Lunar Pathfinder Laser Retroreflector Array

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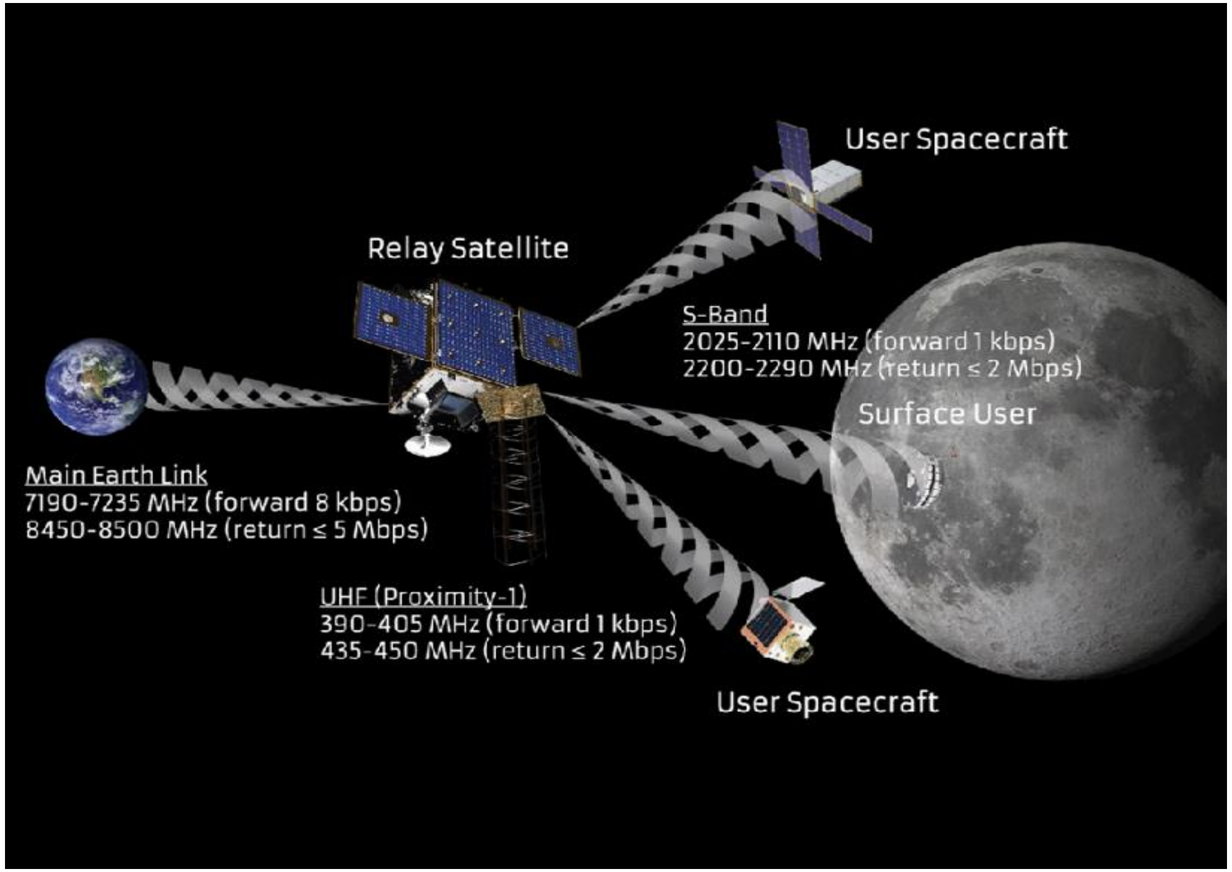
Lunar Pathfinder Overview

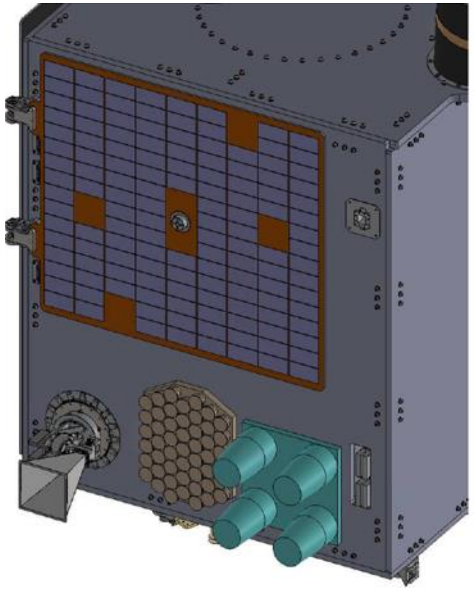
Lunar Pathfinder is a European Space Agency (ESA) communications relay satellite in lunar elliptical orbit to provide services to missions in Cislunar space

