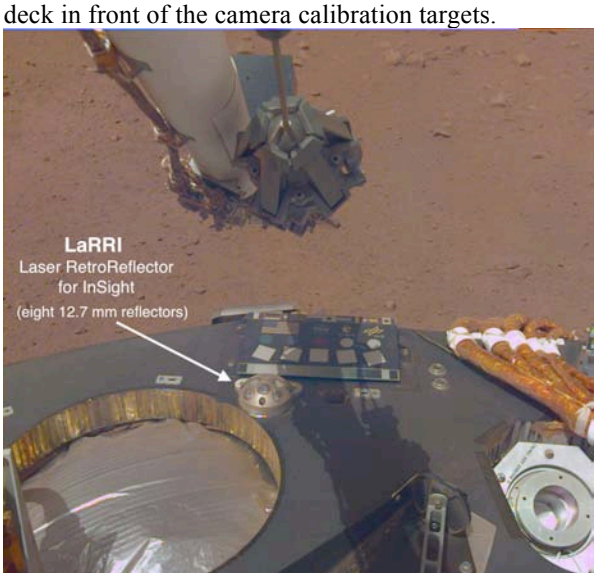
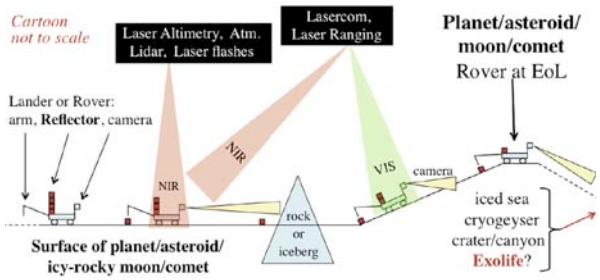
Laser Retroreflectors for InSight and an International Mars Geophysical Network (MGN). S. Dell'Agnello[1], G.O. Delle Monache[1], L. Porcelli[1,2], M. Tibuzzi[1], L. Salvatori[1], C. Mondaini[1], M. Muccino[1], L. Ioppi[1], O. Luongo[1], M. Petrassi[1], G. Bianco[1,3], R. Vittori[1,4], W.B. Banerdt[5], J.F. Grinblat[5], C. Benedetto[3], F. Pasquali[3], R. Mugnuolo[3], D.C. Gruel[5], J.L.Vago[6] and P. Baglioni[6]. [1]Istituto Nazionale di Fisica Nucleare–Laboratori Nazionali di Frascati (INFN–LNF), Via E. Fermi 40, 00044, Frascati, Italy (simone.dellagnello@lnf.infn.it); [2]Dipartimento di Fisica, Università della Calabria (UniCal), Via P. Bucci, 87036, Arcavacata di Rende, Italy; [3]Agenzia Spaziale Italiana–Centro di Geodesia Spaziale "Giuseppe Colombo" (ASI–CGS), Località, Terlecchia 75100, Matera, Italy; [4]Italian Air Force, Rome, Italy, ASI and Embassy of Italy in Washington DC; [5]NASA–Jet Propulsion Laboratory (JPL), California Institute of Technology, Pasadena, CA 91109, USA; [6]ESA–ESTEC, Noordwijk, The Netherlands.

Abstract. There are laser retroreflectors on the Moon, but there were no laser retroreflectors on Mars until the NASA InSight mission [1][2] landed and started operating successfully on the surface of the red planet on Nov. 26, 2018. The ESA ExoMars Schiaparelli mission, which unfortunately failed Mars landing in 2016, was carrying a laser retroreflector like InSight [3]. These instruments are positioned by measuring the time-of-flight of short laser pulses, the so-called "laser ranging" technique (for details on satellite/lunar laser ranging and altimetry see https://ilrs.gsfc.nasa.gov). The following image taken in December 2018 shows LaRRI (Laser RetroReflector for InSight) on the lander deck in front of the camera calibration targets.



Starting from 2015 we initiated the delivery to ASI, ESA and NASA-JPL of several miniaturized laser retroreflector payloads (*microreflectors*) designed for Mars, Moon and other planetary missions and to be observed by orbiters capable of laser ranging measurements. Examples of the latter are the past Mars Global Surveyor, the current Lunar Reconnaissance Orbiter and similar future spacecrafts, like Hera (ESA's proposed mission to the Dydimos double asteroid, which is foreseen to carry a lidar/altimeter instrument onboard). The notional concept of microreflectors for solar system exploration research (a pillar of the INFN-ASI *Affiliation-Association* to NASA-SSERVI sservi.nasa.gov) is shown in the figure below.



