

# MoonLIGHT-2

INFN-CSN2 experiment: Test Gravity in the Solar System

CSN2-LNF, 25 June 2019

## Italian Participants:

LNF Services (person-mo): SPCM 6; Electronics: 6; DT: 3; Cryo: 1; Laser: 1

ASI-Matera Laser Ranging Observatory ... 4 FTE (15M€ infrastructure)

INFN-LNF ..... 9.7 FTE (+ 2.6 FTE CTER)

INFN-Padova ..... 2.8 FTE

INFN-Naples ..... 2.1 FTE

## USA Participants:

Univ. of Maryland (UMD), MD

Harvard Center for Astrophysics (CfA), MA

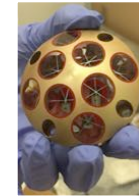
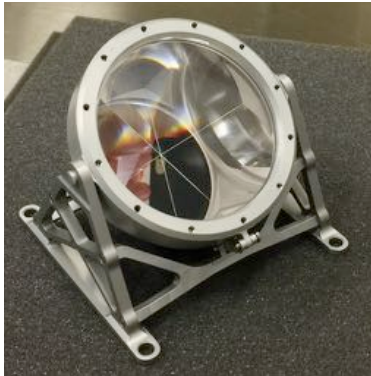
Univ. San Diego, CA, *APOLLO laser station*

NASA-SSERVI

## Three approved flights (2021, 2022 ...):

**NASA, with Commercial Lander: OrbitBeyond/TeamIndus (2 missions)**

**NASA – ESA, with Commercial Lander: Astrobotic (1 mission)**



Partner Space Agencies:



# JointLab INFN-Frascati with ASI-Matera: 2019-2024, 1.5M€

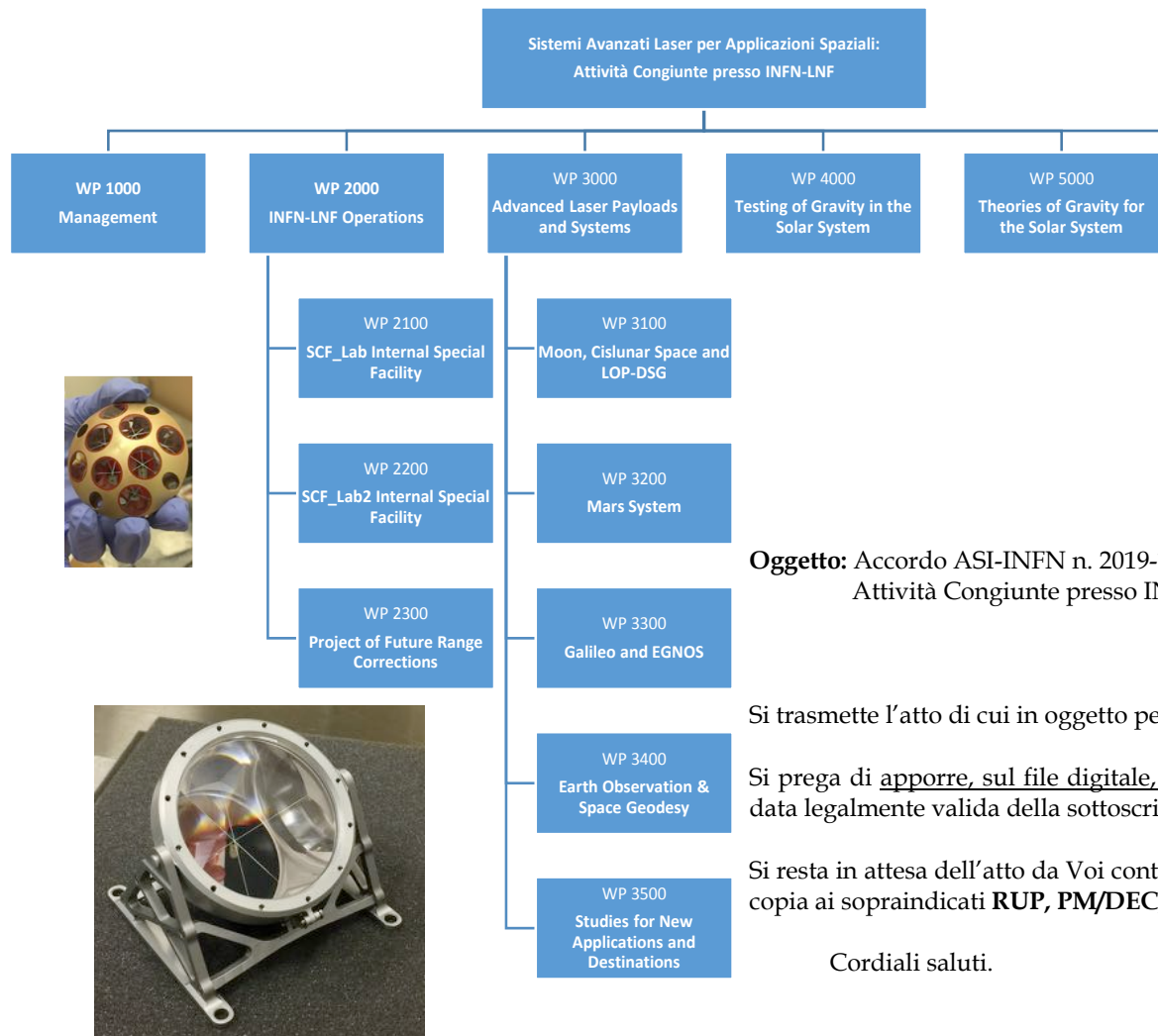


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Presidente

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DEC /PM: Catia Benedetto  
Unità Contratti: Francesca Paccagnini  
Unità contratti - Segreteria Flora Leucci



**Oggetto:** Accordo ASI-INFN n. 2019-15-HH.0 per "Sistemi Avanzati Laser per Applicazioni Spaziali: Attività Congiunte presso INFN-LNF".

Si trasmette l'atto di cui in oggetto per la Vostra sottoscrizione.

Si prega di apportare, sul file digitale, la firma digitale, unitamente alla marca temporale, che attesta la data legalmente valida della sottoscrizione.

Si resta in attesa dell'atto da Voi controfirmato, da inviare ad [asi@asi.postacert.it](mailto:asi@asi.postacert.it), con comunicazione in copia ai sopraindicati RUP, PM/DEC, Responsabile Contrattuale ed Unità Contratti-Segreteria.

Cordiali saluti.

U.O. Contratti  
Il Responsabile  
Dott.ssa Luciana Gentile

# ASI-INFN Joint Lab on Laser Retroreflectors & Ranging

INFN – ASI – MAECI – DEFENCE

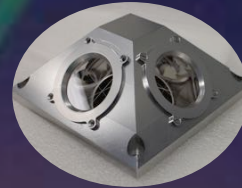
collaboration with USA partners:

NASA, Universities, USGS,  
NOAA-NIC, USA space industries



Comet/asteroid  
NASA-  
SSSERVI

ASI – Matera  
Laser Ranging  
Observatory



Earth  
Observation  
USGS,  
NOAA



Moon

ESA-ESTEC  
U. Maryland,  
U. San Diego,  
Industries,  
NASA-  
SSSERVI



Mars/Moon,  
Europa !  
NASA-JPL



Phobos/Deimos  
NASA-SSSERVI

LAGEOS-  
type  
NASA-  
GSFC

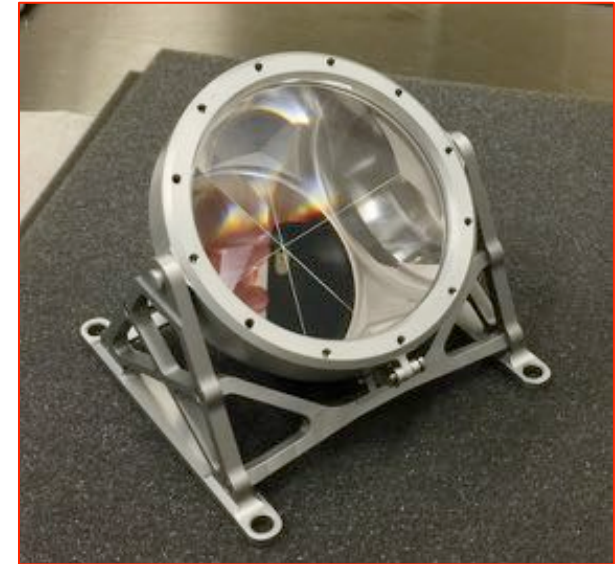
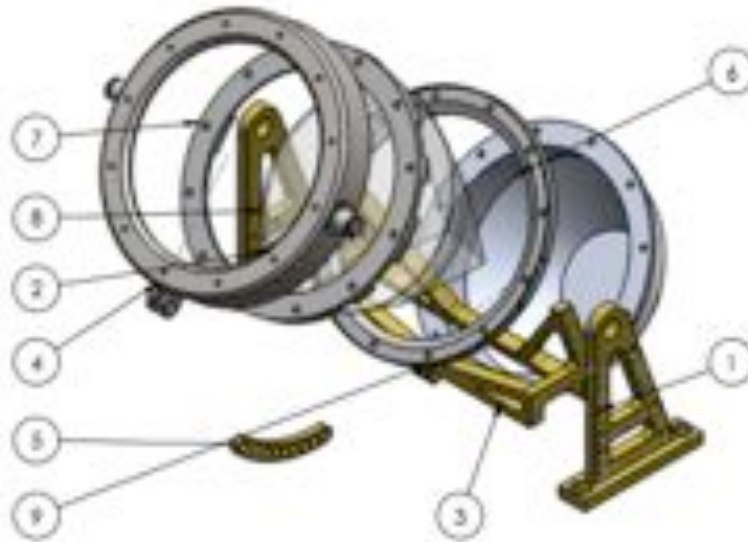


