAD view (without cover).

3. Technology Programmes *(Resp. JH Lecat)*

Major programmes

MIRAGE

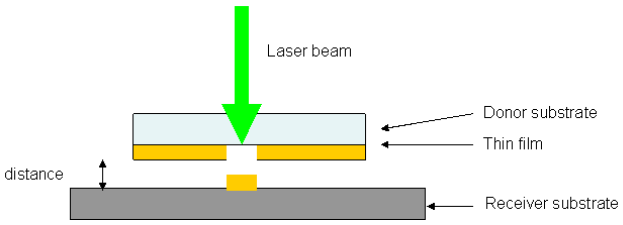
MIRAGE is a set of technological projects borne by a consortium of 24 industrial and academic partners coordinated by ARCELOR and AGC GLASS, with two main objectives:

- ✓ Research of active surface coatings as tools for a better environmental management.
- ✓ Development of a technology platform in order to allow industrial valorization of innovative concepts.

MIRAGE is funded by the Walloon Region, in the frame of the MECATECH cluster.

In this project, CSL research teams have contributed to the following topics:

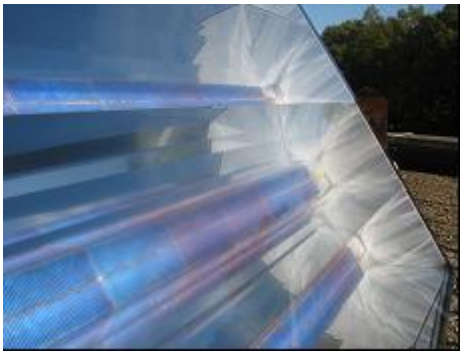
- ➢ Development of local coating deposition induced by laser (LIFT) for connection application in industrial process



- ➢ Experimental and theoretical study for the encapsulation process of electrochromic and thermochromic coatings.
- ➢ Development of flexible encapsulation method allowing optimization of outcoupling and angular distribution of emitted light for OLED.

- Development of metrology tools and experimental set-up for performance characterization of AGC & ARCELOR new mirrors concepts related to Solar Thermal Power application.

- Prototyping of solar concentration technology for photovoltaic industry.



MICROBIOMED (MICROtechnologies for BIOMEDicine application).

This project has been selected in the Operational Programme INTERREG IV-A Euregio-Maas-Rijn. It aims to develop a network of expertise in the fields of microtechnology applied to new products for biomedicine.

The following partners are present on the project:

Academisch Ziekenhuis Maastricht

GIGA

Interuniversitair Micro-Electronica Centrum (IMEC)

Experimental Medicine and Immunotherapy (EMI)

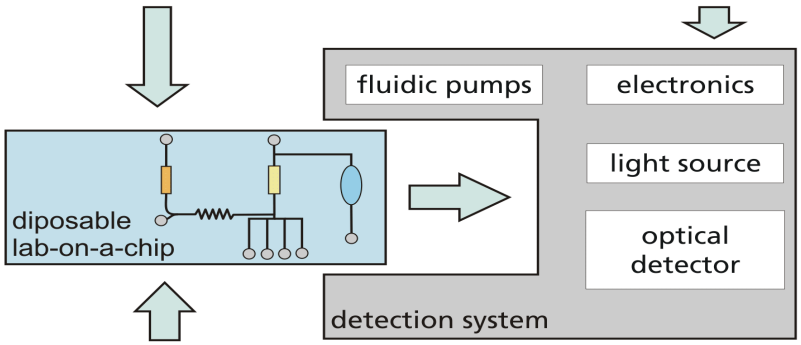
UHasselt, Instituut Voor Materiaalonderzoek (IMO),

Institut für Werkstoffe in der Elektrotechnik I, RWTH Aachen

Institut für Pathologie, U Aachen

Technifutur

The partners will develop a lab-on-a-chip demonstrator (design and realization of a low-cost, automated and highly sensitive diagnostic system) for the immunological detection of human diseases, in the framework of the in vitro diagnosis. Through a high level of automation and ease of use, the aim is to provide clinicians with a faster and more sensitive way to diagnose multiple pathogens in parallel (multiplexing of the detection capabilities), therefore eliminating the need for expensive and time-consuming laboratory testing.

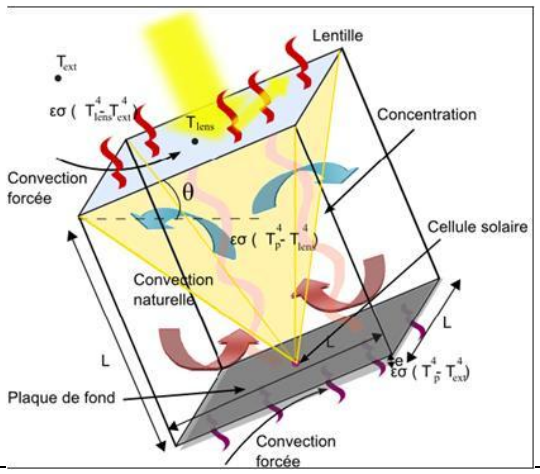


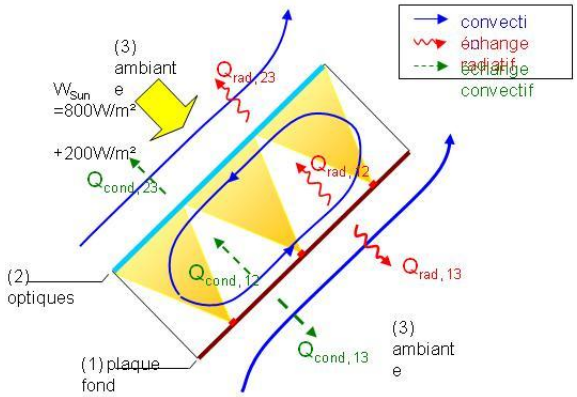
SOLMACS

See more details on page 59.

TNO GAIA

GAIA is an ESA mission, whose objective is to derive a three-dimensional map of our galaxy, providing information on its composition, formation and evolution.
TNO in The Netherlands is developing the all silicon carbide basic angle monitoring opto-mechanical assembly (BAM OMA) for this mission.
As subcontractor of TNO in this project, CSL has performed the operations of coating engineering, qualification and deposition on flight hardware, for the GAIA BAM sub-systems.





Successful Delivery Review Board of GAIA BAM subsystem has been achieved with ASTRIUM and ESA in end of January 2012.