- **Primary payload**
  - Moon Link communication-relay payload providing **data relay communications between Earth and Lunar assets**
  - Two simultaneous channels of communication to lunar assets (**S-band** and **UHF)**
  - Communications relayed back to Earth ground station via **X-band**
- **Tentative launch date :** 2025
- **ESA-NASA International cooperation**:
  - Service provision (ESA),
  - Rideshare provision (NASA)
  - LRR accommodation and experimentation (NASA & ESA)



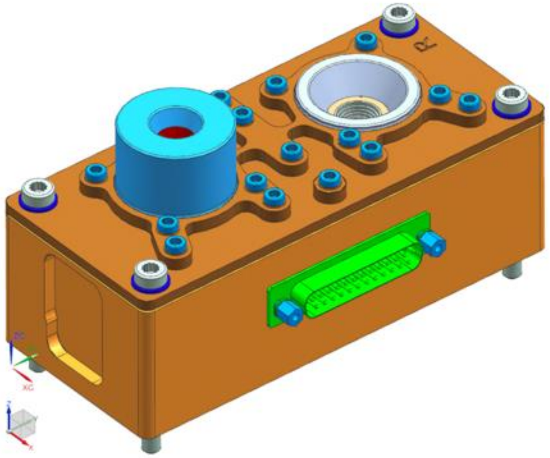
Hosted Experiment Payloads

ESA



Navigation IoD Payload

ESA



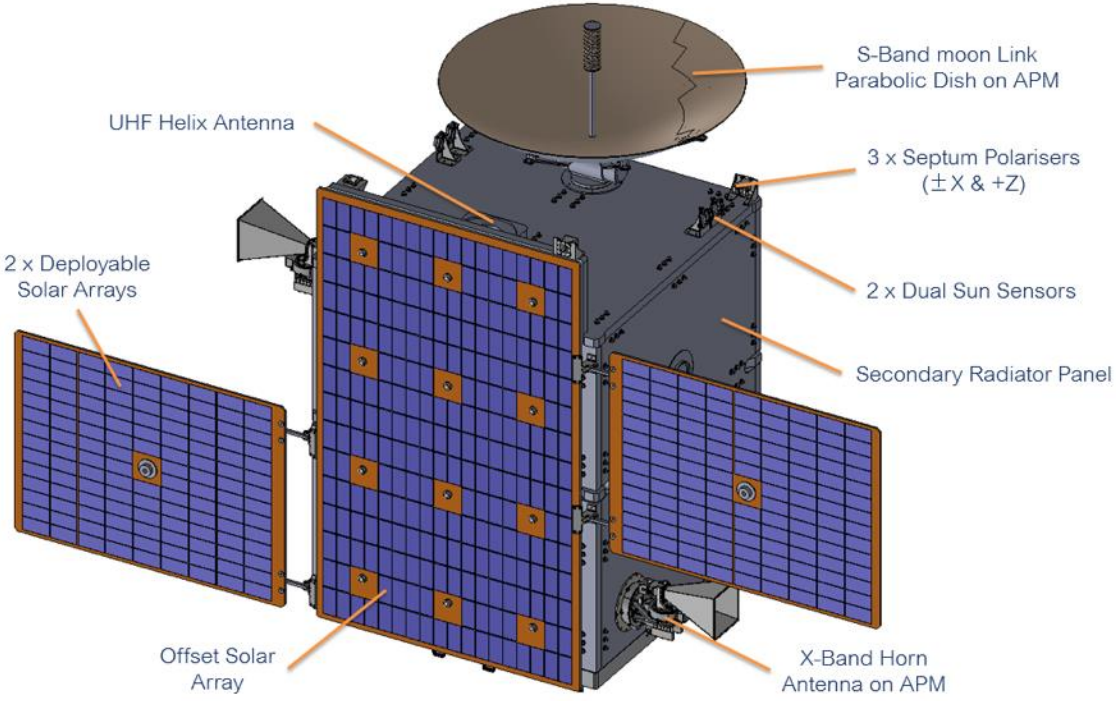
Radiation Monitor Payload

NASA

Laser Retro-Reflector Payload

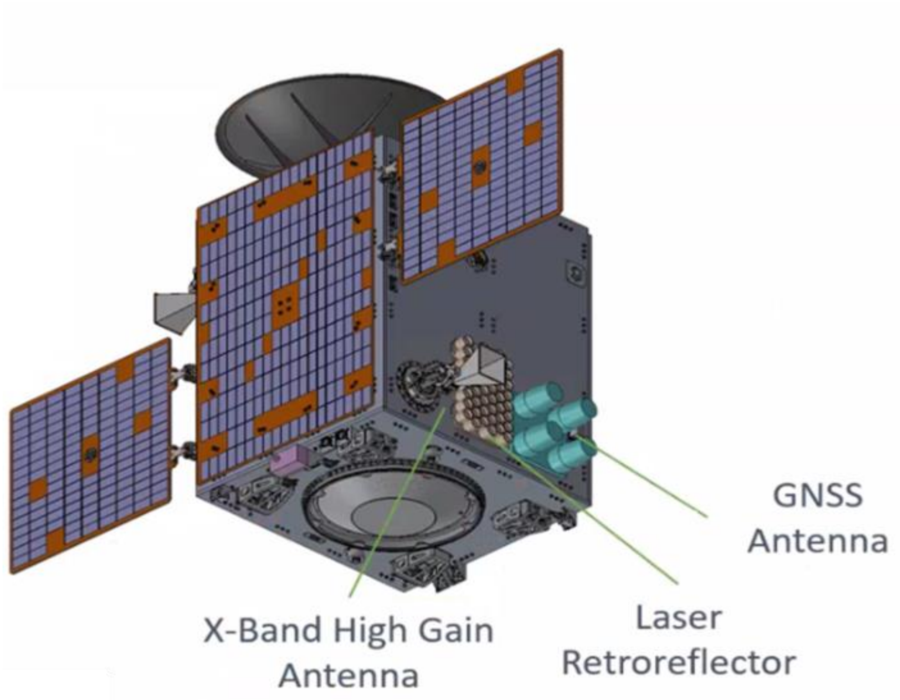
Spacecraft Characteristics (Preliminary)

