MoonLIGHT-2

INFN-CSN2 Experiment: Test of Gravity in the Solar System

CSN2-LNF, 27th June 2024

Italian Participants:

INFN-LNF ➔ ~ 9 FTE

INFN/University - Padova ➔ ~ 2 FTE

INFN/University - Naples ➔ ~ 6 FTE

ASI-Matera Laser Ranging Observatory ➔ ~ 3 FTE

USA Participants:

University of Maryland College Park (UMD), MD

Harvard-Smithsonian Center for Astrophysics (CfA), MA

University of California San Diego (UCSD), CA

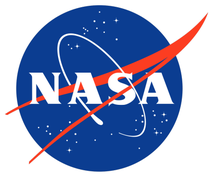
NASA-SSERVI

Approved Flights:

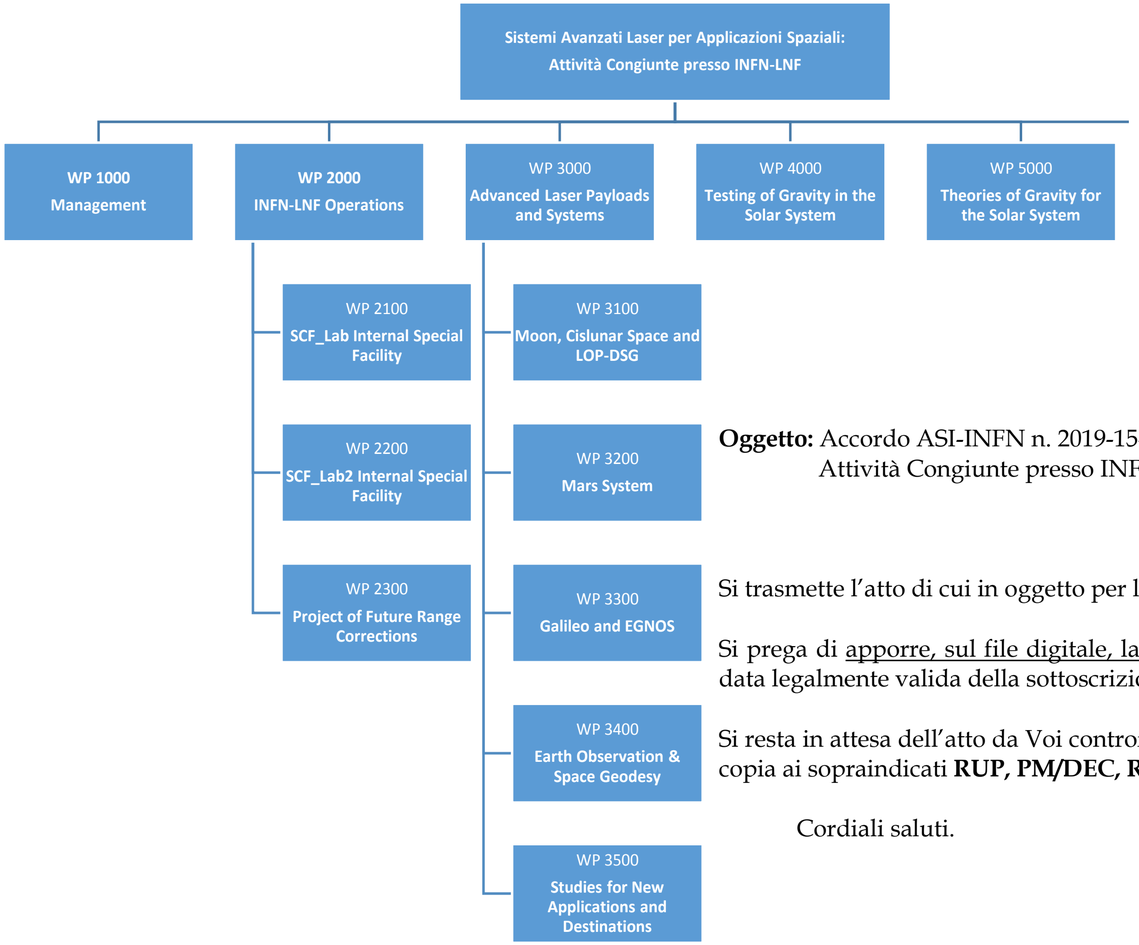
ESA (Prime = Intuitive Machines): 2025

NASA (Prime = Firefly): late 2024/early 2025

Partner Space Agencies:



JointLab INFN-Frascati with ASI-Matera: 1 July 21 - 30 June 26: (delay/suspension due to COVID-19) 1.5M€



Spett.le
Istituto Nazionale di Fisica
Nucleare - INFN
Via Enrico Fermi, 40
00044 - Frascati

Att.ne
Prof. Fernando Ferroni
Presidente

PEC: presidenza@pec.infn.it

c.c.: RUP: Giuseppe Bianco
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 apporre, 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, 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

Fundamental gravity with Lunar Laser Ranging (2024 mission CP11 of NASA-ESA)

M. Muccino[1,2] (PI/Dep. PM), S. Dell'Agnello[1] (PM), L. Porcelli[1] (CSN2 Manager), L. Salvatori[1], M. Tibuzzi[1], L. Filomena[1] (PAM), S. Carocci[1], J. Chandler[3], P. Viloresi[4], G. Vallone[4], S. Capozziello[5], R. Vittori[1], P. Lognonné[6], K. Jani[7]

ESA PoCs: N. Boersma (PM), A. Brandão and James Yardley (PAM), L. Cacciapuoti (Project Scientist), J. Carpenter (Program Coordinator)

NASA-CLPS Mission (CP-11) PoCs: H. Haviland (Project Scientist), R. Watkins (Program Scientist), J. Villareal (PM)

ASI (INFN-LNF & ASI-Matera Joint Lab) PoCs: C. Benedetto (PM), G. Bianco, D. Dequal

1 National Institute for Nuclear Physics – Frascati National Labs (INFN-LNF), via E. Fermi 54, Frascati (RM), 00044, Italy
2 aeroTecno s.r.l., via dei Savonarelli 3, Rome, 00165, Italy
3 University of California San Diego (UCSD) & Centre for Astrophysics (CfA)
4 University and INFN of Padua (PD), Italy
5 University and INFN Naples, Italy
6 Institut de physique du globe de Paris, Paris, France.
7 Vanderbilt University, Nashville, Tennessee, USA

