MoonLIGHT-2

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

CSN2-LNF, 27th June 2022

Italian Participants:

INFN-LNF ➔ ~ 10 FTE

INFN/University - Padova ➔ ~ 2 FTE

INFN/University - Naples ➔ ~ 5 FTE

ASI-Matera Laser Ranging Observatory ➔ ~ 3 FTE (15 M€ infrastructure)

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): mid 2024

NASA (Prime = Firefly): mid 2024

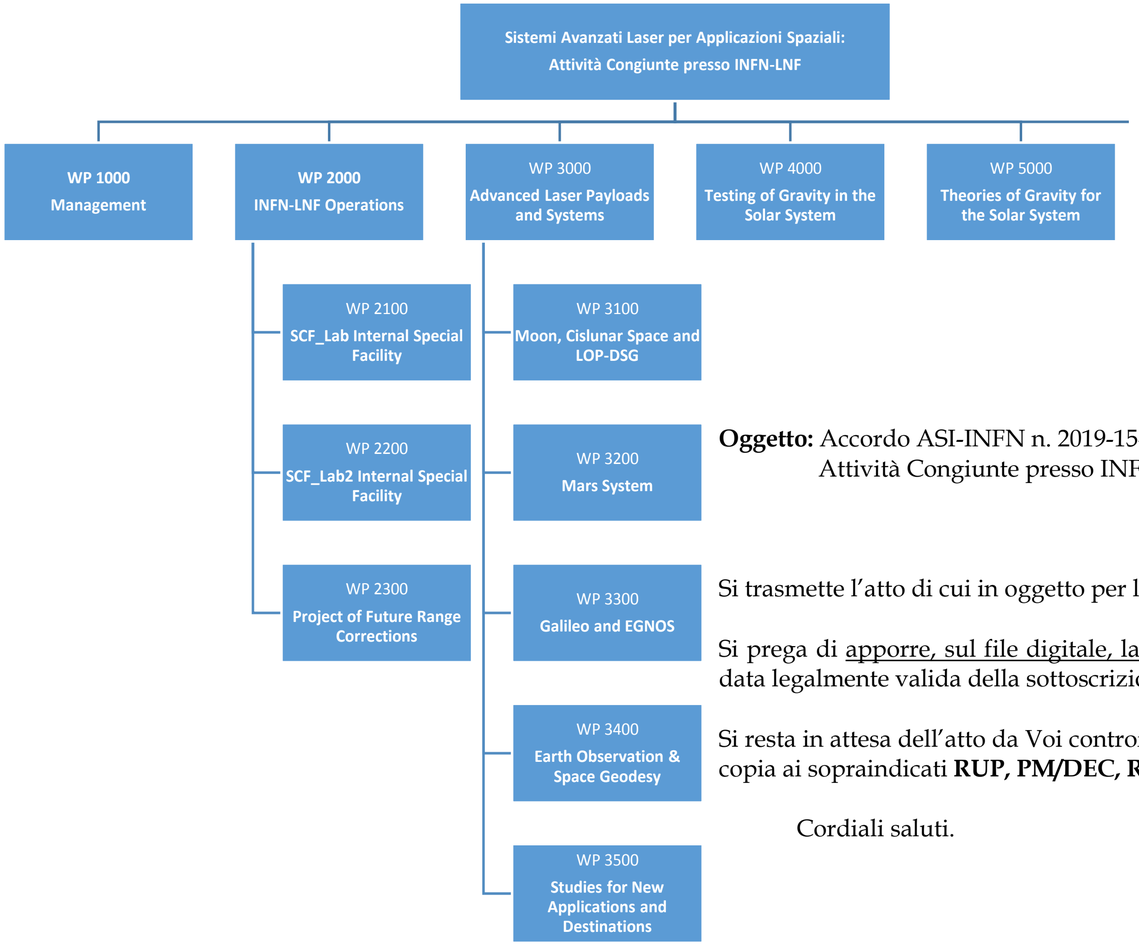
Partner Space Agencies:

JointLab INFN-Frascati with ASI-Matera: 1 July 21 - 30 June 25: 1.5M€ (delay/suspension due to COVID-19)

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.