By courtesy of TNO/ESA (Fred Kamphues)

Interreg Projects

a. **PLASMOBIO** [Advanced microtechnologies for biological instrumentation]

See more details on page 62.

b. **+ COMPOSITES** [Awareness and Transfer of Innovation in composite materials]

Program INTERREG IVB North West Europe

This project aims to reinforce innovation and technology transfer amongst companies in NWE, in order to provide support and assistance throughout the period of profound industrial change linked to the arrival of composite materials. The aim is to rely on the "technological centres of excellence" and on the dynamics that they have created in their area of expertise, whilst providing a favorable climate to generate the necessary synergies, which will allow us to reach our final objective. The objective of this project is to encourage technology transfer from these networks specialized in the field of composite materials to SMEs in NWE.

In terms of communication and education, the project expects to add value to 500-1000 SMEs, selected in the targeted sectors, among which 15 to 25 might even start their complete mutation to the composite technology, from the device design to the final disposal of the composites, in accordance with the rules of sustainability.

The question is to develop the most adequate tools to collect and share technological information (work package 1), and of developing a common program in the field of continuing education (work package 2). A common methodology for technology transfer is put into place, with the aim of encouraging innovation within the SMEs located in the geographical project area (work package 3). One of the objectives is also to encourage transnational cooperation between small and medium businesses, whilst aiming to improve the competitiveness of these networks on a global scale (work package 4). The approach is transversal. Target priority sectors are the transport industry (aeronautic, automotive, railway…) and related equipment capital, as they are common trends between the regions, which gives a consistency to the project. The 2 sectors include a large number of different activities giving rise to an increasing level of transfer of expertise..

Project partners :
1. Centre de Recherche Public Henri Tudor [LU]
2. Chambre de Commerce et d'Industrie Territoriale de l'Aisne (CCIT) [FR]
3. Chambre de Commerce et d'Industrie de Region Lorraine (CCIRL) [FR]
4. Leibniz-Institut für Neue Materialien gGmbH [DE]
5. Multitel [BE]
6. SIRRIS [BE]
7. Institut universitaire de formation continue (IUFC) de l'Université catholique de Louvain (UCL) [BE]
8. GRETA LAON HIRSON CHAUNY [FR]
9. APAF (Action Plasturgie Artois Flandres) : Pôle plasturgie Nord-Pas de Calais [FR]
10. CREPIM - Centre de Recherche et d'Etude sur les Procédès d'Ignifugation des Matériaux [FR]
11. Université de Liège, Centre Spatial de Liège (CSL) [BE]
12. CENAERO, Centre de Recherches en Aéronautique ASBL [BE]

c. **TRANSCOMAS** [Transregional Network in testing and Measurement for Aeronautical and Space industries]

Program Interreg IVA Grande Région

The objective is the creation of a cross-border network of testing and measurement competences to accompany companies towards the technologies of the aeronautical and space industries. The main players acting in the space and aeronautical fields have decided to group together to create a dynamic structure at the Greater Regional level.

They provide the development conditions for SME competitiveness in the space and aeronautical fields by contributing to the meeting the demands of very important and diversified standards as precisely as possible and by supporting innovation by supervision that is directly operational on mastering the fields of testing and measurement.

Project partners :
1. Université Henri Poincaré (UHP) - P2ICM - Pôle Innovation Instrumentation Contrôle et Mesure (Lo)

2. Université Henri Poincaré (UHP) – LIEN - Laboratoire d'Instrumentation électronique de Nancy (Lo)
3. AERIADES
4. SKYWIN Wallonie (W)
5. Université de Liège - CSL – Centre spatial de Liège (W)
6. Centre de Recherche Public Henri Tudor – Laboratoire Advanced Materials Structures (GDL)

Other (methodological) partners :

1. Messier Bugatti SAS (Lo)
2. LUXINNOVATION (GDL)
3. MATERALIA (Lo)

d. **MICROBIOMED** [Microtechnologies for BioMedical applications]

See more details on page 86.

4. Quality Management *(Resp. M. Thomé)*

CSL maintains an approved Quality Management System based on two types of requirements:

- Requirements from the European Space Agency and, consequently from all partners dealing with the Space area, through the Agency standards (previously PSS, and presently ECSS),
- Requirements from the European ISO system through the ISO 9000 series.

CSL is regularly audited and certified for both requirements as follow:

European Space Agency

CSL is audited as a test centre for the European Space Agency.

Certification following the new ECSS standard System (ECSS.Q.20.07A – "Quality assurance for test centre") is valid from November 2010 until August 2013.

ISO certification

CSL is also certified following the European standard ISO, by AIB Vinçotte and is, by the way, integrated in the "International certification Network – IQNet", recognized all over the world.

The certification ISO 9001:2008 has been obtained as follows and covers:

- The testing of space and ground based equipment including the design and the development of related test equipments
- The design and the development of high technology instruments.

Valid from February 2010 until February 2013

AWARDS

Patents

List of Patents involving CSL :

- A monomode optical fibre [EP1317682 - 2003-06-11];
- Solar concentrator (1) [EP1301396 - 2003-04-16]
- Solar concentrator (2) [EP1396035 - 2004-03-10]
- Solar concentrator (3) [EP1807870 – 2007-07-18]
- Photometer [EP1214569 - 2002-06-19]
- Method for assembling an optical array comprising coaxial shells [US6449826-2002-09-17]
- Optical device for projection display system [EP1055954 - 2000-11-29]
- Light guiding plate with internal micro-prisms [US6575584 - 2003-06-10]
- Illumination device [EP1469324 - 2004-10-20]
- An illumination device formed by cutting and laminating coated plates [EP1469324 - 2004-10-20]
- Method and system for large dimension profile measurement [WO03076874 - 2003-09-18]
- Portable holographic marling unit [WO03073173 - 2003-09-04]
- Detection device [EP1417457 - 2004-05-12]
- Comparison of a Rutherford back scattering signal with a particle induce X-ray emission signal [WO2004025285 - 2004-03-25]
- A sensor based on surface Plasmon resonance [WO2007137995 – 2007-12-06]

- Authors: FLEURY-FRENETTE KARL, HABRAKEN SERGE; RENOTTE YVON; HASTANIN JURIJ

Object 1: Thermal Detector

The thermal detector is a radiation detector comprising an energy absorber, for absorbing incident radiation (RAD) and thus undergoing a temperature increase; and an optical readout system, for detecting temperature variations

Object 2: Micromechanical Sensor

The micromechanical sensor comprises a micromechanical oscillator and optical readout system for detecting any displacement of the micromechanical oscillator.