THE ESA'S MOONLIGHT LASER RETROREFLECTOR FOR NASA'S CP-11 2024 MISSION

L. Porcelli[1], M. Muccino[1,2], M. Montanari[1], R. Lauretani[1], A. Remujo Castro[1], L. Rubino[1], U. Denni[1], L. Mauro[1], L. Salvatori[1], M. Tibuzzi[1], L. Filomena[1], G. Delle Monache[1] and S. Dell'Agnello[1],
[1]INFN-LNF (Via E. Fermi 54, PO Box 13, 00044, Frascati, Italy),
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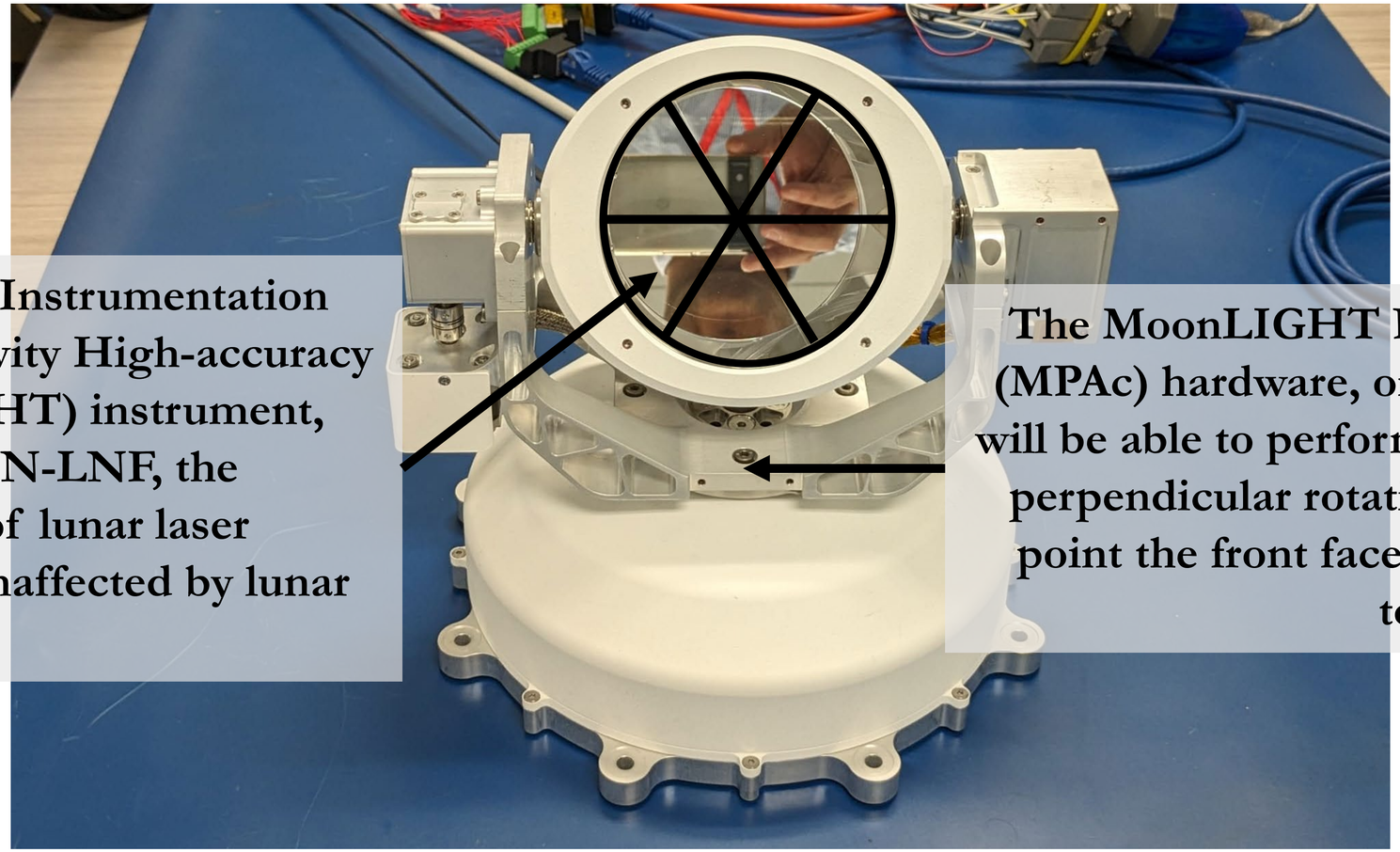
correspondence: luca.porcelli@lnf.infn.it.

MoonLIGHT+MPAc

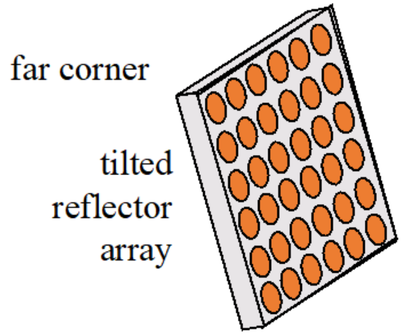


The Moon Laser Instrumentation for General relativity High-accuracy Tests (MoonLIGHT) instrument, envisaged at INFN-LNF, the next-generation of lunar laser retroreflectors, unaffected by lunar librations.

The MoonLIGHT Pointing Actuator (MPAc) hardware, once on the Moon, will be able to perform two continuous perpendicular rotations to accurately point the front face of MoonLIGHT towards the Earth.

