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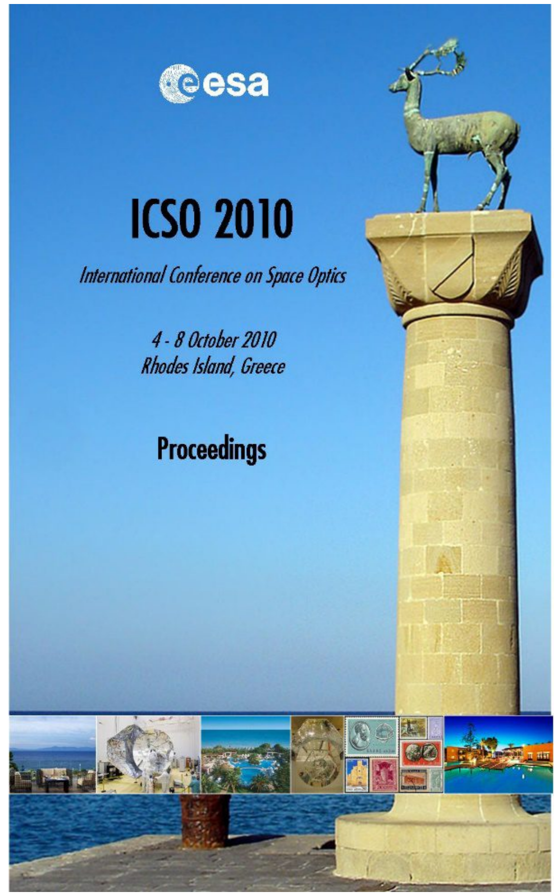

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DEVELOPMENT OF THE LASER RETROREFLECTOR ARRAY (LRA) FOR SARAL

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I. ABSTRACT

CNES (French spatial agency) will provide the AltiKa high resolution altimeter, Doris instrument and the LRA (Laser Retroreflector Array) for SARAL (Satellite with Argos and AltiKa) in cooperation with ISRO (Indian space agency).

The LRA is a passive equipment reflecting the laser beams coming from the Earth ground stations. Computing the send-return time travel of the laser beams allows the determination of the satellite altitude within an accuracy of a few millimeters. The reflective function is done by a set of 9 corner cube reflectors, with a conical arrangement providing a 150 degrees wide field of view over the full 360 degrees azimuth angle.

According to CNES optomechanical specifications, the LRA has been developed by SESO (French optical firm). SESO has succeeded in providing the corner cube reflectors with a very stringent dihedral angle error of 1.6 arcsec and an accuracy within ±0.5 arcsec. During this development, SESO has performed mechanical, thermal and thermo-optical analyses. The optical gradient of each corner cube, as well as angular deviations and PSF (Point Spread Function) in each laser range finding direction, have been computed. Mechanical and thermal tests have been successfully performed. A thermo-optical test has successfully confirmed the optical effect of the predicted in-flight thermal gradients.
Each reflector is characterized in order to find its best location in the LRA housing and give the maximum optimization to the space telemetering mission.

II. SARAL MISSION

The SARAL mission results from the common interest of both CNES (French space agency) and ISRO (Indian space agency) in studying ocean from space using altimetry system and in promoting maximum use of the ARGOS data collecting system of it. The payload is composed of an ARGOS-3 instrument for data collection and localisation, of AltiKa which provides altimetric measurements to study ocean circulation and sea surface elevation, of DORIS and a LRA (Laser Retro-reflector Array) for precise orbit determination.

III. LRA GENERALITIES

This paper presents the design and the optical performances of the LRA developed for SARAL. CNES with SOPHIA CONSEIL subcontractor was responsible for the design and the optical performances. SESO was in charge of the development and especially of the Corner Cubes (CC) manufacturing.
The LRA is used for calibration of the satellite altitude within few millimetres accuracy. The measurement principle is telemetry. The device is nadir-oriented and reflects laser shots from ground stations network. The analysis of the time delay of these laser shots permits to determine the orbit of the satellite.

The LRA is an optomechanical device, totally passive, no specific operational constraint and no calibration are needed. The Corner Cubes constitute the key elements for the optical performances of the LRA. The optical challenge is to determine and to manufacture the CC dihedral offset angle that spreads energy in relevant angular directions.

IV. DESCRIPTION OF THE INSTRUMENT

The LRA for SARAL is a wide field reflecting system thanks to nine corner cubes. Cf. figure 1. It is an hexagonal array type with eight cubes all around the LRA and one at the top, nadir pointing. Such a design permits to position each Corner Cube on a common sphere. The center of this sphere constitutes the LRA phase center. The knowledge of the location of this center in the satellite frame is very important for accurate LRA corrections.
The CC are coated in order to make the LRA response homogeneous in the whole field of view. The table 1 gives the main characteristics of the LRA Instrument.

Table 1 : Main characteristics of the LRA

Dimensions	Φ 165 mm x H 67 mm
Device mass	1,4 kg
Field of view	> 150°
For each CC, cone with optical performances	50°
Number of Corner Cubes (CC)	9
Clear aperture of the CC	30 mm

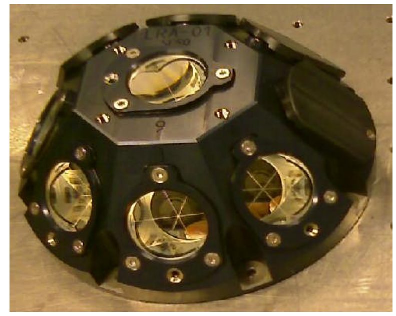

Figure 1. LRA with nine Corner Cubes.