ACADEMIC ACTIVITIES

P. Rochus
Academic & Scientific Affairs

Lectures given by CSL scientists and professors at ULg

Christian Barbier

	ECT
Theoretical physical cosmology – SPAT0010-1	
Master in Space Sciences, research focus, 1st year	4
Master in Space Sciences, research focus, 2nd year	4
Spatial systems for observing the earth – SPAT0031-1	
Master in Aerospatiale Engineering, in depth approach, 2nd year	3
Master in Engineering Physics in depth approach, 2nd year	3
Master in Space Sciences, research focus, 1st year	3
Master in Space Sciences, research focus, 2nd year	3
Teledetection – SPAT0032-1	
Master in Space Sciences, research focus, 1st year	3
Master in Space Sciences, research focus, 2nd year	3

Jean-Marc Defise

Space mission design, partim 1 - SPAT0016-1	
Master in Space Sciences, research focus, 1st year	1
Space mission design, partim 2 - SPAT0016-2	
Master in Space Sciences, research focus, 1st year	15
Master in Space Sciences, research focus, 2nd year	15

Serge Habraken

Coherent and incoherent optics – PHYS0048-1	25
Instrumental optics 1 – PHYS0124-1	18
Instrumental optics 2 – PHYS0125-3	57
Lasers in physics and applications – PHYS0238-2	5
General physics 2 – PHYS0238-4	8
Physical and mathematical bases for biomedical sciences – PHYS0311-1	11
Coherent optics and laser applications – PHYS0934-1	21
Electromagnetism and optics – PHYS2008-1	7
Training sessions and personal activities – STRA0005-3	10

Jérôme Loicq

Spectroscopy in Astrophysics and Geophysics – SPAT0039-1	
Master in Engineering Physics in depth approach, 2nd year	2.5
Master in Space Sciences, research focus, 1st year	3

Pierre Rochus

Space Experiment Development – AERO0018-3	
Master in Aerospatiale Engineering, in depth approach, 2nd year	5
Master in Engineering Physics in depth approach, 2nd year	5
Master in Space Sciences, research focus, 1st year	5
Master in Space Sciences, research focus, 1st year	5
Master in Space Sciences, research focus, 2nd year	5

Spacecraft Design and Instrumentation
Master of Space Studies KUL (3pt. 25h)

Lectures for external customers

Michel Thomé :
Clean rooms : theoretical and practical basic approaches
Clean rooms and contamination control
(Technifutur - Liège)

Antonio Cucchiaro – Isabelle Domken – Isabelle Tychon :
Vacuum Technologies
(Technifutur - Liège)

Antonio Cucchiaro :
Contamination Controls
(ESA – Estec)

Karl Fleury :
Micro-machining with excimer laser
Cold plasma sputtering deposition
(Technifutur - Liège)

Patrick Gailly :
Micro-machining with excimer laser
(Technifutur - Liège)

Yvan Stockman :
Metrology and inspection adapted to micro-technologies
Solar optics, solar panels and related technologies
(Technifutur - Liège)
"Optique diffractive " - Physiol society
Physical measurements: Non contact measurement and interferometry.

Yvan Stockman – M. Georges
"Mesure Physique"
Laser Promoptica

Jérôme Loicq – Tanguy Thibert :
Solar optics, solar panels and related technologies
(Technifutur - Liège)

Seminars / Conferences organized by CSL

2010

1) SPENVIS : SPACE ENVIRONMENT INFORMATION SYSTEM.
M. KRUGLANSKI (09/02/10).

2) LA RECHERCHE DE PLANETES ET DE LA VIE HORS DU SYSTEME SOLAIRE.
J. CLAVEL (29/03/10).

3) SMART MATERIALS FOR BETTER VISION.
T. GALSTIAN (14/04/10).

4) APPLICATION DE L'INTERFEROMETRIE HOLOGRAPHIQUE ET DE L'INTERFEROMETRIE DE SPECKLE µm POUR LA MESURE DE DEFORMATION DE REFLECTEURS SPATIAUX.
JF. VANDENRUJT (27/05/2010).

5) LENTILLE LIQUIDE VARIOPTIC.
P. CRAEN (21/06/2010).

6) ETUDE ET DEVELOPPEMENT DE TECHNIQUES DE METROLOGIE DE DEPLACEMENTS EN LUMIERE COHERENTE EN INFRAROUGE THERMIQUE.
THESE DE DOCTORAT DE **JEAN-FRANCOIS VANDENRIJT** (13/09/10).

7) ESPACE, SECURITE ET DEFENSE.
D. MOURA (03/12/10).

2011

1) ACTIVITIES IN THE NEW SPACE CENTER IN STUTTGART – FROM UAV TO SMALL SATELLITES.
H.P. ROESER (04/02/11).

2) ETUDE DE L'EVOLUTION DE L'ETAT DE SURFACE DE MATERIAUX OPTIQUES SOUS BOMBARDEMENT IONIQUE A FAIBLE ENERGIE.
Thèse de doctorat de **PATRICK GAILLY**, défendue le 02/05/11.

3) RECHERCHES EN OPTIQUE, LASER ET ETAT SOLIDE A L'IFGW – UNIVERSITE DE CAMPINAS (BRESIL).
JAIME FREJLICH (24/05/11).

4) CINQUANTENAIRE DE GAGARINE, LES PETITES HISTOIRES DE LA CONQUETE SPATIALE (ET / OU COMMENT DE VON BRAUN ET KOROLEV ON EST ARRIVE A LA LUNE).
J-P MARTIN (10/06/11).

5) LES APPLICATIONS ET IMPLICATIONS STRATEGIQUES DE L'OBSERVATION DE LA TERRE DEPUIS L'ESPACE .
G. BRACHET (01/12/11).

6) SSA/SW – SPACE SITUATION AWARENESS – SPACE WEATHER
D. MOURA (12/12/11).

Master Theses

Deneuville Jean-Philippe, Helmo Gramme (Karl Fleury)
Etude des profils de dépôts métalliques par pulvérisation ionique sur substrats silicium.

Gallante Nicolas, FUNDP (Jérôme Loicq)
Etude optique de l'interaction cellule-lentille d'un système photovoltaïque à haute concentration.

Lenoir Pierre-Yves, Helmo Gramme (Karl Fleury)
Etude des propriétés thermo optiques de films minces de nitrure de titane.

Magnette Elisabeth, ULg (Karl Fleury)
Procédé de dépôt laser pour microcomposants.