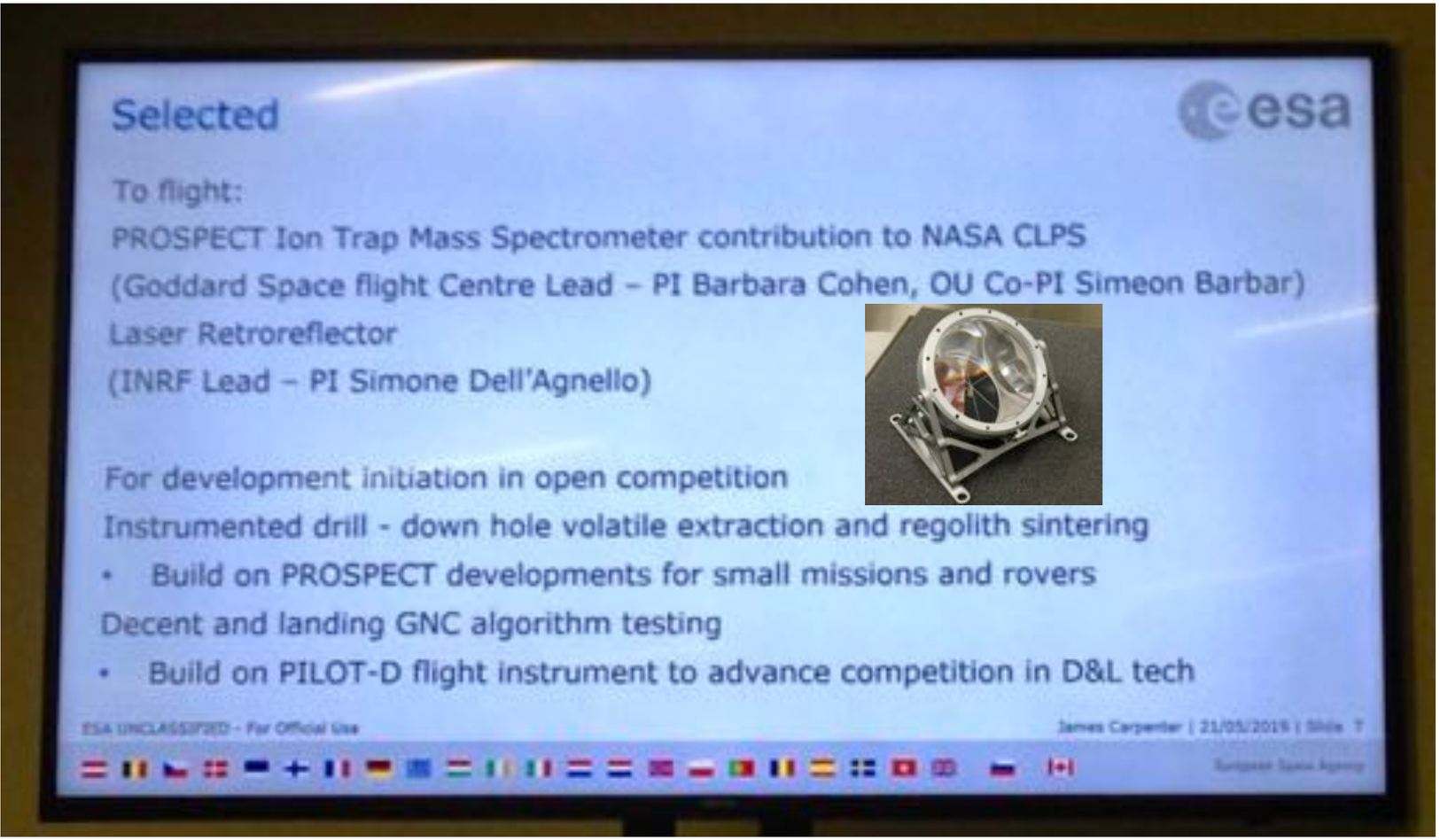
Si prega di apporre, sul file digitale, la firma digitale, unitamente alla marca temporale, che attesta la data legalmente valida della sottoscrizione.