Galileo T.S.  
GPS

- *Big, single laser retroreflector observed from Earth*
  - Italy/US: **MoonLIGHT** = Moon Laser Instrumentation for General relativity High accuracy Tests
- *Miniaturized retroreflector observed from orbiters*
  - **microreflectors** suited for landing-roving investigations on the Moon, Mars (& other airless solar system bodies)
- *Orbital, positioning SW*
  - We use **PEP** (Planetary Ephemeris Program) for Lunar & Martian positioning: developed in USA at the Harvard-Smithsonian Center for Astrophysics (CfA), by Shapiro, Reasenberg, Chandler since 1960/70s



# MoonLIGHT (4" optics), micro (8 × 1/2" optics)



**Microreflector** ~5 cm, 25 gr  
(mouse shown as a 'ruler')

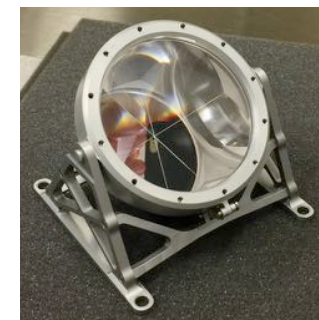


Improvements of space segment up to  $\times 100$  with MoonLIGHTs plus current LGN of Apollo/Lunokhods