Matthys Sabine, ULg (Tanguy Thibert)
Etude des effets thermiques d'un système photovoltaïque à haute concentration.

Salvador Lucas, ULg (Pierre Rochus)
Detailed thermal analysis and prototype of Solar Orbiter EUI entrance baffle thermal link.

Thunus Gaëtan, Helmo Saint-Laurent (Marc Guiot)
Standardisation de la régulation thermique pour les essais environnementaux d'instruments spatiaux, sécurisation par le développement d'un module de télécommunication et automatisation des cyclages.

PhD Theses

J.F. Vandenrijt

- Développement de techniques de métrologie de déplacement en lumière cohérente en infrarouge thermique.
- Étude de la diffusion à 10 µm
- Applications de l'holographie à 10 µm
- Simulations numériques en holographie digitale
- Financement : assistant « recteur »
- Thèse défendue le 13/09/2010.

P. Gailly

- Etude de l'évolution de l'état de surface de matériaux optiques sous bombardement ionique à faible énergie
- Etude de l'évolution de la rugosité de matériaux optiques
- Comité de thèse : K. Fleury (CSL), C. Jamar (CSL), J. Delwiche (Chimie ULg)
- Financement : néant
- Thèse défendue le 02/05/2011.

On going PhD Theses

Jean-Philippe Halain

- Instrumental Performances of the Heliospheric Imager on-board the STEREO mission, and its exploitation for futur missions
- Jury : P. Rochus (CSL), Jean-Marc Defise (ULg / Thales), Gaetan Kershen (ULg), et extérieurs (USA et UK).
- Financement : en partie BELSPO
- Date défense : Fin 2011/début 2012.

A. Carapelle

- Développement d'un système XRF (Xray fluorence) portable
- Comité : P. Rochus, S. Habraken
- Financement : néant (activité supplémentaire).

L. Salvador

- Matériaux à changement de phase pour application spatiale
- Comité : P. Rochus, M. Hoge, G. Kerschen
- Financement : néant (activité supplémentaire).

C. Michel

- Concentrateur solaire pour le spatial
- Comité : S. Habraken
- Financement : bourse FRIA

JF. Simarlope

- Large dynamic piston sensor for segmented mirror co phasing

Trainee Programs

NAME	SURNAME	SCHOOL	FROM	TILL	RESPONSIBLES	SUBJECTS
ADVISSE	Lionel	ISAT France	2/09/2010	17/12/2010	Y. Stockman	Conception d'un télescope compact et déployable de type Dobson
ANANDRAYEN	Nicolas	Institut de Technologie de la Ville de Liège	1/10/2009	1/06/2010	JM. Gillis	Projet HM+
AURIAULT	Florent	ISAT Institut Supérieur de l'Automobile et des Transports France	2/09/2010	17/12/2010	P. Rochus	Matériaux composite et nanomatériaux pour instruments spatiaux
BAIDAOUI	Mohamed	Ecole d'Ingénieurs du Pas-de-Calais EIPC France	1/06/2010	26/07/2010	P. Rochus	Etude et conception d'une machine à chocs et application à la qualification d'instruments spatiaux
BERTONI	Pierre	Ecole des mines d'Ales France	2/05/2010	31/07/2010	P. Rochus	Les matériaux composites dans les charges utiles spatiales
CALCIONI	Maria Carla	University of Trieste Italie	1/06/2010	31/08/2010	P. Rochus	Design optomécanique de la camera NAC de ESMO
COSTE	Sylvain	Ecole des mines d'Alès France	3/05/2010	31/07/2010	P. Rochus	Applications des nanomatériaux dans le spatial
CUNILLERA	Ignasi	Escola Técnica Superior D'enginyería Química De La Universitat Rovira I Virgili Espagne	1/10/2009	1/09/2010	J. Loicq	Participation au projet Mirage CPV (Basse concentration). Participation à l'élaboration et aux tests du proto 2
DAOUDI	Mostafa	Université de Mons	26/04/2011	6/05/2011	J. Loicq	Mesure ellipsométrique relative à des surfaces développée dans le cadre du projet Mirage-OLED.
DELEAU	Alexandre	Ecole des mines d'Alès France	11/04/2011	12/08/2011	E. Callut	Participation à l'étude de l'électronique de contrôle d'une caméra basée sur un capteur CMOS
DUMONT	Maïté	Université de Liège	7/10/2010	12/11/2010	P. Rochus	EUI Solar Orbiter Compression d'images
DUPONT	Solène	IPSA - Institut Polytechnique des Sciences Avancées France	6/06/2011	20/08/2011	P. Rochus / J-P Halain	Caractérisation de la conductivité des filtres d'entrée de l'instrument EUI de la mission Solar orbiter
GAZEL	Adrien	ESTACA Ecole Supérieure des Techniques Aéronautiques et de Construction Automobile France	26/05/2010	15/09/2010	P. Rochus	Etude thermique et optique sur EUI Solar Orbiter

GIDE	Dorian	HELMO Gramme	1/02/2010	30/06/2010	F. Denis	Développement SIW du profilomètre
GUIRAL	Florent	Ecole des mines d'Ales France	9/05/2011	6/08/2011	M. Thome	Analyse de risque et FMECA (Failure Mode Effects and Criticality Analysis) d'une cuve à vide
PECHEUX	Benoît	HELMO Gramme	15/11/2010	24/12/2010	P. Rochus	Stage d'observation en instrumentation spatiale
SALVADOR	Lucas	Université de Liège	20/10/2009	31/05/2010	J-P Halain	Projet Solar Orbiter EUI
SIMONIS	Vincent	Haute Ecole de la Province de Liège Rennequin Sualem	9/02/2011	30/06/2011	E. Callut	Travail dans le cadre du projet Solar Orbiter EUI. Aide au design de la camera de l'instrument
VAN AUTREVE	Stijn		28/02/2011	1/07/2011	P. Rochus	ESMO-NAC : étude thermomécanique

Publications

2010

J. Bernier "La gestion de la confidentialité dans un centre de recherche universitaire", Présentation lors de la conférence « L'espionnage économique : Comment réussir ? Comment se protéger ? », 13 décembre 2010, Château de Colonster.

Derauw D., Orban A., Barbier C. "Wide Band SAR Sub-Band Splitting and Inter-Band Coherence Measurements", Remote Sensing Letters 1(3), 133-140 (2010).

