International Conference on Space Optics—ICSO 2014

La Caleta, Tenerife, Canary Islands

7–10 October 2014

Edited by Zoran Sodnik, Bruno Cugny, and Nikos Karafolas

Coarse lateral sensor optical box

Javier Moreno

Javier Serrano

David González

Gemma Rodríguez

et al.

International Conference on Space Optics — ICSO 2014, edited by Zoran Sodnik, Nikos Karafolas,
Bruno Cugny, Proc. of SPIE Vol. 10563, 105635N · © 2014 ESA and CNES
CCC code: 0277-786X/17/$18 · doi: 10.1117/12.2304130

COARSE LATERAL SENSOR OPTICAL BOX

Javier Moreno[a] (morenofj@lidax.com), Javier Serrano[a] (serranotj@lidax.com), David González[a], Gemma Rodríguez[a], Stephane Gallet[a], Violeta Sanz[a], Heribert Argelaguet[a], Rocío García[b], Emmanuel Rossi[b], Roberto Sánchez-Labrador[b], Carlos Vernich[b], Rafael Navarro[b]

[a]*LIDAX, Antonio Alonso Martín 1, 28860 Paracuellos de Jarama (Madrid), Spain*
[b]*Thales Alenia Space España, C/ Einstein 7, 28760 Tres Cantos (Madrid), Spain*

I. INTRODUCTION

This paper describes the Engineering & Qualification Model (EQM) thermo-mechanical design of the Coarse Lateral Sensor (CLS) Optical Box (OB) developed by Thales Alenia Space España and LIDAX.

The Coarse Lateral Sensor is a low cost, low mass optical metrology sensor able to provide medium accuracy angular measurements and able to be easily accommodated on all the identified formation flying missions, acting as the final positioning system or as a bridge between the Radio Frequency (RF) and the fine optical metrology systems. The operational measurement distance of the CLS goes from 25m to 250m and the working angular range is ± 5°, with an angular accuracy better than ± 5 arc sec.

The Coarse Lateral Sensor is composed of three main components:

1. Optical Box (OB), which contains the optical system, consisting of a CMOS detector, a light source (LED), a diaphragm and optical filters
2. Electronics Box (EB), which contains the electronics
3. Receiver, which contains the passive retro-reflector (on the receiver satellite)

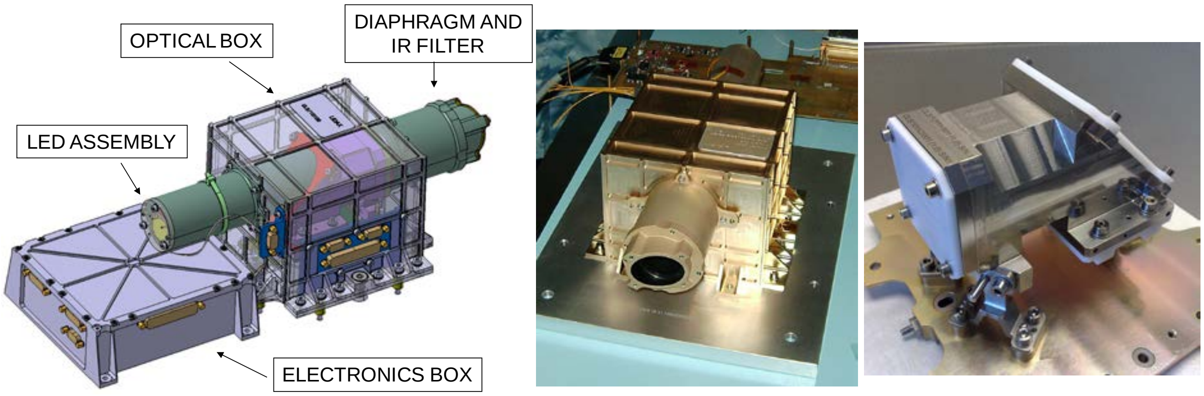

Figure 1: CLS instrument (left), CLS Optical Box (center), Optical Assembly (right)

CLS is able to operate in a large temperature range, between -20ºC and +50ºC, thanks to its active thermal control system based on heaters and thermistors, which avoids misalignments and ensures an appropriate operation within the accuracy requirements.

CLS functional concept is shown in Figure 2.