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

MoonLIGHT-2 selected by ESA for a lunar mission (490kE for dual Earth pointing actuators)



ESA Contract No. 4000129000/19/NL/TFD

with

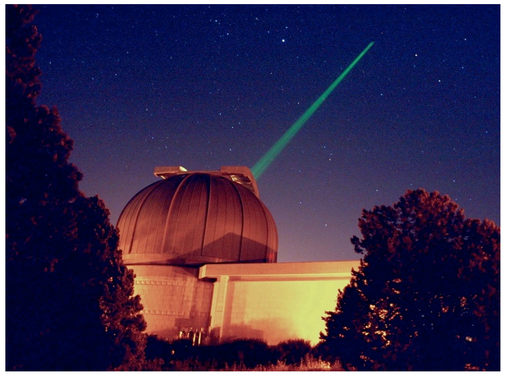
INFN - Laboratori Nazionali di Frascati

LUNAR LASER RETROREFLECTOR POINTING ACTUATOR

Contract for development of MPAc (MoonLIGHT Pointing Actuator)

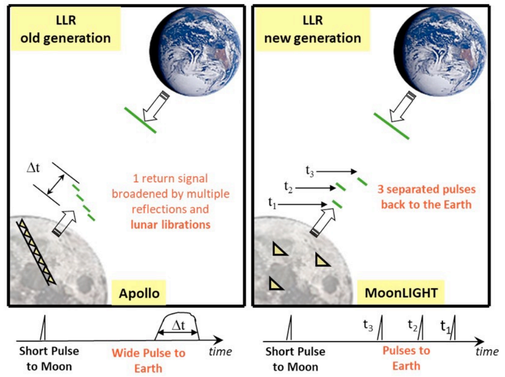
INFN Resp.: M. Muccino

The MoonLIGHT Experiment



Apollo and Luna missions placed five arrays of CCRs on the surface of the Moon. These reflectors reflect light parallel to the incident beam. Through a technique known as LLR, it has been possible to perform high accuracy/precision measurements of the Earth-Moon distance by firing short-pulse laser from ground stations to these LRAs on the Moon and measuring two-way time of flight.

The precision of the LRR is limited because Apollo and Lunokhod arrays are affected by the lunar librations in longitude, caused by the eccentricity of the Moon's orbit around the Earth. This tilt increases the dimension of the return pulse and therefore the uncertainty.

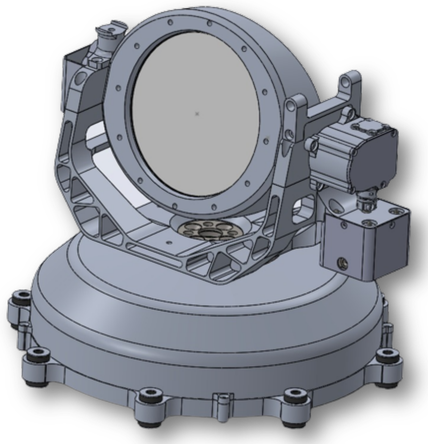


The aim of MoonLIGHT is to reduce the error contribution of LLR measurements by more than two orders of magnitude, taking LLR back to the situation where the error was dominated by the laser pulse.

The idea is to move from a multi-CCR array to a series of single, larger CCRs, whose performance is unaffected by lunar librations. Reaching the ranging precision of 1mm or even less would considerably improve the measurement of different gravitational parameters and consequently, the results of the different scientific studies.

The reflector, designed for MoonLIGHT with a front face of 10 cm, is an uncoated CCR of Suprasil 311, a radiation-resistant grade of Fused Silica, characterized by a very low thermal expansion that minimizes thermal effects that could affect optical performances.

MoonLIGHT Pointing Actuator (MPAc)



The CCR field of view, in far field conditions, is quite narrow (a cone with an opening angle of about 34˚, whose apex is geometrically located in the vertex of the CCR), and it needs to be pointed precisely to the Earth. On account of the fact that the industry of landers could not guarantee such an accurate pointing of the device, INFN proposed the MoonLIGHT Pointing Actuator (MPAc) project to ESA in 2018. In 2019 ESA chose MPAc (and another instrument) among 135 eligible scientific project proposals.