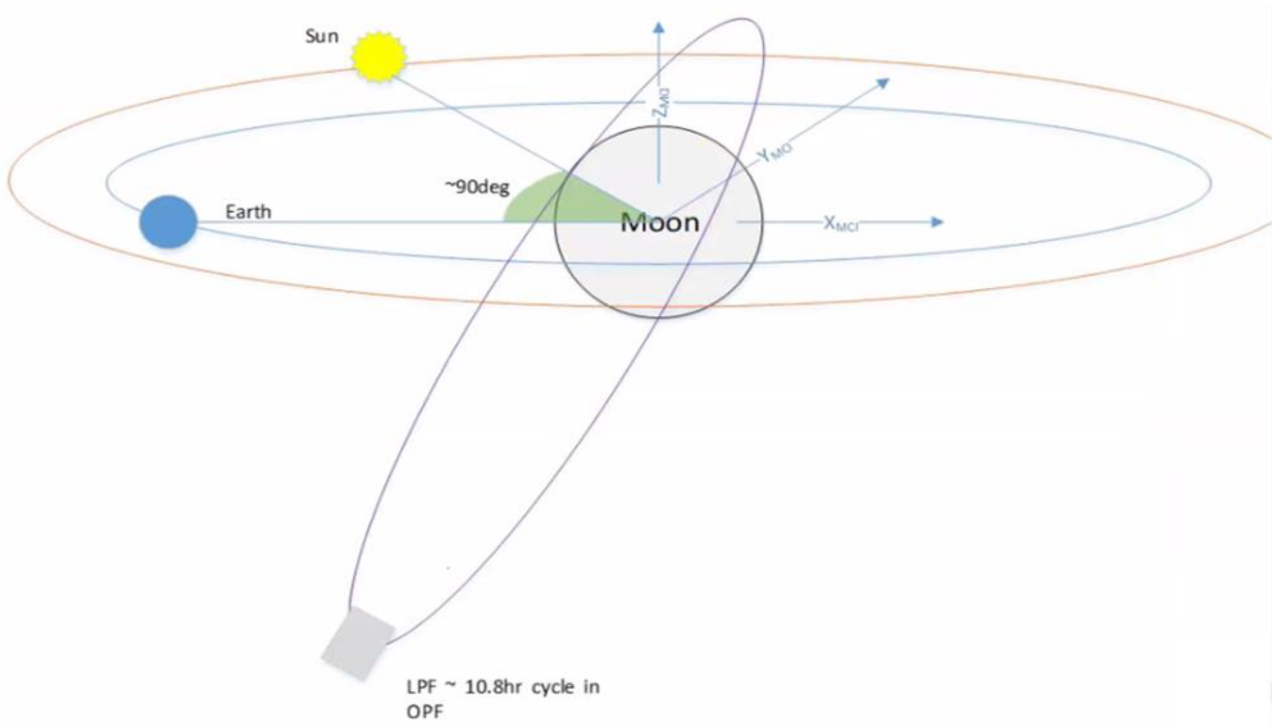
PLATFORM	
Operation Orbit	Aposelene Altitude (km): 7500 Periselene Altitude (km): 500 Eccentricity: 0.61 Inclination (deg): 57.8 RAAN (deg): 61.5 Argument of Pericenter (deg): 90 Epoch: 1 Dec 2022 00:00:00
Lifetime	8.5 years (0.5 y transfer; 8 y Comms service)
Wet Mass	291.6 kg
Power	Solar Array cells Azure 3G30C, battery 2x SAFT 8S3P
Earth Link (Xband)	Orbiter to Earth (RTN) LGA: 51 kbps Orbiter to Earth (RTN) HGA: 5000 kbps Earth to Orbiter (FWD) LGA: low 2 kbps Earth to Orbiter (FWD) LGA medium :31 kbps
Moon Link (S band and UHF)	Orbiter to Moon (FWD) Sband/UHF: 124 kbps (Rover) Moon to Orbiter (RTN) Sband/UHF: 248 kbps (EIRP 13) Moon to Orbiter (RTN) Sband 1986: kbps (EIRP 21.5)
Ranging	Based on two ground stations on different hemispheres, 6 hrs dedicated Earth ranging sessions (using X-Band TT&C link) every 15 days to obtain ≤ 20 km position accuracy
Propulsion	RCS based on 8 1N thrusters blown down mode, 28.6 kg hydrazine (75% fill ratio)
AOCS	Constrained Sun/Nadir pointing Normal mode, STIM Gyro- Sodern Auriga STR-Bison SS, SSW-200 Wheels and RCS
Redundancy	Core DHS, AOCS, Earth link Transponder, BCM, RCS, Moon Link Transponder
Platform Avionics used	PIU/CHIMP, LEO avionics (SSTL & external supplier) based on CoreDHS
Rideshare Provider	NASA
MOON LINK PAYLOAD	
Moon Link Payload	Moon Link Data handling (HSRDX data recorder HW and SW) , Moon Link Comms (Proximity-1 transponders, RF front End, UHF and Sband antennas)