Why Next-Gen LLR CCRs

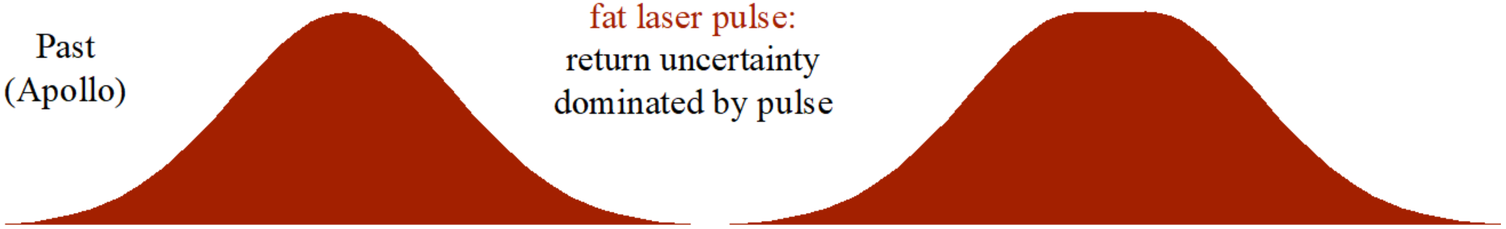
Libration rotations up to 10°.
Current accuracy ~ 2 cm



Laser Pulse

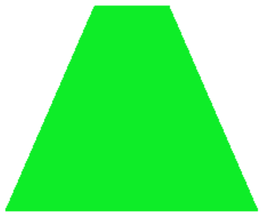
Past
(Apollo)

fat laser pulse:
return uncertainty
dominated by pulse

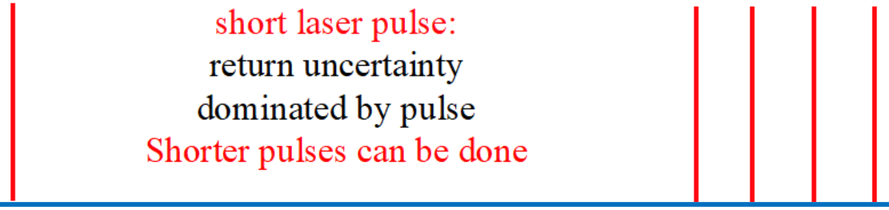


Present
(Apollo)