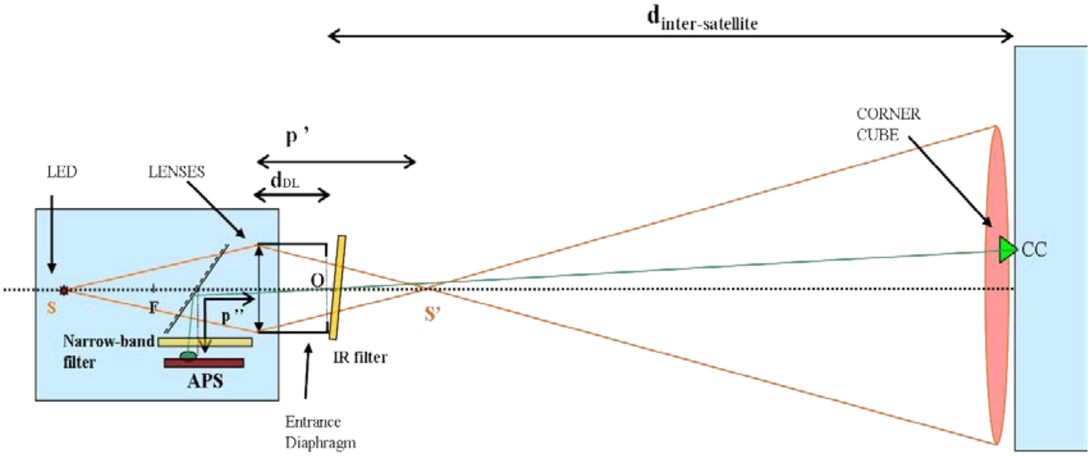

Figure 2: CLS Concept

The doublet of the Optical Assembly sends the light from a LED to the Corner Cube (CC) placed in the satellite to be controlled; then the CC reflects the light beam which is recovered by the lenses doublet and directed to the CMOS sensor by means of a beamspliter. Additional optical elements such as filters and diaphragms are included to guarantee the optical performances.
This paper outlines the thermo-mechanical design of the CLS OB EQM, summarizing design drivers, mechanical and thermal concept, and main performances.

The design of the CLS Optical Box is focused on three main objectives:

1. To provide a stable thermal environment for the optics of the sensor to avoid misalignments and ensure an appropriate operation within accuracy requirements
2. To provide a mechanical support for the optics to withstand launch loads and minimise bias error produced by vibrations
3. To provide a mechanical design appropriate to available envelope and mass and power budgets

Figure 4 shows main parts of the OB assembly.

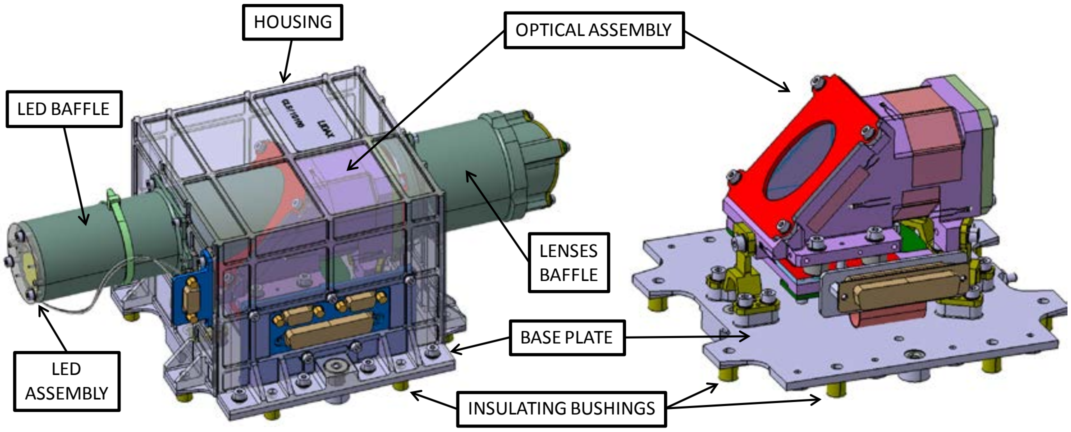

Figure 3: CLS Optical Box general view

II. DESIGN DRIVERS & MAIN REQUIREMENTS

The main objective of this opto-mechanical design is to guarantee the acquisition of the receiver satellite's position with a lateral displacement accuracy of ± 5arcsec.

Taking into account the operative temperature range of the CLS, from -20º to 50ºC, an active thermal control is necessary to avoid misalignments or measurement errors during the CLS operation.

On the other hand, from a structural point of view it is necessary to provide the optics with a support able to guarantee an eigenfrequency above requirement, and support launch loads as well as defined quasi-static loads.