Launch timeframe 2025

NAV/LRR Experiment Objectives



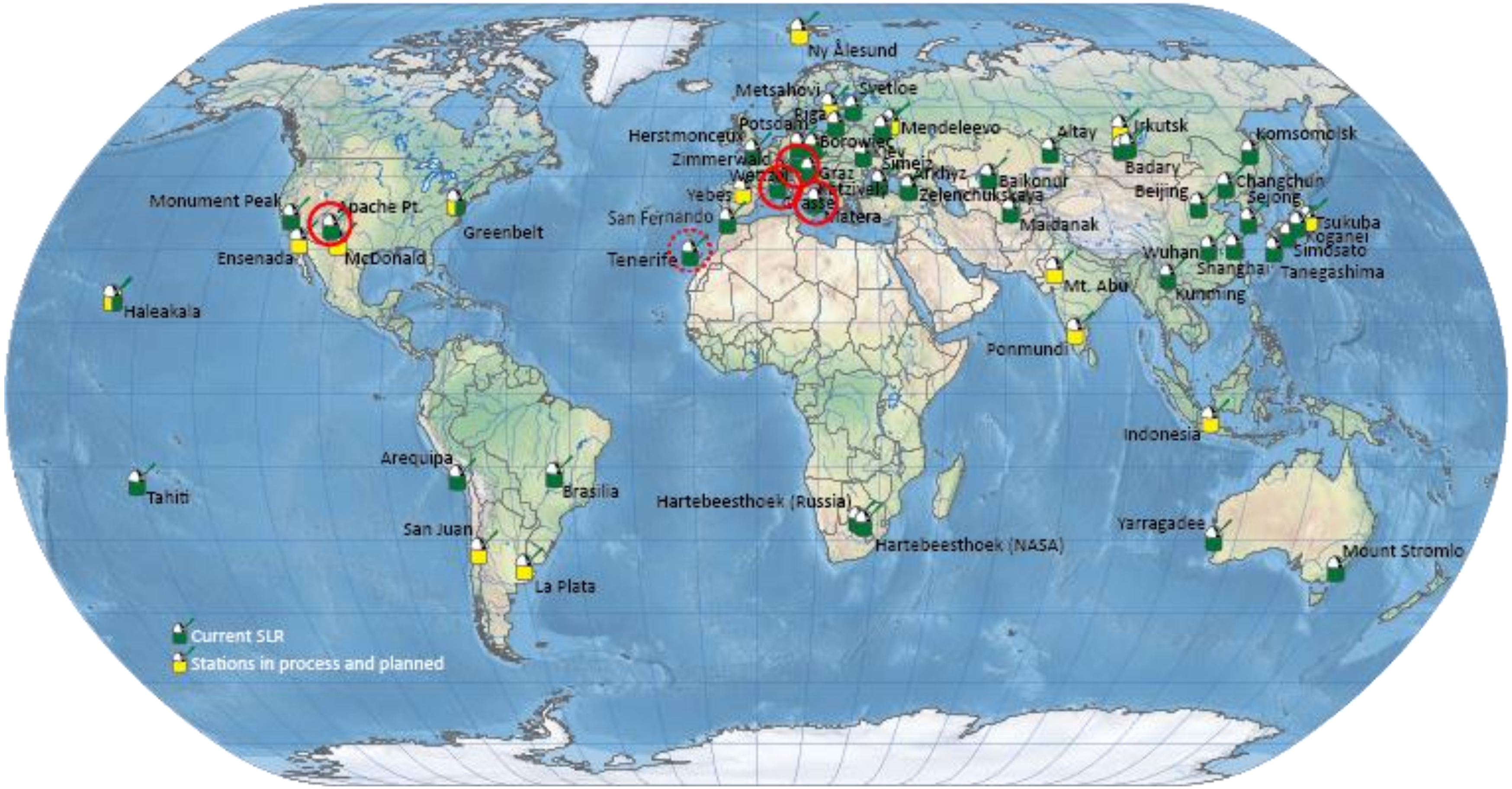


- Demonstrating the feasibility of laser ranging to lunar orbiters (complementing LRO experience)
- First time ever testing simultaneously three ranging technologies in a lunar orbiting satellite (radio, GNSS, and Laser).
- First time ever to test/demonstrate new Precise Orbit Determination concepts and algorithms based on combined processing of GNSS and SLR data for a spacecraft in lunar orbit
- Assess the unique synergies between GNSS and LRR technologies in lunar orbit