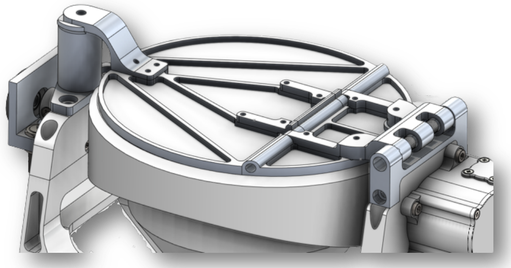
The MPAc design aims to implement a modular configuration, being able to isolate the CCR from the electronics and moving elements. It must operate in Ultra High Vacuum space conditions, in a wide operating temperature range. The MPAc is divided into three main blocks with very different functions and characteristics.

1. The CCR Housing contains the MoonLIGHT retroreflector and its integration structure.
2. The elevation frame, is responsible of the generation of the “Elevation” rotation and contains some actuators and sensors.
3. The base frame represents the interface with the lander and contains most of the electronics and the motor responsible of generating the “Azimuth” rotation.

MPAc can be activated and commanded from Earth. Pointing is performed after knowing the actual attitude of the lander on the lunar surface, sending a command that the integrated microcontroller uses to move the two stepper motors to the desired position.

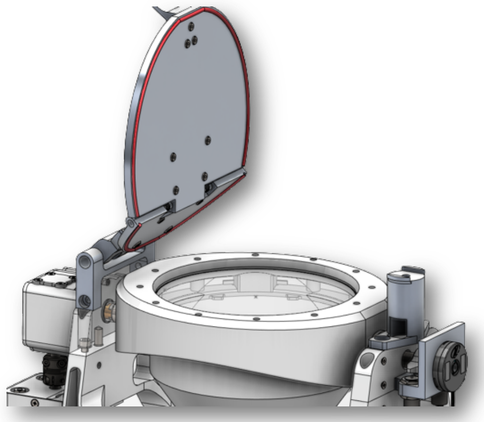
Mechanics, electronics and software have been tested with the 3 first prototypes, two in plastic and one in aluminum. The next step for the qualification is the design and manufacturing of the Engineering Model.

Dust Shield

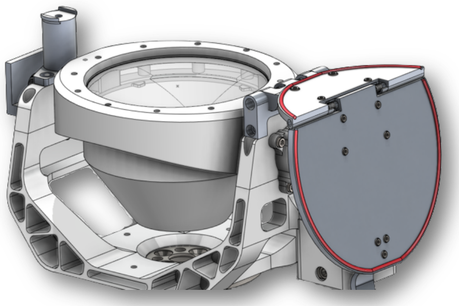


Lunar dust proved to be a challenge for many lunar projects. In particular, optical devices may see their performance degraded by the deposition of these particles. During 2021, the necessity of protecting MoonLIGHT from this danger was answered with the design of a removable dust shield.

The MPAc cover consists of a divisible plate pulled by torsion springs. Once the release mechanism actuator is activated, the cover folds by itself, representing no disturbance for the subsequent operations.



In order to study the behaviour of the dust shield during the aperture of the shield and individuate the possible flaws of the model, tests were made with a plastic prototype, allowing a faster evolution of the design.