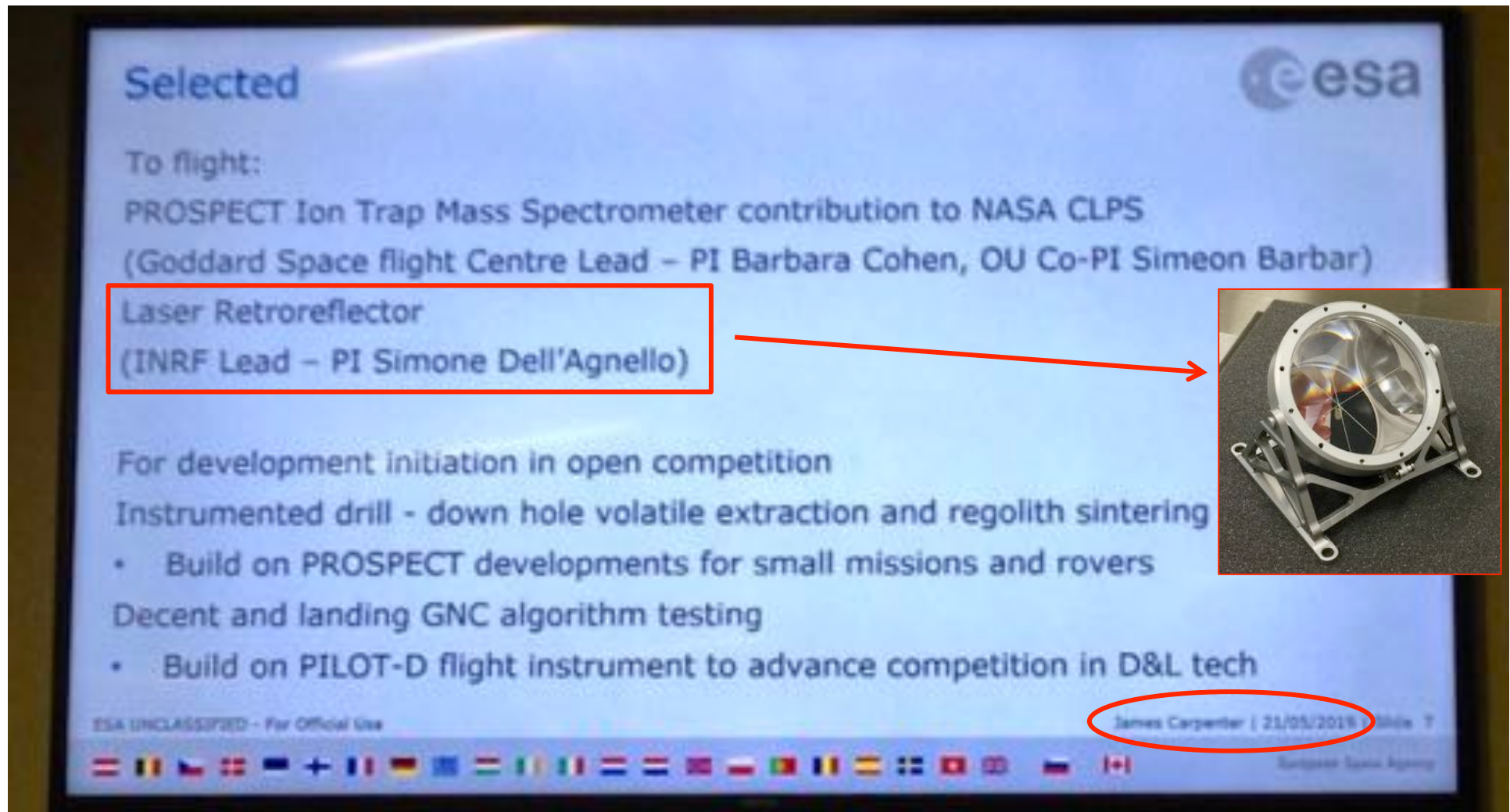
Science measurement / Precision test of violation of General Relativity	Apollo/Lunokhod * few cm accuracy	MoonLIGHTs **	
		mm	sub-mm
Parameterized Post-Newtonian (PPN) $\beta$	$ \beta - 1  < 1.1 \times 10^{-4}$	$10^{-5}$	$10^{-6}$
Weak Equivalence Principle (WEP)	$ \Delta a/a  < 1.4 \times 10^{-13}$	$10^{-14}$	$10^{-15}$
Strong Equivalence Principle (SEP)	$ \eta  < 4.4 \times 10^{-4}$	$3 \times 10^{-5}$	$3 \times 10^{-6}$
Time Variation of Gravitational Constant	$ \dot{G}/G  < 9 \times 10^{-13} \text{yr}^{-1}$	$5 \times 10^{-14}$	$5 \times 10^{-15}$
Inverse Square Law (ISL) - Yukawa	$ \alpha  < 3 \times 10^{-11}$	$10^{-12}$	$10^{-13}$
Geodetic Precession	$ K_{gp}  < 6.4 \times 10^{-3}$	$6.4 \times 10^{-4}$	$6.4 \times 10^{-5}$

\* J. G. Williams et al. PRL 93, 261101 (2004)

\*\* M. Martini and S. Dell'Agnello, R. Peron et al. (eds.), DOI 10.1007/978-3-319-20224-2\_5, Springer Intern. Publishing, Switzerland (2016)



# 21/May/19: MoonLIGHT-2 selected by ESA for 1 NASA lunar mission (ESA-INFN contract: 250k€, 2019-20 for Earth pointing actuators)



The image shows a screenshot of a presentation slide from ESA. The slide is titled "Selected" and lists several projects. The "Laser Retroreflector" project is highlighted with a red box, and a red arrow points from it to an inset image of the physical device. The inset image shows a circular, metallic retroreflector mounted on a four-legged stand. The slide also lists other projects like "PROSPECT Ion Trap Mass Spectrometer" and "Instrumented drill". At the bottom right, the name "James Carpenter" and the date "21/05/2019" are circled in red. The slide footer includes the ESA logo and a row of national flags.