LRA Goals

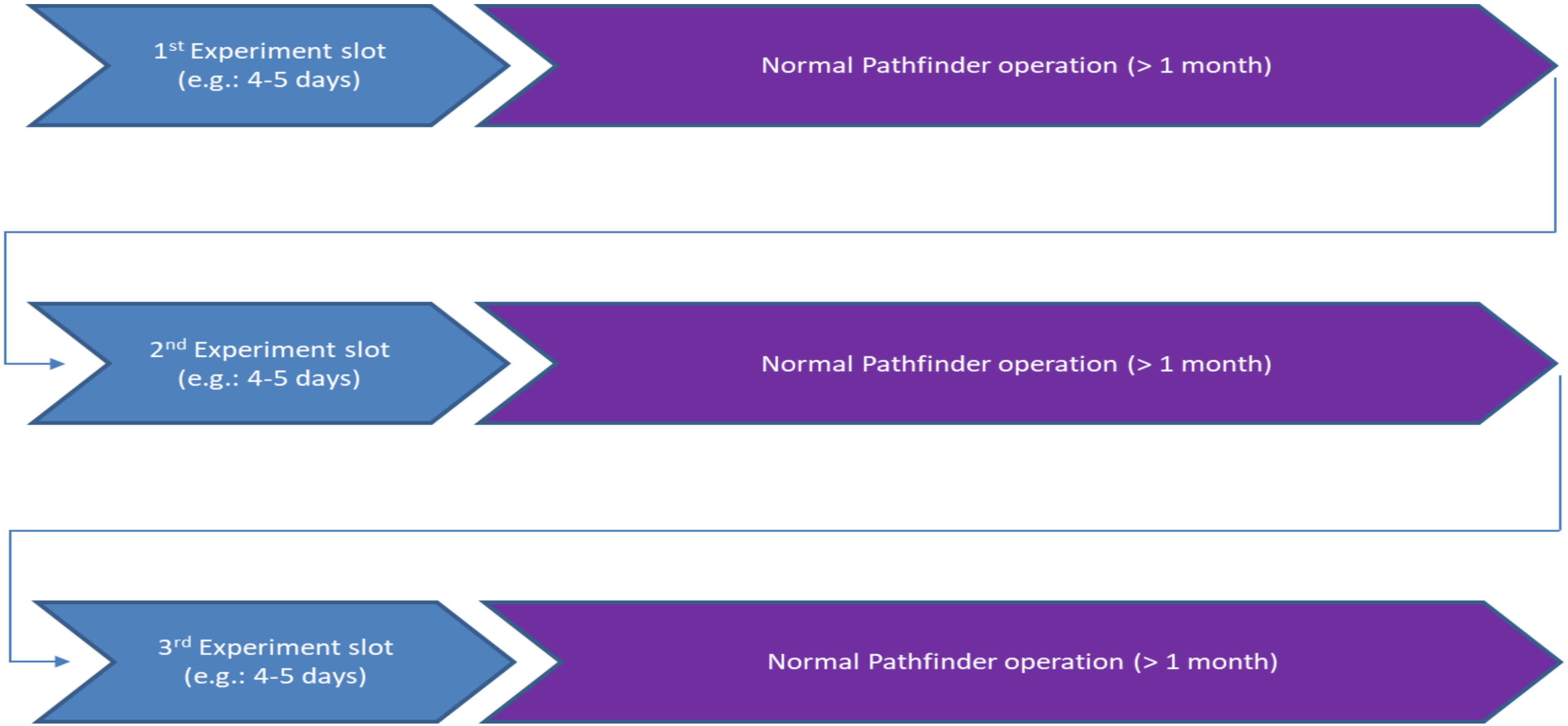
- Demonstration of two-way laser ranging in support of precision orbit determination (POD) for lunar missions
  - Builds upon the successful use of one-way laser ranging to the LRO for improved POD
  - Future lunar orbiter missions will require enhanced POD beyond what was performed on LRO and GRAIL (Gravity Recovery and Interior Laboratory)
- Validation of GNSS-based (GPS and Galileo) positioning for lunar missions
  - Optical laser ranging as an independent and higher-precision measurement technique supports validation of traditional radio tracking and GNSS-based positioning
- Investigate use of lunar orbiter for improved tie between Terrestrial Reference Frame & Lunar Reference Frame
  - Could advance vital capabilities for geolocation of lunar science measurements & geodesy
- Investigate use of lunar orbiter for improved determination of Universal Time (Earth's rotation angle)