Thermal insulation and structural stiffness are conflicting requirements so a commitment solution must be reached between both to fulfil specifications.

Finally, the necessary optics size compared to the total envelope requirement results in a very small space available for integration tasks; hence the design must also be oriented towards ease of assembly.

In conclusion, the following issues have been identified as design drivers:

1. Total power available for active thermal control
2. Relation between thermal conductance and structural stiffness
3. Envelope and mass budget
4. Assembly and integration

Main requirements are shown in Table 1.

ID	**REQUIREMENT**	**VALUE**	**UNIT**
FUNCTIONAL REQUIREMENTS			
1	Lateral displacement accuracy (3 Sigma)	±5arcsec (3.6mm @ 150m) ±24.2 microrad	-
THERMAL REQUIREMENTS			
2	Total power consumption	< 8	W
3	CMOS Dissipation (operational)	0.15	W
4	CLS Optics Min Temperature (Operating mode)	-20	ºC
	CLS Optics Max Temperature (Operating mode)	50	ºC
	CLS Optics Min Temperature (Non Operating mode)	-30	ºC
	CLS Optics Max Temperature (Non Operating mode)	60	ºC
MECHANICAL REQUIREMENTS			
5	Maximum volume	200 x 100 x 100	mm
6	Total mass including shielding	2500	g
7	Minimum Eigen frequency	140	Hz
8	Quasi-static loads (in three directions not combined)	60	g
9	Random qualification loads (axial and radial, 3 axes)	**Frequency Range**	**PSD**
		20-60 Hz	+9dB/oct
		60-400 Hz	0.5 g2/Hz
		400-2000 Hz	-6dB/oct
		-	Overall level: 18.4 g rms
10	Sine qualification loads (axial and radial, 3 axes)	**Frequency Range**	**Levels (zero-peak)**
		5-20 Hz	± 11 mm
		20-100 Hz	± 20 g

Table 1: CLS OB Main Requirements

III. MECHANICAL DESIGN

CLS Optical Box mechanical design is focused on solving the points shown previously and fulfilling requirements shown in Table 1; it is composed of the elements shown in Figure 4.

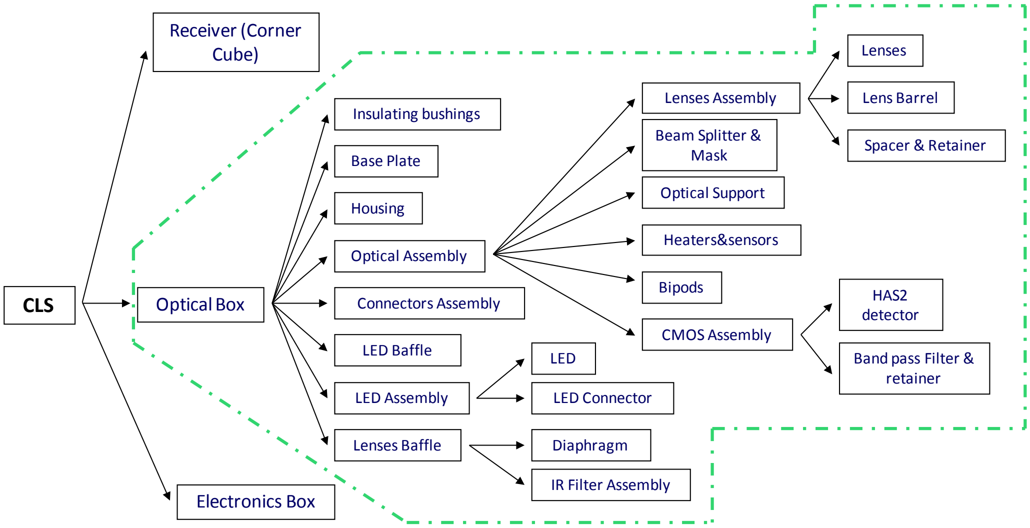

Figure 4: CLS Product Tree

The Optical Box contains both the light source and the optics in a unique assembly which is connected to the Electronics Box (TAS-E responsibility) by means of a harness.

Both the optics and the focal plane are placed in the same integral bracket, the Optical Support. This assembly is located in a baseplate + housing where the LED and the IR filter are also integrated.

The light source, a LED with a peak wavelength of 455nm, is mounted at the necessary distance from the optics by means of a baffle, which is supported by the housing. In the same way, the IR filter and diaphragm are located at the Optical Box exit.