V. THERMAL AND MECHANICAL MODELS

With a Finite Element Assembly Model, SESO has validated that the design is compliant to the quasistatic and dynamic loads.

For thermal analyses, SESO has developed a macroscopic LRA model and a local model for Corner Cubes. The aim of the macroscopic model was to determine the temperature excursion for the LRA. The CC modelisation is very simplified in this model. The external flux, the radiative effects, the internal conductivity and the interfaces properties are taken into account. Additional specific CC model is developed for relevant thermal analysis of the Corner Cubes. The need is to take into account the contribution of the optical flux, the conductive flux inside the cube, and radiative exchanges with the external environment (cold space for the front face and barrel environment for the coated surfaces). Cf. figure 2.

VI. CORNER CUBES

The table 2 gives the main characteristics of the Corner Cubes.

The manufacture of the CC is a great success. The mean error is 0.17 arcsec and the maximum error is 0.42 arcsec! Due to this accuracy, the real optical pattern will be very close to the modelisation and the performances easily achieved.

Experimental Point Spread Functions (PSF) have been characterized and analysed for each Corner Cube. This verification has permited to confirm their position and orientation.
Qualitative and quantitative verifications have been made by comparing measured PSFs and simulated ones. The figure 3 illustrates the analyses made. We have both demonstrated that the dihedral angle offset measurements are relevant and the energy is spread as expected.

Table 2 : Main characteristics of the Corner Cubes.

Dimensions	Φ 30 mm x H 24 mm
Clear aperture of the CC	30 mm
Material	Suprasil
Index of refraction at lambda = 532 nm	1.461
Operational Dihedral offset angle	1.5 arcsec
Coating	Ag coating
Radius of curvature of front face surface	infinite
Wavefront error	< 40 nm RMS

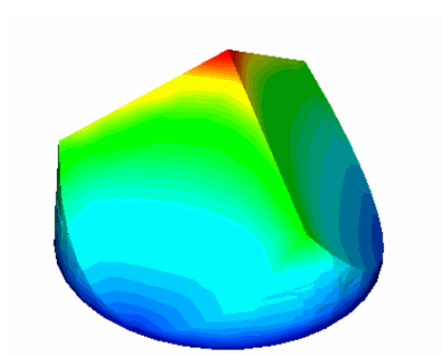

Figure 2. Corner Cube thermal gradient analysis.

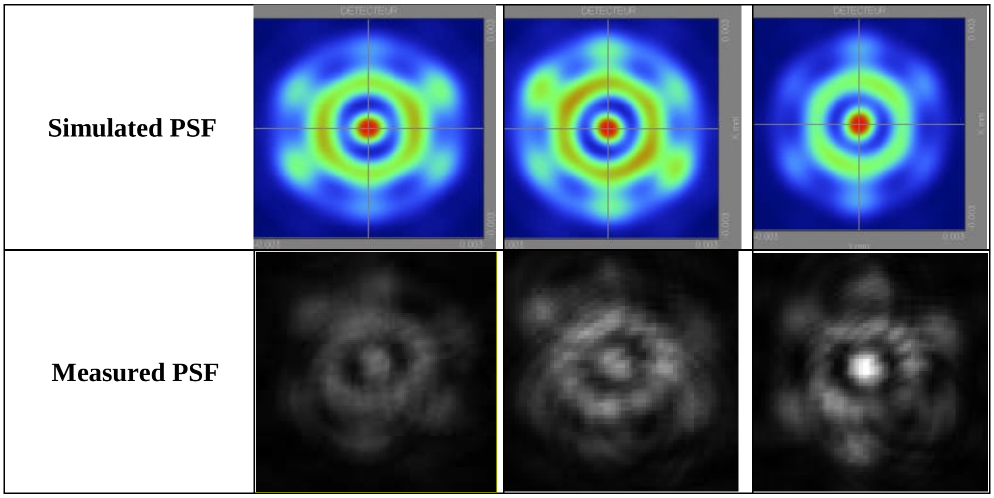

Figure 3. PSF measurements.

VII. TESTS

A qualification model was developed for mechanical and thermal environment tests. LRA assembly has withstood SARAL mechanical loads and thermal cycling between -70°C and +40°C without any change. Optical measurements (wave front error and geometrical verifications) reveal no change.

A specific thermo-optical test has been run. The objective was to verify the thermal effects on the optical spot. The LRA assembly was put in a thermal chamber. Optical measurements were made in different configurations : homogenous temperature cases (+22°C, -8°C, -15°C, -30°C and -45°C) and one gradient case. The gradient case is a LRA's structure gradient. Figures 4 and 5 show the test configuration. The gradient is created with a thermal heater installed in a side of the LRA assembly.

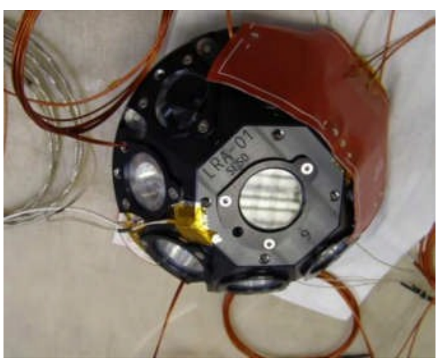

Figure 4. LRA equipped with its heater.

Figure 5. Thermo-optical test configuration.

VIII. CONCLUSION

The LRA development is a success with complementary contributions of CNES, SESO and SOPHIA CONSEIL. The LRA optical performances are compliant and have been verified by tests. A specific thermo-optical test confirmed the Corner Cube thermal gradient impact. The delivery of the LRA flight model was done on December 2009. It has been integrated on the payload. SARAL Satellite launch is scheduled for 2011.