Lunar-Capable Laser Ranging Stations

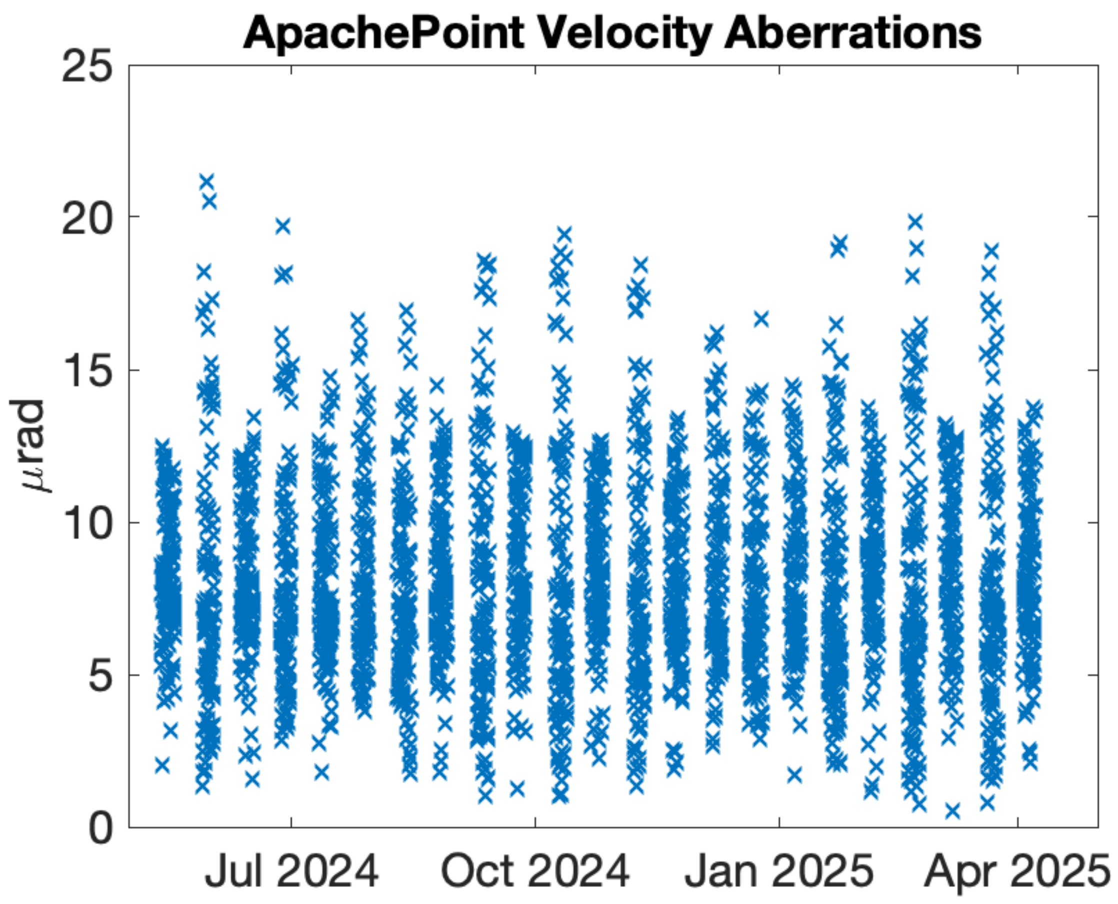


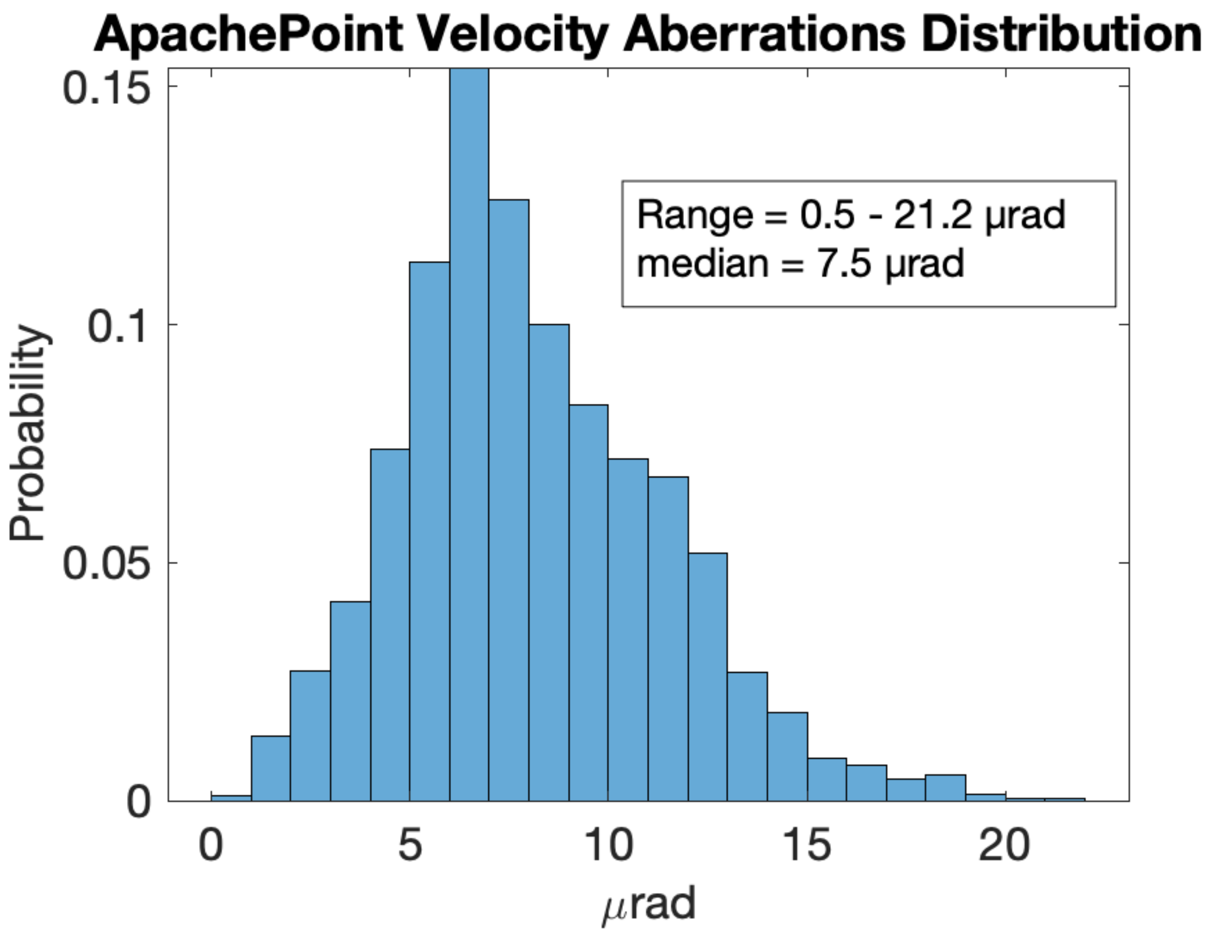
- The four ILRS Lunar Laser Ranging stations can be used for the LPF/LRA experiment: Apache