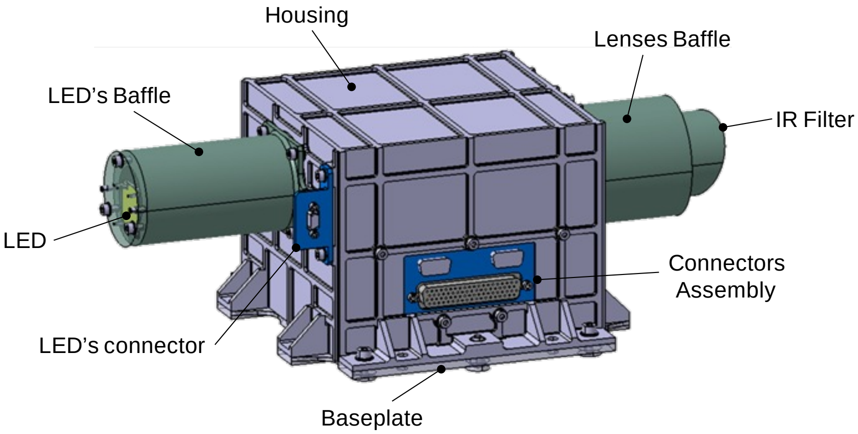

Figure 5: CLS OB

A. Optical Assembly: This assembly contains all the optical elements of the CLS except the IR filter and the diaphragm, providing accommodation to the CMOS sensor, band pass filter, beamspliter and lenses. The Optical Support is an integral part made in Invar 36 to match the CTE of the optical elements, which are made in Fused Silica, as much as possible. This bracket, with the different optics placed inside, is supported by means of three Ti6Al4V Bipods which provide the assembly with the necessary stiffness and at the same time give the required conductive decoupling from the Baseplate (and so from the heat sink) to maximize the efficiency of the thermal control system.

B. Baseplate and Housing: Both parts are made in Aluminum alloy. The Baseplate interfaces with the satellite and provides support for Optical and Connector Assemblies. It is separated from the Housing to facilitate integration tasks. The Housing provides support for the Optical Baffles and Connector Assembly, and also works as protective cover from environmental contamination for the Optical Assembly. Both parts have to obtain a first eigenfrequency above requirement with a moderate mass value.

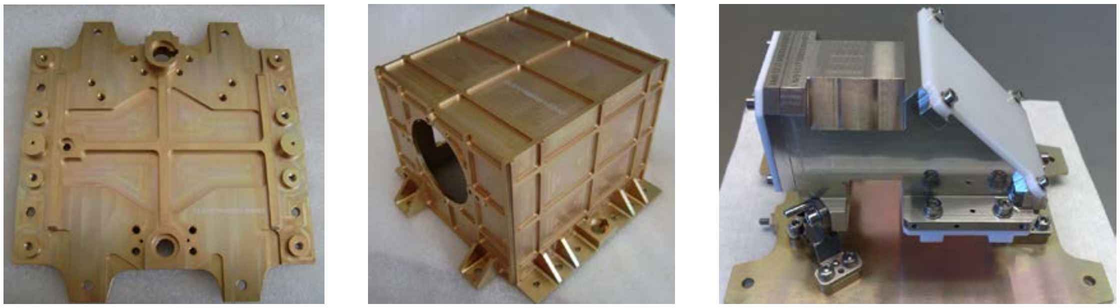

Figure 6: CLS OB Optical Assembly, Baseplate, and Housing

IV. THERMAL CONCEPT

The thermal design is based on maintaining a constant temperature inside the CLS to provide a stable optical configuration, and hence a reliable measurement of the reflector satellite in any mission configuration.

This concept aims to guarantee a good thermal stability along time once the CLS is in the operative mode. After the launch, the CLS thermal environment could range from -20ºC to +50ºC; the Sensor should then be calibrated at the hottest temperature of the range and the thermal control will be in charge of maintaining the same temperature conditions for the optics independently of the thermal environment.

Therefore an active thermal control system composed of four thermofoil heaters and six thermal sensors is used to always keep optical elements at the nominal working temperature (≈50ºC), independently of environmental conditions. It was decided to always work in the hottest area of the range since it is more cost effective to warm up the optics-assembly than to cool it down, and the power budget is limited to 8W. When the CLS environment is at the coldest temperature (-20ºC), the sensor is heated in order to always keep the optics support at the maximum temperature (+50ºC), which is defined as the nominal operation temperature.