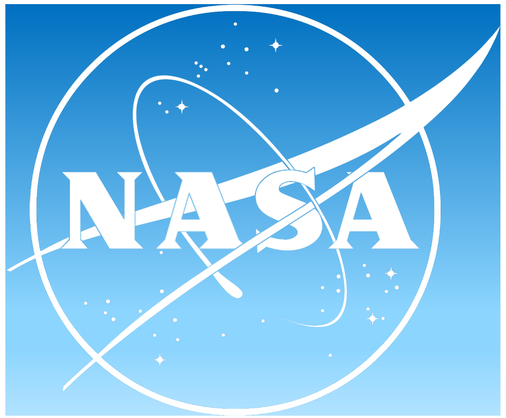


CLPS Mission

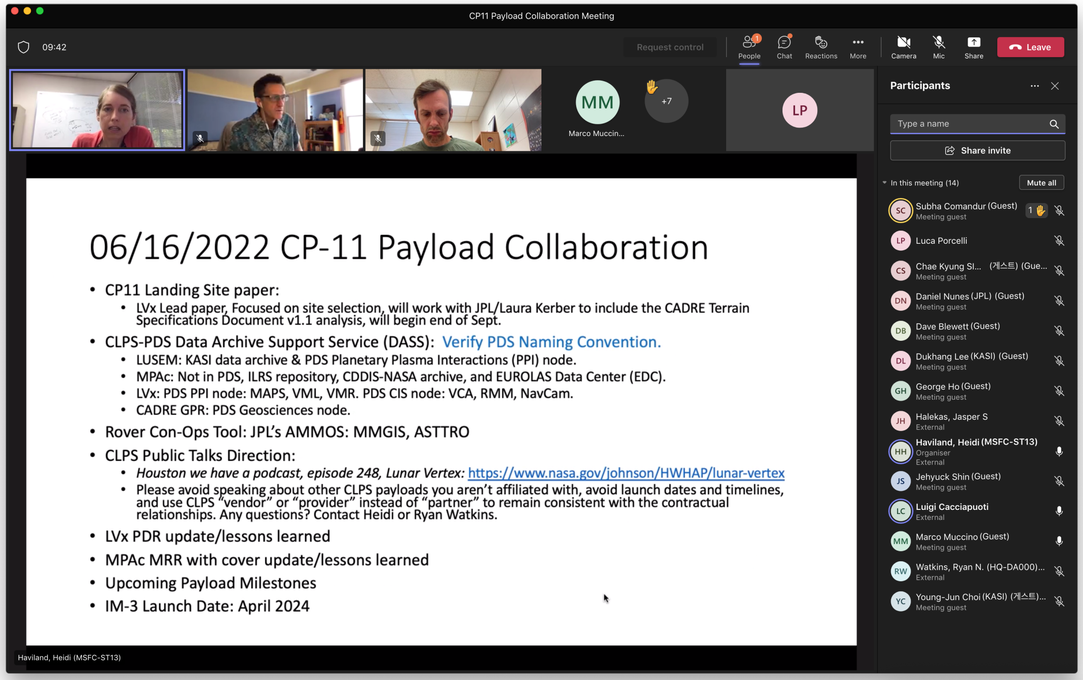
MPAc will fly, together with other 3 scientific payloads as part of NASA's Commercial Lunar Payload Services (CLPS) initiative and the Artemis program. The investigations aboard Intuitive Machines' Nova-C lander include exploration rovers, a high-energy particles detector and a magnetic field measurement device.

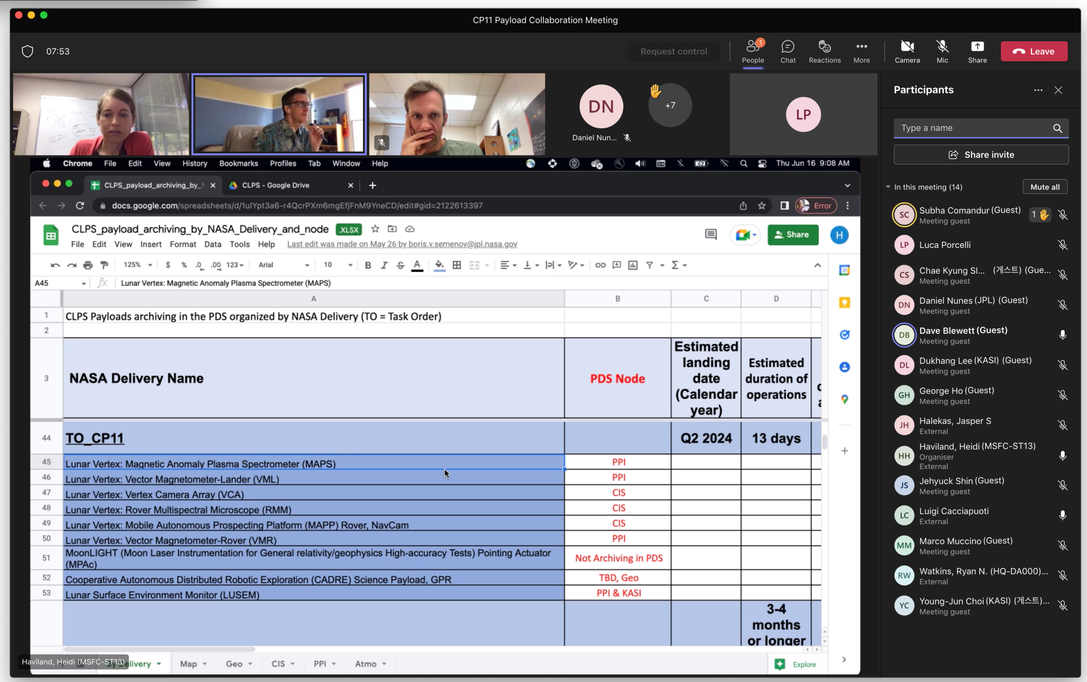
The landing site is Reiner Gamma, one of the most distinctive and enigmatic natural features on the Moon. Known as a lunar swirl, Reiner Gamma is on the western edge of the Moon, as seen from Earth (7.5°N, 59.0°W). It is still to be understood what lunar swirls are, how they form, and their relationship to the Moon's magnetic field.

