SCF_Lab

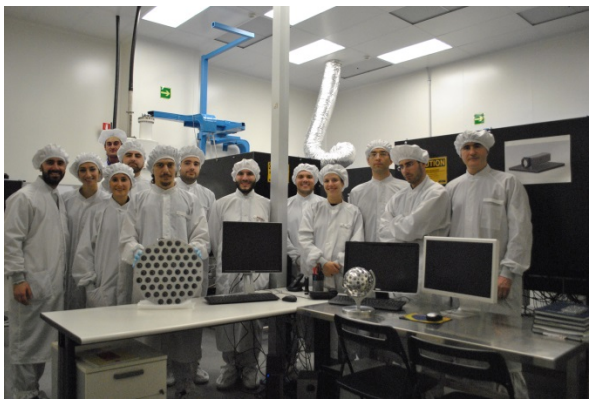


Fig. 1 *Some members of SCF_Lab Team, inside the Laboratory, a room where temperature, humidity and dust level are controlled.*

SCF_Lab

SCF_Lab (Satellite/lunar/GNSS laser ranging/altimetry and Cube/microsat Characterization Facilities Laboratory) is a brand new ISO 7 Clean Room of about 85 m^2 located inside the Frascati National Laboratories of INFN. Unique worldwide, it is dedicated to design, characterization and modeling of the space segment of Satellite Laser Ranging, i.e. the measurement of the position, through laser pulses, of a certain kind of devices (Cube Corner laser Retroreflectors, CCRs), located on artificial satellites orbiting the Earth or on the Moon's surface and, in the future, even on the other planets. In SCF_Lab, thanks to an innovative vacuum test (SCF-Test), we characterize and model the thermal behavior and the optical performances of CCRs. The laboratory procedures are approved by the international organization that coordinates all the laser ranging activities, the International Laser Ranging Service (ILRS); regarding the quality of the CCR, it is evaluated by using an interferometer that allows us to define the shape of the retroreflector at the level of the millionth of a mm. Otherwise, through an appropriate optical circuit, we measure the CCR's performance allowing us to understand if, once launched in space, it will properly fulfill its function. By using the IR camera we can make thermometry measurements without having a direct contact with the object. In the laboratory there are two solar simulators used to reproduce the spectrum of the solar radiation out of the Earth's atmosphere offering the possibility of testing also other space devices besides CCRs. Thanks to these metrological capabilities and to the scientific relevance of this experimental activity, SCF_Lab has been affiliated to NASA-SSERVI (Solar System Exploration Research Virtual Institute), one of the Institutes afferent to the prestigious US space agency, NASA (National Aeronautics and Space Administration).

CCRs and SCF-Test

CCRs are quartz prisms made out of a corner of a Fused-Silica cube whose main characteristic is to reflect light back to the same incident direction. This is achieved thanks to the triple reflection, on the three back faces, of a ray incising the front face. Inside a cryostat where the space out of the Earth's atmosphere is simulated, CCRs are illuminated by light coming from a solar simulator, and we study both thermal and optical behavior during the heating phase and the cooling phase; the latter is when the solar simulator is switched off.

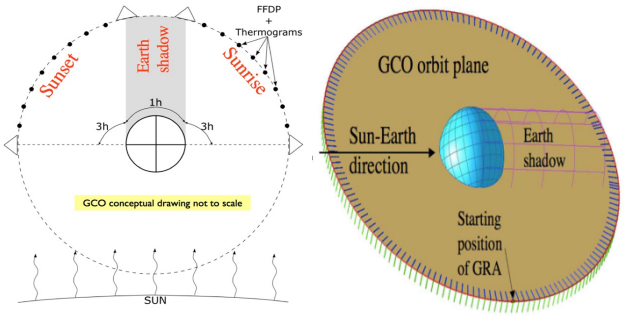
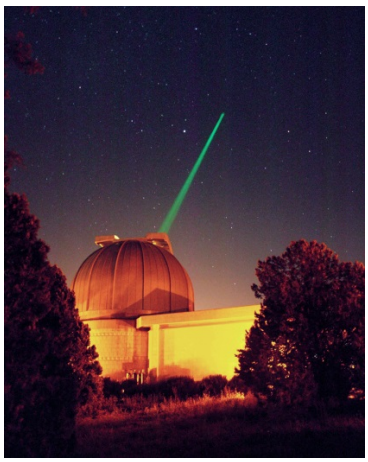


Fig. 2 *GNSS Critical Orbit (GCO) Test concept (left) and the representation of the GCO in space (right). On the bottom, ILRS laser station in Matera.*

The diagnostic capabilities have been recently enhanced by introducing a kind of test (GCO, GNSS Critical Orbit) that simulates an orbit which is critical for CCRs performance: at the beginning, the sun rays illuminate one side of the CCR's front face, the inclination of the rays gradually changes until they fall on the opposite side of the CCR. The simulated orbital plane includes the line connecting Sun and Earth; the half of the orbit that we simulate is the only critical part i.e. where the CCRs are exposed to sunlight, including the amount of time when CCRs are in the cone of the Earth's shade.



Laser Ranging

Satellite Laser Ranging (SLR) is one of the most accurate measuring techniques available at the moment to determine the position of the satellites orbiting the Earth (the only space geodesy technique that directly measures a range) providing a level of accuracy to the centimeter.