**Selected**

To flight:

- PROSPECT Ion Trap Mass Spectrometer contribution to NASA CLPS  
(Goddard Space flight Centre Lead – PI Barbara Cohen, OU Co-PI Simeon Barbar)
- Laser Retroreflector  
(INRF Lead – PI Simone Dell’Agnello)**

For development initiation in open competition

- Instrumented drill - down hole volatile extraction and regolith sintering
  - Build on PROSPECT developments for small missions and rovers
- Decent and landing GNC algorithm testing
  - Build on PILOT-D flight instrument to advance competition in D&L tech

ESA UNCLASSIFIED - For Official Use

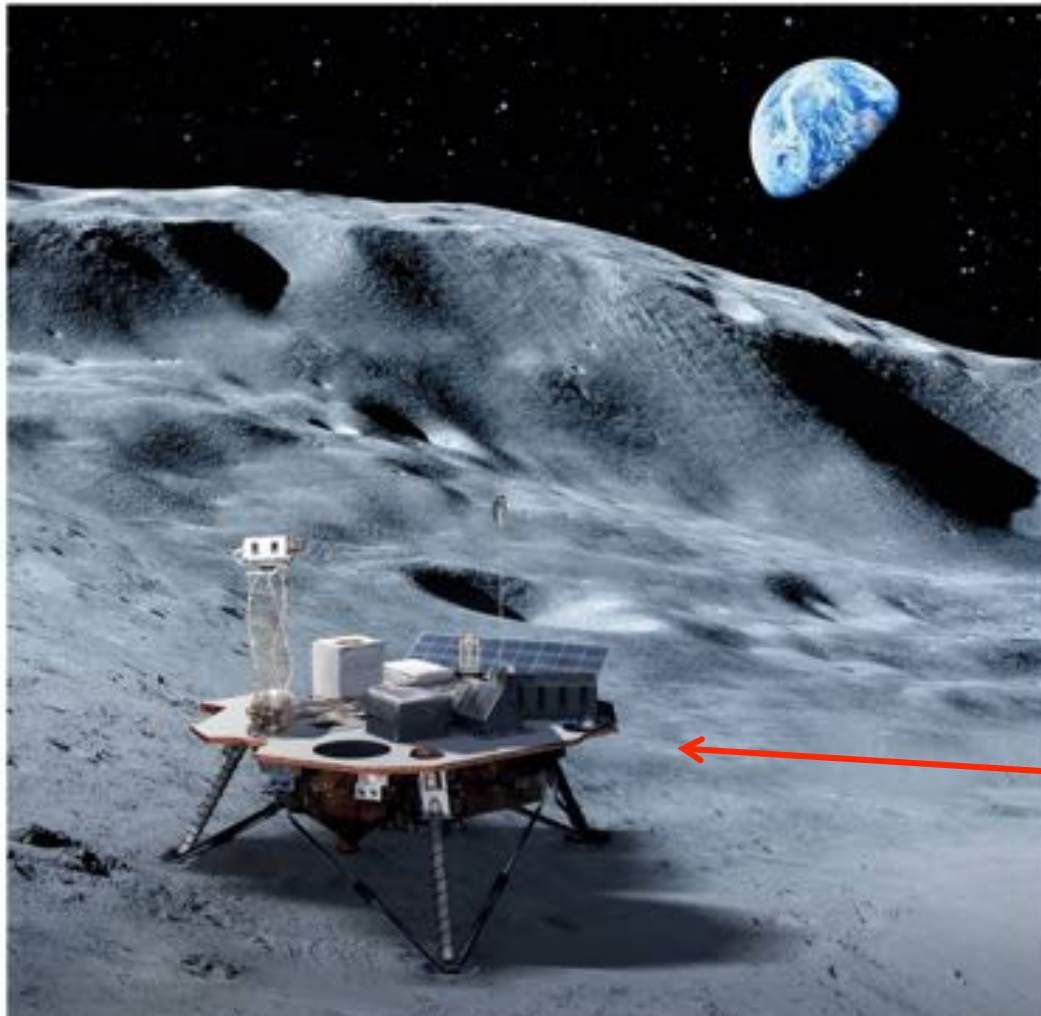
James Carpenter | 21/05/2019 | Slide 7

European Space Agency



# 1/Jul /19: MoonLIGHT proposal by U. Maryland & INFN-LNF selected by NASA for 2 missions

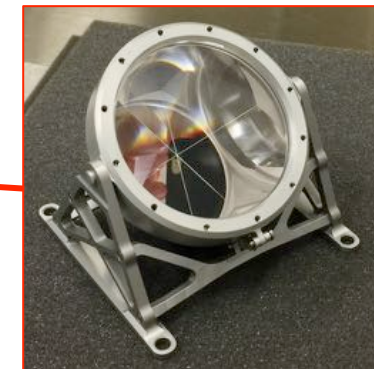
NASA Selects 12 New Lunar Science, Technology Investigations



## Next Generation Lunar Laser Retroreflectors

... target for lasers on Earth to precisely measure the Earth-Moon distance ... and address questions of fundamental physics.