medium laser pulse:
return uncertainty
dominated by array

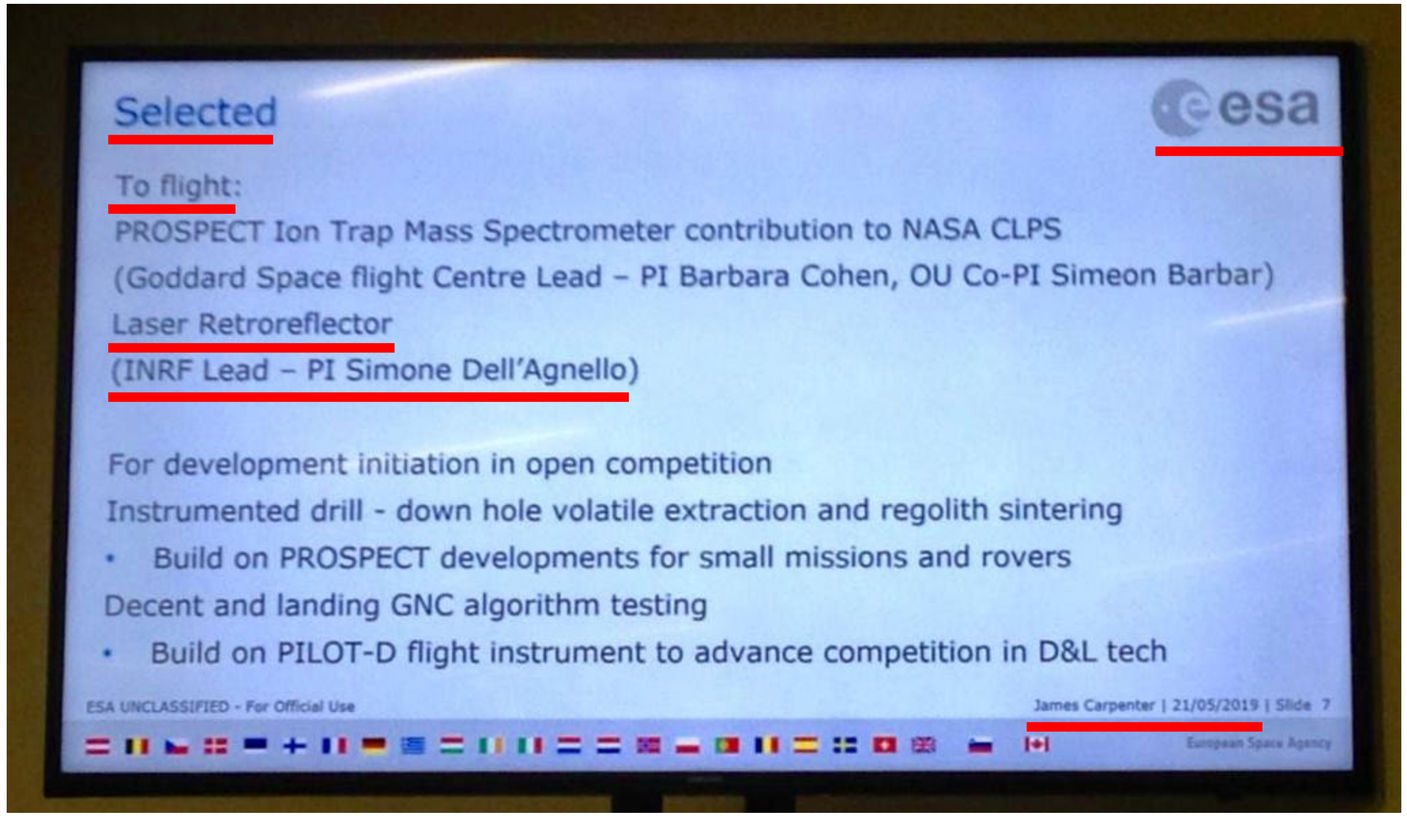


Future
(MoonLIGHT)



short laser pulse:
return uncertainty
dominated by pulse
Shorter pulses can be done

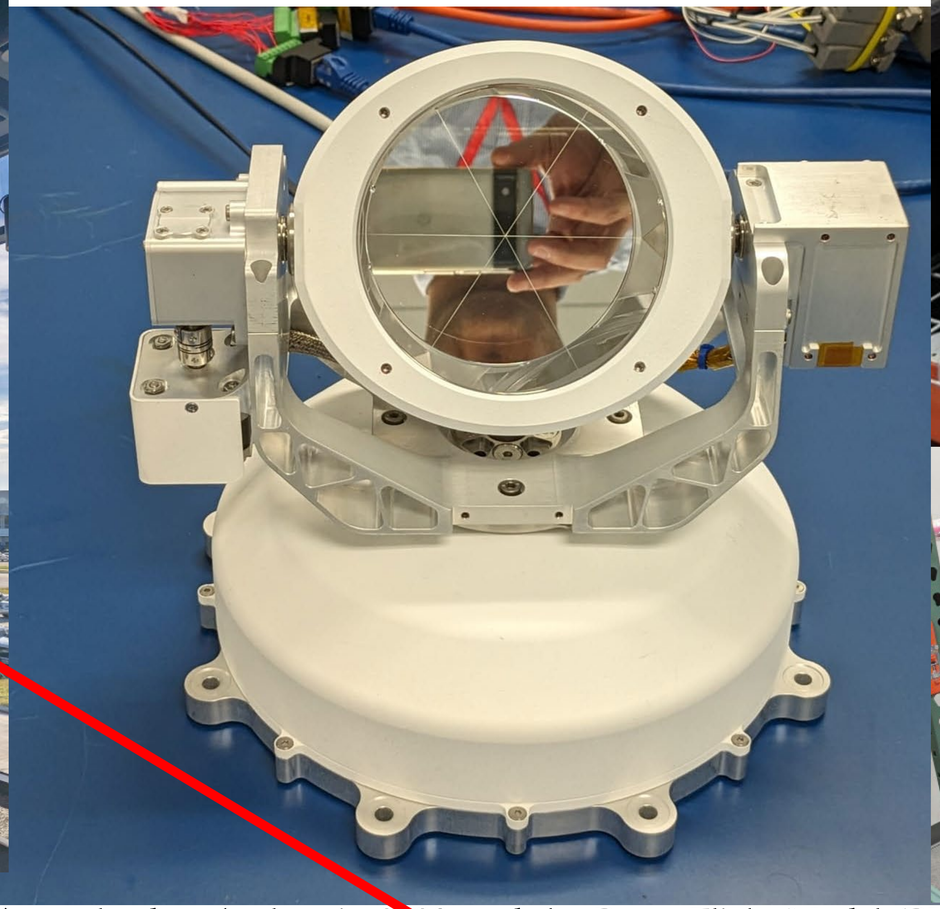
Buildout of MoonLIGHT+MPAc



Selected for ESA Mission of Opportunity in May 2019:

- Publicly announced at the European Lunar Symposium 2019.
- INRF = INFN Retroreflector Frascati.
- Flight will be a NASA-CLPS/PRISM-1A (CP-11) (w/ MPAc = MoonLIGHT Pointing Actuator).

MoonLIGHT+MPA



Final integration of the MoonLIGHT+MPAc payload took place in 2023, and the Proto Flight Model (PFM) hardware space qualification tests were successfully passed in late 2023. The MoonLIGHT+MPAc payload was finally delivered to ESA, and NASA, and IM; it is in storage since 6th December 2023, after acceptance, and waiting for final integration on board IM's CP-11 lander.

Summary

Lunar ‘big’ single-CCR retroreflector payload:

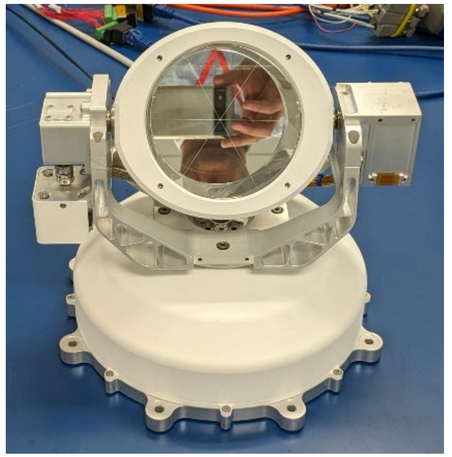
- An **innovative payload**: our fully-fledged 4” (100 mm) PFM, selected by ESA (w/ active MPAc).

- Delivered to ESA, and NASA, and IM in December 2023, and **accepted for flight**.

- **50-year lifetime**, laser retroreflector-based enhancement of the Lunar Geophysical Networks (LGN).

- Improved ‘use’ of the **Moon as a test body** for:

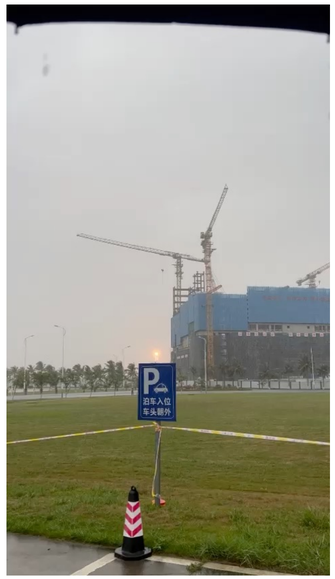
    1. Accurate test of General Relativity (and beyond).
    2. Lunar surface geodesy and deep lunar interior studies.

