SCF_LAB: an infrastructure to characterize satellite/lunar laser ranging and altimetry of icy and rocky moons

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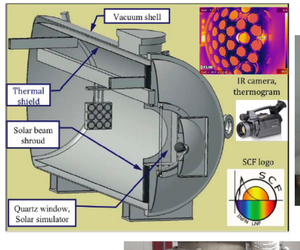
The SCF (Satellite/Lunar laser ranging Characterization Facility) and SCF-Test are a unique and unprecedented test facility and test procedure to characterize and model the detailed thermal behavior and optical performance of cube corner laser retroreflectors (CCRs) for Satellite/Lunar Laser Ranging (SLR/LLR) applications in accurately laboratory-simulated space conditions [1]. The SCF has been developed by INFN-LNF and is in use by NASA for the Earth's Moon, and by ESA and ASI for Galileo and the GNSS (Global Navigation Satellite System) [2] [3].
The SCF modular, versatile and evolutionary design allows also for the laboratory characterization of Laser Altimetry (LA) investigations of moon SUrface SImulants (mSUSI), in place of CCRs. Laser altimetry has been and is an important tool in the exploration and planetary science of Mars (as shown by the past Mars Orbiter Laser Altimeter, MOLA, onboard the Mars Global Surveyor), Mercury (see the current Mercury Laser Altimeter, MLA, onboard MESSENGER) and the Earth's Moon (see the current Lunar Orbiter Laser Altimeter, LOLA, onboard the Lunar Reconnaissance Orbiter).
The SCF is operated in an infrastructure owned by INFN-LNF, the SCF_LAB, which includes a dedicated clean room of class 10000 or better. Our key experimental innovation is the concurrent and integrated measurement and modelling of the optical Far Field Diffraction Pattern (FFDP) and the temperature distribution of CCRs/mSUSIs, under thermal conditions produced with a close-match solar simulator. The apparatus includes infrared cameras for non-invasive thermometry, CCR/mSUSI thermal control and real-time CCR/mSUSI movement to simulate satellite/mSUSI orientation with respect to solar illumination and laser interrogation beams.
These capabilities provide unique pre-launch performance validation and a-posteriori characterization of as-built/in-flight performance of LLR/SLR/LA missions, including investigations in daylight conditions. To give a feeling of the novelty and effectiveness of the SCF, results of selected SCF-Test of CCRs are presented, including the SCF-Test of the first four Galileo In-Orbit Validation (**IOV**) satellites recently done for ESA. We are constantly upgrading the SCF_LAB. In fact, we are now procuring a vibration-insensitive Wavefront Fizeau laser Interferometer (**WFI**) to be used concurrently to CCR FFDP/temperature measurements, and a new close-match solar simulator (our second).
LAGEOS = LAser GEOdynamics Satellite

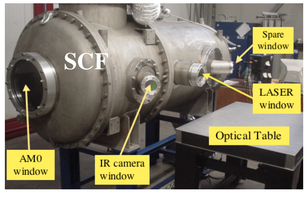
[1] Creation of the new industry-standard space test of laser retroreflectors for the GNSS and LAGEOS, S. Dell'Agnello et al, Advances in Space Research 47 (2011) 822–842.
[2] A lunar laser ranging retroreflector array for the 21st century, D. Currie, S. Dell' Agnello, G. Delle Monache, Acta Astronaut. 68 (2011) 667-680.
[3] ETRUSCO-2: An ASI-INFN project of technological development and "SCF-Test" of GNSS LASER Retroreflector Arrays, S, Dell'Agnello, 3rd International Colloquium on Scientific and Fundamental Aspects of the Galileo Programme, Copenhagen, Denmark, August 2011

Two unique and unprecedented OGSEs (Optical Ground Support Equipments) facilities in a clean room to characterize the SLR/LLR/GNSS space segments

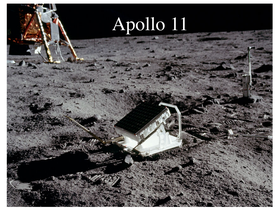
SCF_LAB
Satellite/Lunar/GNSS laser ranging
Characterization Facility LABoratory

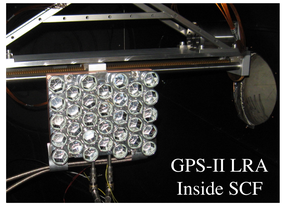
SCF for SLR/LLR [1] [2]



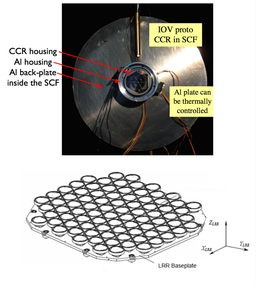


SCF-G for GNSS [1] [3]





Galileo IOV



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SCF-Test: measurement of key performance indicators (KPIs) of CCRs: thermal relaxation time, optical FFDP and WFI; orthogonal laser polarizations [1].

Now upgrading SCF_LAB with 1064 nm laser and optics to characterize IR laser altimetry

Now evaluating new, optimized KPIs to characterize mSUSIs

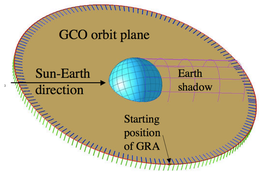
Demo of SCF_LAB capabilities:

Galileo IOV: full, 7-hour, orbital test of Sunrise, Earth shadow, Sunset [3]

GCO: GNSS orbit whose angular momentum is orthogonal to the Sun-Earth direction

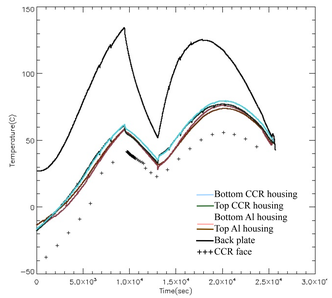
Sunrise-Eclipse-Sunset probes critical features of the thermal and optical behavior of the CCR, including optical breakthrough.

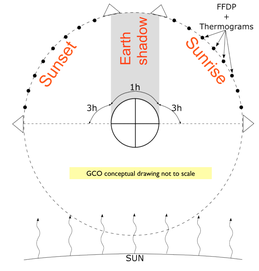
Galileo orbit:
- Altitude = 23222 km
- Period ~ 14 hr, shadow ~ 1hr

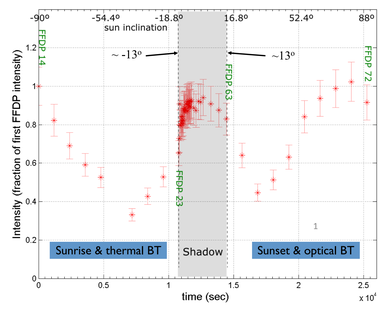


Measured temperatures vs. time (& sun inclination):
- 2 probes on CCR housing
- 2 probes on Al housing
- 1 probe on the back-plate
- IR camera thermograms of the outer CCR face

Note the very large temperature excursion, >100 K



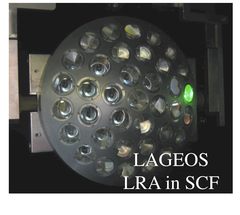




LAGEOS: Earth shadow test

Modest, acceptable FFDP degradation

SCF-Test of the NASA-GSFC LAGEOS Sector



Intensity at 35 μrad velocity aberration vs time