P. Gailly, J. Delhalle, D. Garray, L. Mezzo, O. Rochez, L. Pambaguian "Development of composite materials based on a carbone nanotubes network for space applications", IAC 2010, Prague (IAC International Astronautical Congress-10-C2.8.4).

M. Georges, "Interférométrie holographique et de speckle en infrarouge thermique : développements actuels, applications et perspectives," *Actes du Onzième colloque francophone Méthodes et Techniques Optiques pour l'Industrie*, Toulouse-Labège, France, 15-19 Novembre 2010. Conférence plénière.

M. Georges, **C. Thizy, J.-F. Vandenrijt**, I. Alexeenko, G. Pedrini, W. Osten, I. Aldave, I Lopez, I. Saez De Ocariz, B. Vollheim, G. Dammass, M. Krausz, "FANTOM PROJECT : Electronic Speckle Pattern Interferometry at Thermal Infrared Wavelengths, A New Technique for Combining Temperature and Displacement Measurements," *1st Workshop of European Aeronautics Science Network*, Suresnes, France, 7-8 October 2010. Conférence invitée.

M. Georges, **J.-F. Vandenrijt, C. Thizy, Y. Stockman**, I. Alexeenko, "Electronic speckle pattern interferometry in Long Wave Infrared: a new technique for combining temperature and displacement measurements. Applications in thermo-mechanical assessment of structures," *Proceedings of ICSO 2010 - International Conference on Space Optics*, Rhodes, Greece, 4-8 October 2010.

Surdej, J., Delacroix, C., Coleman, P., Dominik, M., **Habraken, S**., Hanot, C., Le Coroller, H., Mawet, D., Quintana, H., Sadibekova, T., & Sluse, D. (2010). "The Optimal Gravitational Lens Telescope". *Astronomical Journal (The), 139*, 1935-1941.

Hanot, C., Riaud, P., Mawet, D., Absil, O., Surdej, J., & **Habraken, S**. (2010). "Development of a CELestial Infrared Nuller Experiment (CELINE) for broadband nulling and new single-mode fiber testing." In W. C., Danchi, F., Delpancke, & J. K., Rajagopal (Eds.), *Optical and Infrared Interferometry II* (pp. 81). Bellingham, WA, USA: SPIE (Society of Photo-Optical Instrumentation Engineers).

Jean-Philippe Halain, David Berghmans, **Jean-Marc Defise**, **Etienne Renotte, Tanguy Thibert, Emmanuel Mazy, Pierre Rochus**, Bogdan Nicula, Anik De Groof, Dan Seaton, Udo Schühle « First light of SWAP on-board PROBA2 », SPIE 7732-24, 2010.

Jean-Philippe Halain, **Pierre Rochus**, Thierry Appourchaux, David Berghmans, Louise Harra, Udo Schühle, Frédéric Auchère, Andrei Zhukov, **Etienne Renotte, Jean-Marc Defise**, **Laurence Rossi, Karl Fleury-Frenette, Lionel Jacques**, Jean-François Hochedez, Ali Ben Moussa « The technical challenges of the Solar-Orbiter EUI instrument » , SPIE 7732-26, 2010.

J.-P. Halain, **Y. Houbrechts**, F. Auchère, **P. Rochus**, T. Appourchaux, D. Berghmans, U. Schühle, L. Harra, **E. Renotte**, A. Zukhov, « The Solar Orbiter EUI Instrument Optical Developments », ICSO 2010 (International Conference on Space Optics), Poster.

J.-P. Halain, D. Berghmans, **J.-M. Defise, P. Rochus**, B. Nicula, A. De Groof, D. Seaton, "Performances of SWAP on-board PROBA2", ICSO 2010 1980806.

J. Hastanin, **C. Lenaerts, K. Fleury-Frenette, S. Habraken**, "A spectral surface plasmon resonance sensor based on transmission grating : architecture analysis dedicated to spectral sensors", SPIE NanoScience & Engineering; Plasmonics : Metallic Nanostructures and their Optical Properties VIII", SPIE Vol. 7757, San Diego, (2010).

J. Hastanin, C. Desfours, **C. Lenaerts, K. Fleury-Frenette, S. Habraken**, "Innovative spectral surface Plasmon resonance applied to droplet biodetection", Presentation – BioWinDay Congress 2010, Louvain-la-Neuve.

P. Jamotton, I. Domken, B. Marquet, S. Roose, N. Ninane, S. Liébecq, C. Grodent, A. Cucchiaro "Developments done at CSL for the testing of Herschel Telescope and Instruments and of the Planck Reflectors and Spacecraft." 4th European Space Cryogenic Workshop - ESA-ESTEC – 19/21 Oct. 2010.

P. Jamotton, E. Mazy, M.L. Hellin, J.Y. Plesseria, E. Renotte, C. Thizy "JWST MIRI IOC AIT at CSL." 4th European Space Cryogenic Workshop - ESA-ESTEC – 19/21 Oct. 2010.

P. Jamotton, S. Liébecq, C. Grodent, A. Cucchiaro, P. Sekulic , F. Bordas , J. Rodolfo "JWST NIRSpec TMA cryogenic testing in CSL premises". 4th European Space Cryogenic Workshop - ESA-ESTEC – 19/21 Oct. 2010.

Delacroix C., Forsberg P., Karlsson M., Mawet D., **Lenaerts C**., **Habraken S**., Hanot C., Surdej J., Boccaletti A., Baudrand J. "Annular groove phase mask coronagraph in diamond for mid-IR wavelengths: manufacturing assessment and performance analysis" (2010). In J., Oschmann, M., Clampin, & H., MacEwen (Eds.), *Space Telescopes and Instrumentation 2010: Optical, Infrared, and Millimeter Wave* (pp. 157). SPIE.

Delacroix, C., Forsberg, P., Karlsson, M., Mawet, D., **Lenaerts, C**., **Habraken, S**., Absil, O., Hanot, C., & Surdej, J. (2010, October 28). "*First manufactured diamond AGPM vector vortex for the L- and N-bands: metrology and expected performances"*. Paper presented at In the Spirit of Lyot 2010, Paris, France.

F. Landini, **A. Mazzoli**, M. Venet, S. Vives, M. Romoli, P. Lamy, G. Massone. "ASPIICS/PROBA-3 formation flying solar coronagraph : stray light analysis and optimization of the occulter".

Federico Landini, **Alexandra Mazzoli**, Melanie Venet, Sébastien Vivès, Marco Romoli, Philippe Lamy, Guglielmo Rossi "Measurements and optimization of the occulting disk for the ASPIICS/PROBA-3 formation flying solar coronagraph".