CLPS Mission



INTUITIVE MACHINES



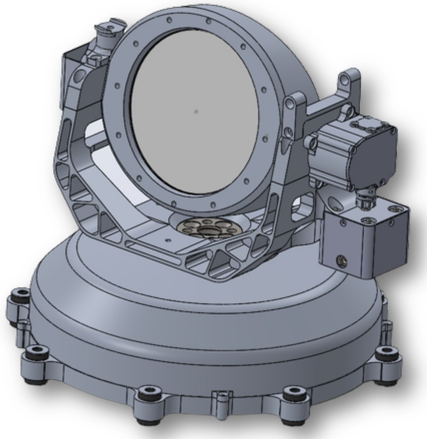


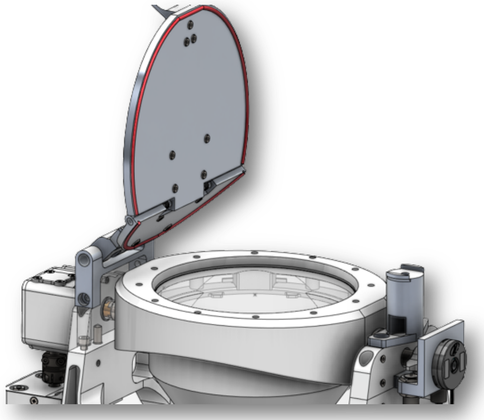
European Lunar Symposium 2022:
https://sservi.nasa.gov/els2022/

MoonLIGHT-2 x 2023

Objective: delivery of flight hardware to ESA/NASA for integration onboard lunar landers.

- **2022 Results:**
  - Milestones of constructions and tests for deliveries in 2023.
  - Manufacturing Readiness Reviews (without and with Dust Cover) passed ➔ road to manufacturing and testing of Engineering Models, Qualification Models and Flight Models open.
  - European Lunar Symposium 2022 (https://sservi.nasa.gov/els2022/).
- **2023 Objectives:**
  - Delivery of ‘MoonLIGHT + MPAc + Dust Cover’ to ESA.
  - European Lunar Symposium 2023.





MoonLIGHT-2 x 2023

Objective: delivery of flight hardware to ESA/NASA for integration onboard lunar landers.

- **FTE (LNF):** ~ 8 FTE (Ricercatori/Tecnologi) e M. Traini (CA) 100%, M. Petrassi (CTER) 100%, L. Salvatori (CTER) 100%, M. Tibuzzi (CTER) 100%
  INFN/University - Padova ~ 2.3 FTE: Villoresi+5
  INFN/University - Naples ~ 4.6 FTE: Capozziello+6
  ASI-Matera Laser Ranging Observatory ~ 3 FTE

- **Richieste CSN2 2023 (overall, TBD):** ~~missioni 35k, consumo 45k, altri cons 10k, inventario 10k, license SW 30k, apparati 80k, servizi 55k~~

- **Richieste LNF 2023 (mesi-uomo, TBD):** ~~Officina 1; SPCM 1; Elettronica 1; DT 1; Crio 1; Laser 1; ES 1~~

- **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