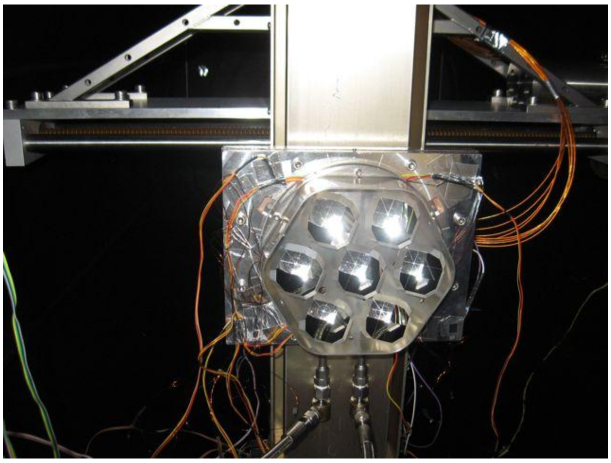
International Technical Laser Workshop 2012 (ITLW-12)

Design, construction and SCF-Test of a prototype Galileo & GNSS Retroreflector Array of Hollow retroreflectors (GRA-H)

Dell'Agnello S., Berardi S., Delle Monache G. O., Boni A., Cantone C., Garattini M., Lops, C., Martini M., Patrizi G., Tibuzzi M., Maiello M., Intaglietta N.
INFN-LNF, Italy
simone.berardi@lnf.infn.it

Some of the present generation of GNSS satellites are equipped with retroreflectors arrays. This first-generation payloads proved poor performances in terms of Optical Cross Section. This lack of light return intensity becomes eventually a limit for the ranging capability of the SLR stations.

In 2005, with the former ETRUSCO program, we had the opportunity to test retroreflectors used on GPS, GLONASS, LAGEOS 1&2 satellites and on the moon surface.
With the SCF lab, capable to accurately simulate several types of space environments for integrated thermo-optical tests, we pointed out the importance of different mounting techniques (insulating, conductive, single screw, multiple screws…) and different optical designs (coated, uncoated, bulk, hollow…) in the overall performances of the entire array.
This work culminated with the publication of the "ETRUSCO paper" on Advances in Space Research and with the definition of the SCF-Test procedure.
In 2009 we started the second part of our work with the new ETRUSCO-2 program.
Starting from the ETRUSCO expertise, ETRUSCO-2 aims to use the state of the art of the optical and mechanical technology to design, build and test the best possible array for the new European GNSS constellation: Galileo.



The complete GRA-H inside the SCF

The hollow retroreflector technology shown several advantages, especially in terms of light return and lightweight. For this reasons, as a first ETRUSCO-2 prototype, we decided to design, build and test a small array made of seven hollow retroreflectors with two different kinds of coatings (aluminum and silver). The retroreflectors used are off-the-shelf components from PLX (U.S.A.), made essentially of three Pyrex orthogonal faces glued together with 0.0+/-0.5 arcsec dihedral angle offsets (DAO). One of the faces (called "the mounted face") is glued on an INVAR stem. At the base of the stem there is a threaded hole to fasten the retroreflector. Beyond the CCR choice we

designed and built the rest of the array (baseplate and side screen) and several kind of fastening solutions to maximize insulation or conductance of heat to and from the rest of the simulated satellite body.
Once the array was completed and integrated with all the instrumentation inside the thermo-vacuum test chamber (the SCF), we planned a complete test campaign that lasted for about 2 months.

The first test phase was carried out with a single reference HCC with Al coating mounted at the center of the array. After more than 15 test sessions we observed a decrease by 55% of the intensity at zero velocity aberration and an increase of OCS at the GNSS velocity aberration (24 μrad) compared to the nominal OCS. It's worthwhile to notice that this can be misleading, since the ageing is more severe for the space qualification than the OCS increase. We observed also that OCS increases with thermal gradients, but with large asymmetries in azimuth, while the unperturbed OCS is symmetric. These asymmetries and consequent fluctuations of the laser signal strength are problematic for the operation of SLR ground stations. Lastly there are large thermal gradients among mounted and non-mounted faces.

The second test phase was carried out with the complete GRA-H (7 HCCs with Al and Ag coating) in different conditions and array temperature setpoints. In this second test part we learnt that:

- Under SS illumination the Silver coated HCC n. 1:
  - Has temperature increase significantly lower than the Aluminum coated HCC n. 4
  - Has significantly longer thermal relaxation time constants (τ_{HCC}) than the Al HCC n. 4

- OCS azimuth asymmetries persist and are large

- After these thermo-mechanical stress-fatigue cycles, we have observed a permanent and significant degradation of both the FFDP intensity and shape caused by some structural deformation(s) of Al HCC n. 4. This cycles are a little part of what a GNSS satellite will experience in 15 years of expected lifetime.

- Compensating the decrease of the HCC OCS intensity over time would require more HCCs. The HCC advantage of having less mass can be lost.

SCF-Tests campaign main outputs are:

- thermal relaxation time constants of the tested CCRs.
- FFDP trends, i.e., the optical response over time upon varying environmental conditions and internal temperature gradients

During tests, the payload is subject to thermal stresses typical of real operating conditions, and at the same time, the optical response of each retroreflector is measured.
The last test phase was the structural stability test on a single HCC (HCC n. 4, the same used for first phase).

- Again, the **Al HCC n. 4** was mounted **alone** at the center of the GRA-H but with **two conductive washers** to enhance the thermal link with the SIP-H
- Temperature cycle in range larger than **[+100 C, -60 °C]** range **indicated by ESA** for Galileo and larger than range indicated by NASA for GPS3
  - Heating: with thermal control plate first, then aided by Sun Simulator
  - Cooling: thermal control and Sun Simulator off, effect of LN2 shield

Furthermore, over the entire test campaign period, we observed and monitored a strong ageing effect gathered by the retroreflectors structure and bonding between the three faces.