Sébastien Vives, Luc Damé, Philippe Lamy, A. Antonopoulos, W. Bon, G.Capobianco, G. Crescenzio, V. Da Deppo, M. Ellouzi, J. Garcia, C. Guillon, **A. Mazzoli**, T. Soilly, F. Stathopoulos, C. Tsiganos. "Demonstrator of the formation flying solar coronagraph ASPIICS/PROBA-3".

A. Mazzoli, F. Landini, S. Vives, P. Lamy, **J.P. Halain, P. Rochus**. "Stray light analysis and optimization of the ASPIICS/PROBA-3 formation flying solar coronagraph".

A. Mazzoli, P. Holbrouck, **Y. Houbrechts**, L. Maresi, **Y. Stockman**, M.Taccola, J. Versluys, "Baffles design of the PROBA-V wide FOV TMA", International Conference on Space Optics 4 - 8 October 2010, ICSO 2010 (International Conference on Space Optics) Rhodes, Greece.

Géraldine Guerri, **Stéphane Roose** ,**Yvan Stockman, Alexandra Mazzoli**, Jean Surdej, **Jean-Marc Defise**, "First steps in the development of a piston sensor for large aperture space telescopes", Poster 7731-192, Proc. SPIE Conference 7731 (2010).

Y. Stockman, A. BenMoussa, I. Dammasch, **J.-M. Defise**, M. Dominique, **J.-P Halain**, J.-F Hochedez, S. Koller, W. Schmutz , U. Schühle, "In-flight performance of the solar UV radiometer LYRA / PROBA-2", International Conference on Space Optics 4 - 8 October 2010, ICSO 2010 Rhodes, Greece.

T. Thibert, **M-L Hellin, J. Loicq, E. Mazy, J-M. Gillis**, F. Languy, **S. Habraken, J-H. Lecat** and **J-M Defise**, 2010, « Continuous solar simulator for concentrator photovoltaic systems », 25th European Photovoltaic Solar Energy Conference, Valencia.

C. Thizy, **C. Barbier**, **P. Barzin, I. Tychon, S. Roose, Y. Stockman, M. Georges** "Dynamic holographic interferometry for dilatation measurements in vacuum-thermal condition.", Proc. SPIE 7398, 73981P (2010).

F. Eliot, **C. Thizy**, A. Shannon, **Y. Stockman**, D. Logut, "Thermo-elastic distortion measurements by holographic interferometry and correlation with finite element models for SiC connections/junctions on spacecraft", Proceedings of the 61st International Astronautical Federation Congress, Prague, Czech Republic, September 2010 (IAC-10.C2.2.6).

C. Thizy, **J.-F. Vandenrijt, M. Georges, Y. Stockman, P. Rochus**, P. Queeckers, F. Dubois, **J.-M. Defise**, D. Doyle, "Development of digital holography in the long wave infrared range for assessment of space reflectors," *Proceedings of ICSO 2010 - International Conference on Space Optics*, Rhodes, Greece, 4-8 October 2010.

J.-F. Vandenrijt, **M. Georges**, "Electronic speckle pattern interferometry and digital holographic interferometry with microbolometer arrays at 10.6 µm," *Appl. Opt. 49 (Applied Optics)*, 5067-5075 (2010).

J.-F. Vandenrijt, **M. Georges, C. Thizy**, F. Dubois, P. Queeckers, D. Doyle, "Displacement measurements of a parabolic reflector by holographic interferometry in the long-wavelength infrared," Proceedings of the 61st International Astronautical Federation Congress, Prague, Czech Republic, September 2010 (IAC-10.C2.2.9).

I. Alexeenko, **J.-F. Vandenrijt**, **M. Georges**, G. Pedrini, **C. Thizy**, W. Osten, "Digital holographic interferometry by using long infrared radiation (CO_2 laser)", *7th BSSM International Conference on Advances in Experimental Mechanics*, Liverpool, United Kingdom, September 2010.

2011

Carapelle A., Defise J-M, Strivay D., Garnir H-P "Modern computer brings new features to portable X-ray fluorescence coating thickness measurement device", *Computer Physics Communications* (2011) 182 (6), 1304-1306.

M. Dominique, J.-F. Hochedez, W. Schmutz, I.E. Dammasch, A.I. Shapiro, M. Kretzschmar, A. Benmoussa, D. Gillotay, **Y. Stockman**, " The LYRA instrument on-board PROBA2: description and in-light performances" Solar Physics 2011

Domken I., Plesseria J-Y, Mazy E., Rossi L., Hellin M-L, Marcotte S., Liebecq S., Tychon I., Renotte E., Grodent C., Thomé M., Cucchiaro A. "MSI instrument (ESA Sentinel-2) : from the diffuser procurement until the test instrument at CSL", *26th Aerospace Testing Seminar*, Los-Angeles,March 2011.

Della Vedova F., Henrion D., Leipold M., Girot T., Vaudremont R., Belmonte T., **Fleury-Frenette K.,** Le Couls O., "The Solar Sail Materials (SSM) project – Status of activities", *Advances in Space Research* (2011), 48 (11), 1922-1926.

Languy F., **Fleury-Frenette K., Lenaerts C., Loicq J.,** Regaert D., **Thibert T., Habraken S.** "Flat Fresnel doublets made of PMMA and PC : combining low cost production and very high concentration ratio for CPV", *Optics Express* (2011), 19 (S3), 280-294.

Gailly P. « Etude de l'évolution de l'état de surface de matériaux optiques sous bombardement ionique à faible énergie ». *Thèse de doctorat 2011*.

Duterte C., Lecourt J-B, Cserteg A., Hernandez Y., Giannone D., Martin P-E, Kupisiewicz A., **Gailly P., Fleury-Frenette K., Hastanin J**. "Ultra-short pulse fibre laser parameters optimisation for CdTe thin film solar cells processing and fibre laser design", *Fiber Laser Applications (FILAS),* 2011. Communication orale.

Uribe-Patarroyo N., Alvarez-Herrero A., Garcia Parejo P., Vargas A., Heredero R.L., Restrepo R., Martinez Pillet V., del Toro Iniesta J.C, Lopez A., Fineschi S., Capobianco G., **Georges M**., Lopez M., Boer G., Manolis I., "Space-qualified liquid-crystal variable retarders for wide-field-of-view coronographs", *Proc. SPIE Vol. 8148 on Solar Physics and Space Weather Instrumentation IV*, 2011, 814810.