It is based on a global network of ILRS ground stations that measure the round-trip time of flight of a laser pulse transmitted from the Earth and retro-reflected by satellites equipped with CCRs providing an absolute positioning in space respect to the Earth's center of mass (geocenter), which is metrologically defined by ILRS through this technique: there are some spherical satellites orbiting the Earth completely covered by CCRs such as LAGEOS I e II (Laser GEOdynamics Satellites), whose orbits define the geocenter. CCRs are also on the lunar surface, since 1969, when the first astronauts landed on the Moon with the Apollo 11 mission.

Only few ILRS laser stations have an adequate instrumentation for lunar CCRs laser ranging: one of the most important of them is the ASI (Agenzia Spaziale Italiana) ground station; it is located in Matera and collaborates closely with the SCF_Lab. Due to its level of accuracy to the cm, the laser ranging technique is used to define the orbits of artificial satellites and of the Moon very precisely, giving, this way, an important contribute to the fundamental physics studies regarding the gravitational interaction properties. Moreover, the satellite laser ranging is essential to measure the temporal variation of Earth's gravity to study the Earth, its Atmospheric and Ocean systems (mapping volumetric changes in continental ice masses), to evaluate long-term climate changes.

Fig. 3 *LAGEOS, NASA (on the left, courtesy of NASA, NASA-SSERVI logo (right)*

SCF, SCF-G and the Galileo program

There are two cryostats inside the SCF_Lab, i.e. two metal cases with several inspection windows and aimed to recreate the space environment in terms of pressure and temperature. The first cryostat realized is the SCF whose main target is to provide instruments to diagnose, optimize and test all the space programs regarding the use of CCRs.

The great social and economic revolution due to the use of GNSS (Global Navigation Satellite System) has boosted the development of a second cryostat, the SCF-G, optimized to give the highest support to this kind of space programs. These navigation devices are common objects that give a great support in everyday life.

Not all the people know that besides indicating us the most convenient itineraries to drive through, GNSS provides data that fix the exact moment when each electronic-financial transaction happens. Currently, the data in use are the ones coming from the US GNSS constellation: the well-known GPS (Global Positioning System). The great importance of this kind of technology encouraged the European Union to finance the realization of its own constellation, named Galileo after the Italian scientist.

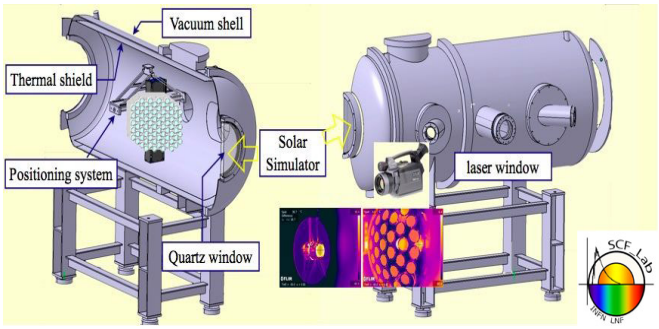
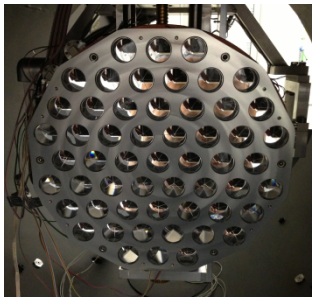


Fig. 4 *Schematic view of SCF cryostat with: IR photo of a LAGEOS sector and of a Galileo CCR under test, IR camera and SCF_Lab logo.*

Outcomes



In accordance with the guidelines issued by ILRS, it is fundamental to SCF-Test different CCRs of all GNSS constellations in order to ensure the highest efficiency: when the scheduled GNSS constellations will be completed and full operative, ILRS will have more than 100 satellites to track, respect to the ~30 satellites that it is tracking now. Besides ILRS, NASA and ASI, SCF_Lab also collaborates intensively with ESA (European Space Agency): we designed an array with excellent performances, the GRA (GNSS Retroreflector Array) to propose for Galileo satellites; moreover, ISRO (Indian Space Research Organization) asked SCF_Lab to test some CCRs for its own GNSS constellation. Furthermore we have already realized a new CCR for the next lunar missions, much larger and efficient than the ones currently in use, and we are developing an array of CCRs for Earth Observation in the framework of national and international missions.

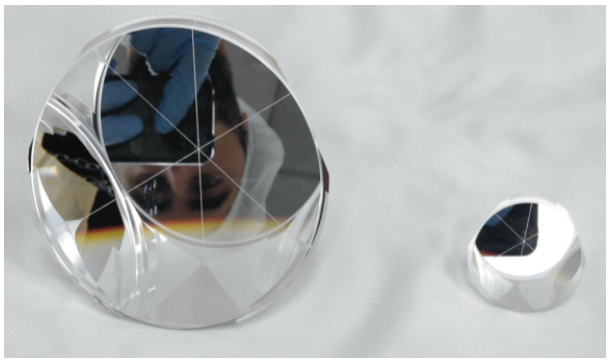


Fig. 5 *The new big lunar CCR and the previous Apollo CCR (bottom), GRA (top right)*