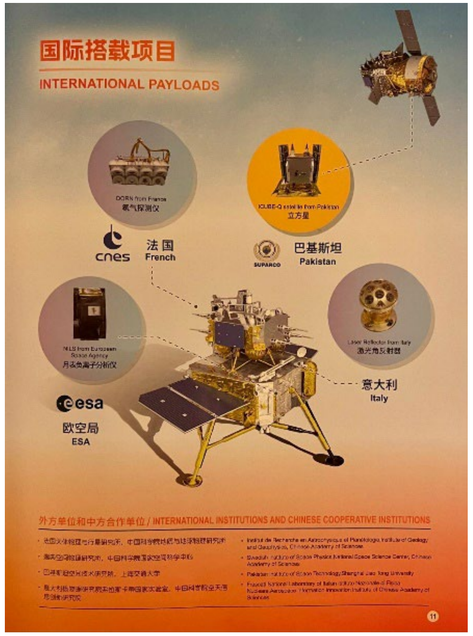


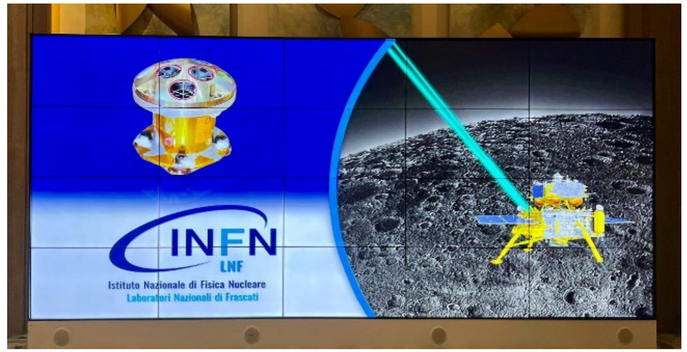
2025 Contribution Trailer

Review of INFN's 'microreflectors' for Lunar and Planetary Sciences:

- 3 already on Mars (TRL 8).
- 1 newbie on the Moon (TRL 8 > 9).