Alvarez-Herrero A., Uribe-Patarroyo N., Garcia Parejo P., Vargas J., Heredero R.L., Restrepo R., Martinez-Pillet V., del Toro Iniesta J.C., Lopez A., Fineschi S., Capobianco G., **Georges M**., Lopez M., Boer G., Manolis I., "Imaging polarimeters based on Liquid Crystal Variable Retarders : an emergent technology for space instrumentation", *Proc. SPIE Vol. 8160 on Polarization Science and Remote Sensing V*, 2011, 81600Y.

Georges M. "Using holography to reduce aircraft costs", *Projects Magazine* (2011), 26, 66-67.

Georges M., "Metrology and Non Destructive Testing by Holography at the Space Center of Liege. From research to industrial applications", *Invited Seminar at the Institute of Physics Gleb Wathagin*, Brésil 2011.

Georges M., "LIBS : Identification rapide de composants chimiques. Application au recyclage des matériaux et détection de pollution du sol », *Colloque Optique et Environnement*, Les Isnes 2011.

Georges M. « Mesures LASER », *Cours organisé par PROMOPTICA donné dans le cadre de Technifutur*, Centre Spatial de Liège 2011.

Georges M. « FANTOM FP7 Project: Innovative NDT Technique Development. Single sensor for simultaneous temporal and spatial full-field thermography and deformation measurements in structural tests », *Conference Aerospace Testing*, 5-6 April 2011, Hamburg, Germany.

Georges M., "FANTOM Project Overview", *Aerodays 2011 : Innovation for a Sustainable Aviation in a Global Environment*. 30 March 2011- 1 April 2011, Madrid, Spain.

Georges M., Thizy C., Vandenrijt J-F, Alexeenko I., Pedrini G., Osten W., Aldave I., Lopez I., Saez de Ocariz I., Vollheim B., Dammass G., Krausz M., "Electronic speckle pattern interferometry at thermal infrared wavelengths : a new technique for combining temperature and displacement measurements", *Photomechanics 2011 : An International conference on full-field measurement techniques*, 7-9 Février 2011, Vrije Universiteit Brussel.

Grevesse N., Asplund M., Sauval A-J, Scott P. "The new solar composition and the solar metallicity", *The Sun, the Solar Wind and the Heliosphere*, ed. M.P.M. Miralles et J. Sanchez Almeida, IAGA Special Sopron Book Series, Springer, Berlin, 2011, p 51.

Grevesse N., Asplund M., Sauval A-J, Scott P. "The chemical composition of the sun", *Canadian Journal of physics* (2011), 89, 327.

Desfours C., **Habraken S., Hastanin J., Lenaerts C., Fleury-Frenette K**. "Experimental investigation of droplet biosensing by multi-wavelength plasmonic", *SPIE Proceedings "Plasmonics in Biology and Medicine IX"*, 8234-19, 2011.

Piron P., Blain P., **Habraken S**. "Polarization measurement with space-variant retarders in liquid crystal polymers", *SPIE Proceedings Vol. 8160 & SPIE Optics and Photonics*, San Diego 2011.

Mawet D., Murakami N., Delacroix C., Serabyn E., Absil O., Baba N., Baudrand J., Boccaletti A., Burruss R., Chipman R., Forsberg P., **Habraken S**. "Taking the vector vortex coronagraph to the next level for ground-and space-based exoplanet imaging instruments : review of technology developments in the USA, Japan and Europe", *SPIE Proceeding Vol. 8151 "Techniques and Instrumentation for Detection of Exoplanets V"*, San Diego 2011.

Billen R., Carré C., Van Ruymbeke M., Schenke C., **Habraken S.,** Laven N., Thirion P., Martin G., Blain P. "Virtual Leodium – video de présentation", *Fonds d'opportunité de l'ULg*, Octobre 2011.

Billen R., Blain P., Carré C., **Habraken S**., Renotte Y., Silva V., Van Ruymbeke M. "Virtual Leodium : Maquette virtuelle de la ville de Liège au dix-huitième siècle", *Archéométrie 2011*, *Colloque du GMPCA*, Liège 2011.

Halain J-P, Rochus P., Defise J-M, Mazy E., Mazzoli A. "Straylight-Rejection performance of the STEREO HI Instruments", *Solar Physics*, July 2011.

Jonckheere S., Bergen B., **Halain J-P, Rochus P.,** Desmet W., Vandepitte D. "Filter failure analysis for the SWAP instrument on-board of PROBA2", *3rd ECCOMAS Thematic Conference on Computational Methods in Structural Dynamics and Earthquake Engineering*, 25-28 May 2011, Corfu, Greece.

Hervé A., **Hastanin J., Habraken S**., Rauw G. "Study of a possible X-ray sensor based on the Plasmon Surface Resonance for the next generation of instruments", *Bulletin de la Société Royale des Sciences de Liège*, (2011) 80, 500-503.

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Library

F. Defraigne
Library responsible

CSL hosts in its own library around 1900 specialized books covering fields like:

- Astronomy & Astrophysics
- Optics
- Physics
- Space Technology
- Vacuum Technology
- Mechanics

The Research center clusters the biggest collection of optical journals of the University of Liège. It is member of the Optical Society of America and of the Society of Photo-Optical Instrumentation Engineers (SPIE) for which at least 500 conferences are documented covering many various fields of fundamental modern Optics.

All CSL series are indexed in the General Library Catalogue of the University.

Many ESA publications (symposiums, proceedings, technical reports, workshops summaries,….) are also held by the research center (around 1150) either on paper or on CD-ROM supports.

The increasing rate (including all documents) turns around 6% per year.

All the training course reports, Master theses or PhD theses defended at CSL are kept and at the disposal of everyone.

It has to be outlined that the library plays a major part in the CSL seminars organization and in the dispatching of information inside the University intranet and our partner relationship.

INTERNATIONAL RELATIONSHIP

Estonian journalists visit in the frame of “Wallonie-Bruxelles International”.

European journalists visit in the frame of an AWEX invitation.

Chinese Provincial Committee (Fujinan) visit.

Visit of 45 International experts from the conference EUROPE-INNOVA.

Visit of French journalists in space sciences on the AWEX invitation.

Visit of the Academic authorities of the University of St-Petersbourg (Russia)

Visit of PROMOSURF (coatings industry association).

Visit of Brazilian delegation.