PI = D. Currie of U. of Maryland  
Co-PI group = SCF\_Lab of INFN.

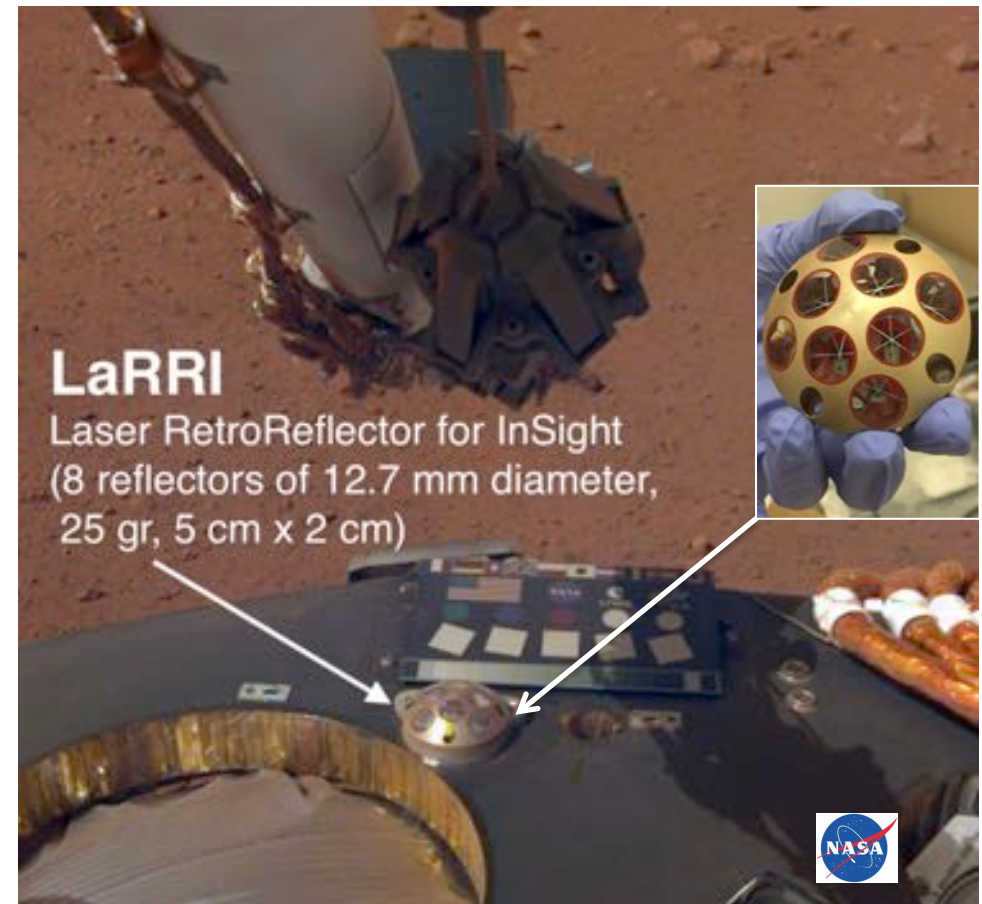




# FM laser microreflectors for Mars-Moon (also far side) & rest of solar s.

- Accuracy dominated by orbiting laser
- Additional crust tie points on orbiter maps
- Good performance in space conditions:  
*L. Porcelli et al. Space Sci Rev, 215 (2019), Iss. 1*
- PFM space qualifications (for InSight)
  - Bakeout:  $T = 97^{\circ}\text{C} \pm 1^{\circ}\text{C}$  for  $> 48$  hr
  - Contamin. Control & Planet. Protection
  - TVT: 3 cycles, max =  $+110^{\circ}\text{C} \pm 1^{\circ}\text{C}$ , min =  $-135^{\circ}\text{C} \pm 1^{\circ}\text{C}$ , w/2-hr dwell time
  - Random vibration & pyroshock (table)

Frequency (Hz)	PFM (g)
100	42
2000	2121
10000	2121



**EXOMARS 2016**

**INSIGHT 2018**



**EXOMARS 2020**

**(SPARE)**



**MARS 2020**

**(SPARE)**