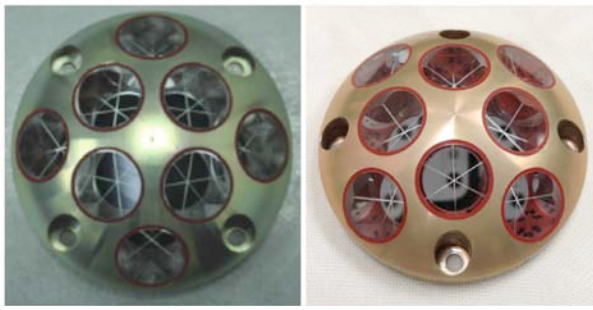
The goals of the microreflectors and their role as the passive, maintenance-free, long-lived instrument component of a future Mars Geophysical Network (MGN) are described in [2][3]. Hopes for a future international MGN now rest solidly on the success of InSight, which will always be the first, *core node* of such an MGN.

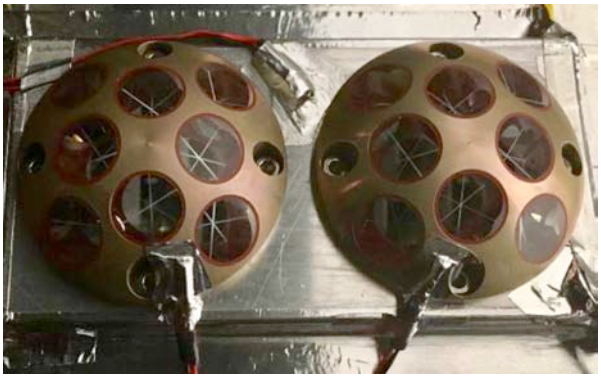
Science applications of microreflectors include surface geodesy, geophysics (when combined with seismometers, heat flow probes, etc., like the instrument suites of InSight [1] and Apollo[1] [4][4a]) and the test of fundamental relativistic gravity. We performed test physics simulations of the contribution of a 5-microreflector MGN to test General Relativity with the Planetary Ephemeris Program developed by I. Shapiro et al (see for example [5]). Under specific and conservative assumptions (about laser observations from orbit, tracking of the orbiter, etc.) the contribution of this MGN is found to improve the measurements of Gdot/G (possible time changes of the gravitational constant) and of β, the Parametrized Post Newtonian constant related to gravitational self-energy and to possible violations of the strong equivalence principle. This test will be complementary to (and with experimental errors independent of) the one performed [6][7] with large-size lunar laser retroreflectors (Apollo 11, 14, 15; Lunokhod 1, 2) observed by lunar laser ranging from Earth since 1969.

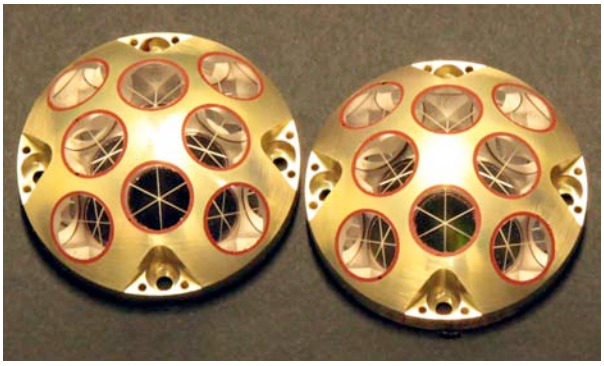
[1] EASEP and ALSEP = Early Apollo Scientific Experiment Package/Payload (Apollo 11) and Apollo Lunar Surface Experiments Package (≥ Apollo 12).

The following photos show six microreflector payloads, each equipped with eight ½ inch (12.7 mm) diameter laser retroreflectors of fused silica, built and fully qualified for Mars surface missions:

- ESA Schiaparelli [8] (top left, delivered to ESA on Sep 2015 for integration by Thales Alenia Space - Italy)
- NASA InSight (top right, delivered to JPL on Aug 2017 for integration by Lockheed Martin Co.)
- ESA ExoMars Rover [9] (middle right, delivered to ESA on Oct 2018); image taken at thermal test
  - Middle left: identical spare available at INFN for other *international* mission opportunities
- NASA Mars 2020 Rover [10] (bottom, both ready to be delivered to JPL in very early 2019)
  - After Mars 2020 launch one will be returned to INFN for other *international* opportunities.







Prior to delivery the optical performance and thermal behavior of laser retroreflectors is characterized at the SCF_Lab (www.lnf.infn.it/esperimenti/etrusco/) of INFN-LNF in environmental conditions accurately representative of their deployment at their respective destinations (see [11] for LaRRI on InSight and [12] for the general approach, specialized equipment and procedures, as well as applications to LAGEOS-type and to GNSS laser retroreflector payloads[2]).

References

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[2] Laser GEOdynamics Satellite by NASA in 1976 and LAGEOS 2 by ASI in 1993; Global Navigations Satellite System (GPS, GIOVE-Galileo, IRNSS, etc.).