PUBLIC OUTREACH

Visits

Schools

Primary schools
Liège, Deigné, Sart Tilman, Sohey-Tinlot, Crisnée : 225 children

« Place aux enfants » Event 2010 : 39 children and 39 parents
« Place aux enfants » Event 2011 : 42 children and 30 parents

Secondary schools:

- (Liège, Visé, Mouscron, Jeunesses Scientifiques, découvertes entreprises, immersion anglaise, Rhétos) : 156 élèves.
- (Rhétos Promotion études ULg, stage Astrophysique, Ecole Polytechnique Herstal, Athénée Pont à Celles, Lycée Abbaye de Flône et étudiants italiens, Collège Saint Louis Liège, Athénée Vauban Charleroi, Athénée de Visé,) : 165 élèves.

High schools – Universities:

- (1ers Bac. Ing. ULg, Master Ing. Gestion ULg, BEST de Liège, Province de Liège, Namur, KUL, ULB) : 200 students
- (Institut Supérieur Industriel de Bruxelles, Master Ing. ULB, 1ers Bac. Ing. ULg, Master Ing. Aéro-Spatial ULg, Erasmus Ing. ULg, Physique FUNDAP Namur, Journalisme ULg, Institut des Arts Techniques et Artisanaux Namur, Haute Ecole Bibliothécaires Liège, Master Sciences Spatiales KU Leuven): 140 students

Associations

- (UTAN Namur, Lions Club Beaufort Huy, Militaires Ans, Anciens ULg du Luxembourg, Club Athena, Anciens VUB) : 149 visitors.
- (Estonie, Journalistes Européens avec AWEX, Province de Fujian, Chine avec SPI+, Workshop Europlanet, Experts de la conférence Europe-Innova) : 91 visitors
- (Club OuftiMac Liège, AstroVega Gembloux, Probus Belgique, Association Dirigeants de Personnel Liège + visiteurs Français, Koperen Passer Antwerpen, Club de Lecture ULg, Maison Laïcité Sainte Walburge, Interface ULg, Promosurf Belgique) : 202 visitors
- (Université de Léningrad, Journalistes Européens avec AWEX, Traducteurs allemand-français, Colombie, Province Limburg Hollande) : 25 visitors.

Exhibitions

- Exhibition « OpportuniDay » à l'Aéroport de Bierset (15th June 2010)
- Exhibition « Space Days » à Charleroi (12-14 October 2010)
- Exhibition « L'Homme et L'Espace » à l'Abbaye Saint-Gérard de Brogne from14th January to 28th February 2011.
- Exhibition « Nouvelles Technologies, Nouveaux Métiers » à la Maison de la Métallurgie et de l'Industrie, à Liège,from 21th March 2011 to 21th June 2011
- Exhibition « De la Terre aux Etoiles…passe par les Métiers du Spatial » à la Maison de la Métallurgie et de l'Industrie, à Liège, from 22th November 2011 to 16th December 2011

PARTICIPATION TO EXTERNAL COMMITTEES

C. Barbier	- ESA FRINGE Working Group on SAR interferometry. - CSL is a founding member of the ESA FRINGE Working Group on SAR interferometry - NEREUS Earth Observation GMES Working Group
A. Cucchiaro	- Member of the Institute of Environmental Sciences and Technology (USA).
M. Georges	- CMOI (Contrôles et Mesures Optiques pour l'Industrie) Committee - Member of the OPTIMESS Workshop Committee
S. Habraken	- Member of the OPTIMESS Workshop Committee
P. Rochus	- IAF (International Aerospace Federation) committee - Member of the OPTIMESS Workshop Committee - Reviewer at "Mathematical Reviews" since 1978 - Associate Fellow of the AIAA (American Institute of Aeronautics and Astronautics) since 1996. - Chairman of Liege Espace (since 2005) - Member of the SPIE Programm committee on Solar Physics And Space Weather Instrumentation - Journal of Aircraft Reviewer - Acta Astronautica Reviewer - Vice President of Euro-Spaceward - Member of SPIE Newsroom. Astronomy
Y. Stockman	- Scientific Committee ICSO conference (International Conference on Space Optics) - ESA conference of European spacecraft structures, materials and mechanical testing. - Member of the OPTIMESS Workshop Committee

BOARDS

CSL Management Council

- Mr. Albert Corhay – First Vice-Rector (representative of the Rector of the University of Liege) *President*
- Mr. Laurent Despy – Administrator of the University of Liege
- Mrs. Anne Girin – Director FRA
- Mrs. Evelyne Goujon – Director HRA
- Mrs. Véronique Boveroux – Director Juridical Affairs
- Mr. Michel Hogge – Dean of the Faculty of Applied Sciences
- Mr. Rudy Cloots – Dean of the Faculty of Sciences
- Mr. Thierry Chantraine – CSL General Manager
- Mrs. Christelle Bertrand – CSL Deputy General Manager - *Secretary*
- Mr. Etienne Renotte – CSL Scientific Staff representative
- Mr. François Allegro – CSL administrative & technical staff representative
- Mr. Jean-Pierre Swings – Scientific Adviser

CSL Science Council

- Mr. Denis Grodent – *President*
- Mr. Pierre Rochus – CSL – *Secretary*
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- Mr. Gregor Rauw – Sc
- Mr. Gaétan Kerschen – ScA
- Mr. Jean-Yves Plesseria – CSL
- Mr. Serge Habraken – Sc/CSL
- Mr. Marc Vandroogenbroeck – ScA
- Mr. Yves Cornet – Sc
- Mr. Emmanuel Mahieu – Sc

RUNNING PROJECTS

COMMENTS

A. Cucchiaro
Official Representative

The present publication gives an overview of the activities which have been conducted by the Space Centre of Liège (CSL) during the biennial period 2010-2011.

Despite some turmoil which has marked the period, a lot of high level, original and remarkable works has been accomplished by the various Centre laboratories in fields as various as SAR Image Processing, Optical Design, Space Surface Coatings or Extreme Space Condition Simulations just to mention some of them. The main aspects of the different projects and programs are described in related chapters and the presentations are under the scientific and technical responsibility of each manager.

Are also mentioned in this document the academic activities that CSL has performed through lectures, publications and student training for Master and PhD theses.

Public outreaches and exhibitions participations demonstrate the interactivity between the center and its socio-economic environment.

The reader will find finally some general data like financial aspects, structure, boards…

This summary could not be edited without the contribution of a major number of CSL responsible; having collected and reassembled all these data, I must outline that despite an experience of more than forty years, I have been at the same time impressed and proud to rediscover the diversity and the extend of the centers of interest of CSL.

Antonio Cucchiaro