At the same time, thermal design is focused on maintaining a high thermal stability to minimize gradients and avoid rotations and displacements of the optical elements which could cause deterioration of the sensor features.

In order to fulfil these requirements the following directives have been established:

- Heater power is applied directly to the Optical Assembly
- Optical Support is thermally decoupled from the environment:
  - Optical Support conductively decoupled from Baseplate by means of bipods
  - Optical support decoupled in radiation from Baseplate and Housing by means of a low IR emissivity
- Optical Box is thermally decoupled from the environment:
  - Baseplate conductively decoupled from satellite by means of Titanium insulating bushings
  - Baseplate and Housing decoupled from the radiation point of view from the satellite by means of a low IR emissivity coating (Alodine 1200)
- Optical properties must be carefully defined to maximize heaters efficiency

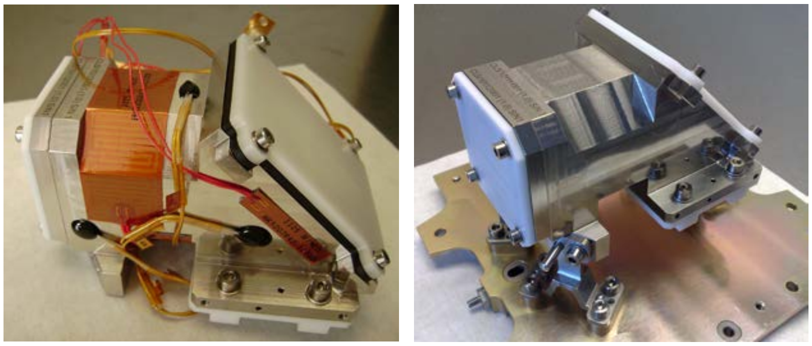

Figure 7: Heaters & Thermal Sensors on Optical Assembly (LEFT), Optical Assembly supported by Bipods

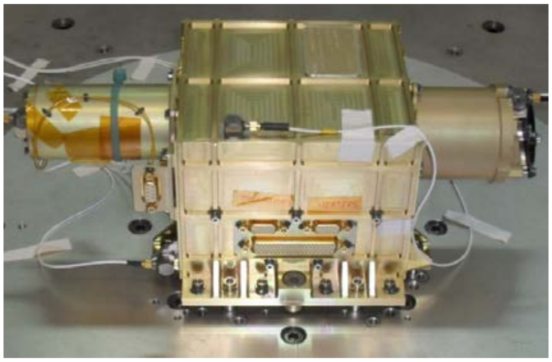

Figure 8: CLS Optical Box external finishing

V. PERFORMANCES

Comparison between specification and performances is shown in Table 2.

REQUIREMENT	**SPECIFICATION**	**PERFORMANCE**	**REMARKS**
Lateral displacement accuracy (3 Sigma)	±5arcsec (3.6mm @ 150m) ±24.2 microrad	OK	
Total power consumption	< 8W	6.5W	Including 20% of contingency
Maximum volume of receiver (optics)	200mm x 100mm x 100mm	172mm x 336.8mm x 123 mm	NC driven by configuration change (LED included in OB)
Total mass (optics and electronics) including shielding	2500g	2550g	Use of Invar 36 for the Optical Support driven by the optical design
Minimum Eigen frequency	140Hz	285Hz	
Quasi-static loads (in three directions not combined)	60g	OK	
Random qualification loads (axial and radial, 3 axes)	**Frequency Range/ PSD**	OK	
	20-60 Hz → +9dB/oct		
	60-400 Hz → 0.5 g2/Hz		
	400-2000 Hz → -6dB/oct		
	Overall level: 18.4 g rms		
Sine qualification loads (axial and radial, 3 axes)	**Frequency Range/ Levels (zero-peak)**	OK	
	5-20 Hz → ± 11 mm		
	20-100 Hz → ± 20 g		

Table 2: CLS OB performances

VI. CONCLUSIONS

The following conclusions can be established:

- The CLS EQM has been successfully designed and tested
- CLS OB is compliance to its main requirements except for the envelope, as a result of a design configuration change not foreseen at the beginning of the project (light source included in OB), and slightly the mass
- CLS EQM has proven the feasibility of a low cost, low mass optical metrology sensor able to provide medium accuracy angular measurements and able for formation flying missions
- CLS OB EQM could be easily upgraded to a FM, only replacing some COTS components

VII. ACKNOWLEDGEMENTS

The activities described in this paper were possible thanks to the collaboration and support of LIDAX staff.