INFN's INRRI for ESA's ExoMars 2016

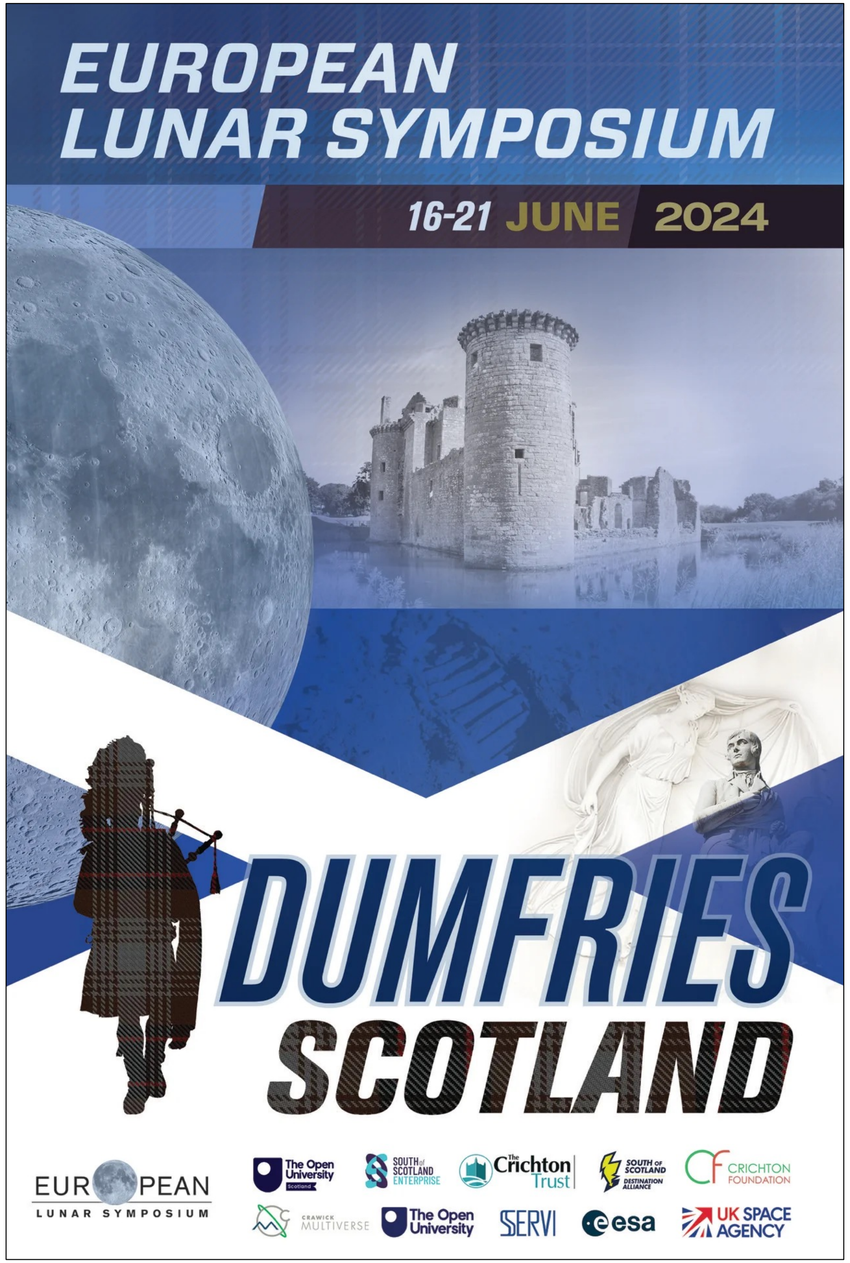
INFN's LaRRI for NASA's InSight 2018

2 x INFN's INRRI for ESA's ExoMars landing platform (delivered in October 2018)

2 x INFN's LaRA for NASA's Mars 2020 Rover (delivered in June 2019)

European Lunar Symposium 2024:
https://sservi.nasa.gov/els2024/

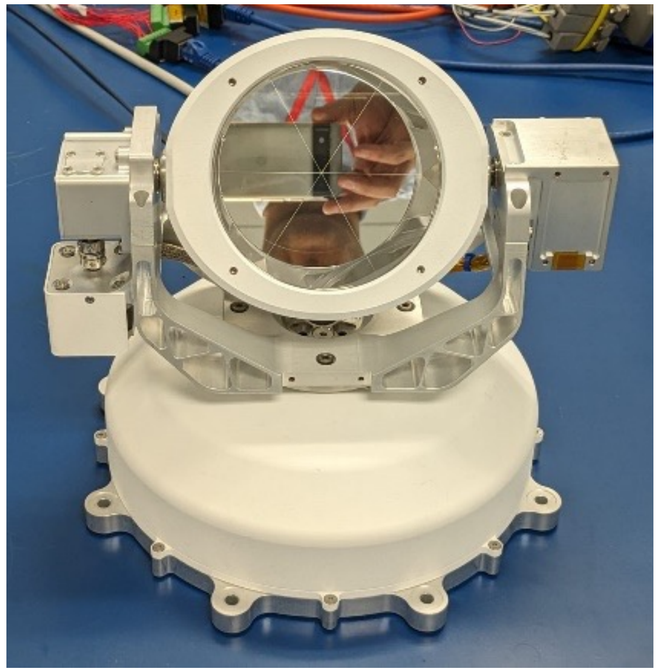
EUROPEAN LUNAR SYMPOSIUM

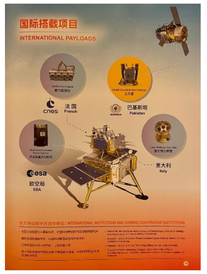


MoonLIGHT-2 x 2025

Objective: launch of ‘first’ MoonLIGHT+MPAc to the Moon and start of data taking/analysis ‘machinery’.

- **2024 Results:**
  - Delivery of the ‘first’ MoonLIGHT+MPAc to ESA, and NASA, and IM.
  - Landing of INRRI on the Moon onboard Chang’E-6.
  - European Lunar Symposium 2024 (https://sservi.nasa.gov/els2024/).
- **2025 Objectives:**
  - Launch of the ‘first’ MoonLIGHT+MPAc to the Moon.
  - Start of data taking/analysis ‘machinery’.
  - European Lunar Symposium 2025.





MoonLIGHT-2 x 2025

Objective: launch of ‘first’ MoonLIGHT+MPAc to the Moon and start of data taking/analysis ‘machinery’.

- **FTE (LNF):** G. Bellettini (50%), G. Bianco (50%), S. Dell’Agnello (100%), L. Filomena (100%), M. Maiello (100%), R. March (80%), M. Muccino (100%), L. Porcelli (50%), … + personale TA ‘dedicato’
- **Richieste CSN2 2025 (overall, TBD):** ~~missioni …k, consumo 30k, altri cons …k, inventario …k, license SW 30k, apparati …k, servizi …k~~
- **Richieste LNF 2025 (mesi-uomo):** richieste fatte dal Joint Lab
- **Fondi Esterni:** Joint Lab INFN-Frascati with ASI-Matera, 1.5 MEuro; ESA, 250kE+240kE=490kE for dual Earth pointing actuator (MPAc) and Dust Cover