Point, Grasse, Matera, and Wettzell. ESA also plans to add the enhanced Tenerife-based station.

Notional Concept of Operations



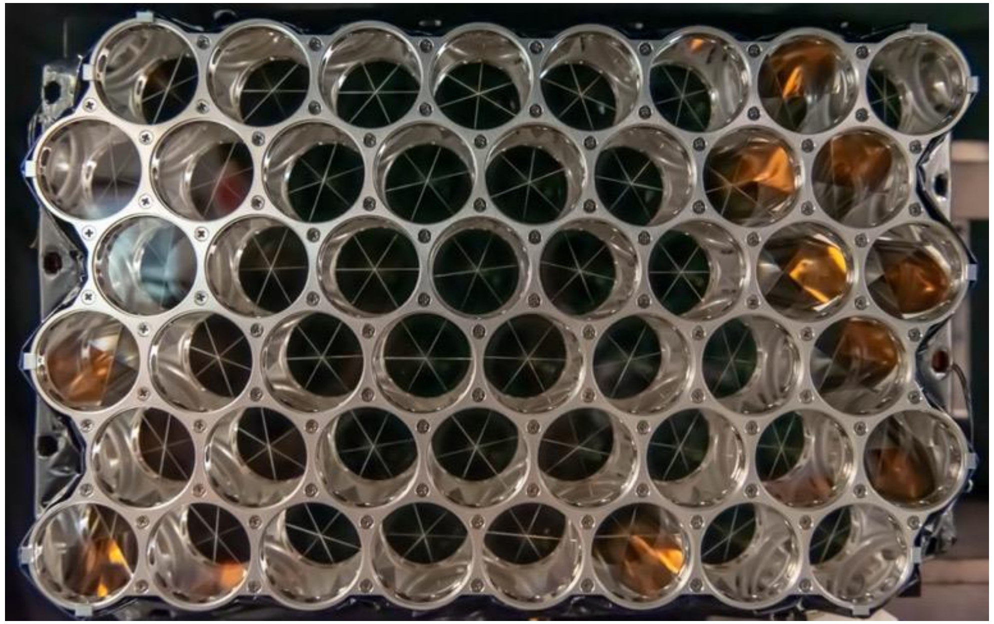
Lunar Pathfinder Velocity Aberrations

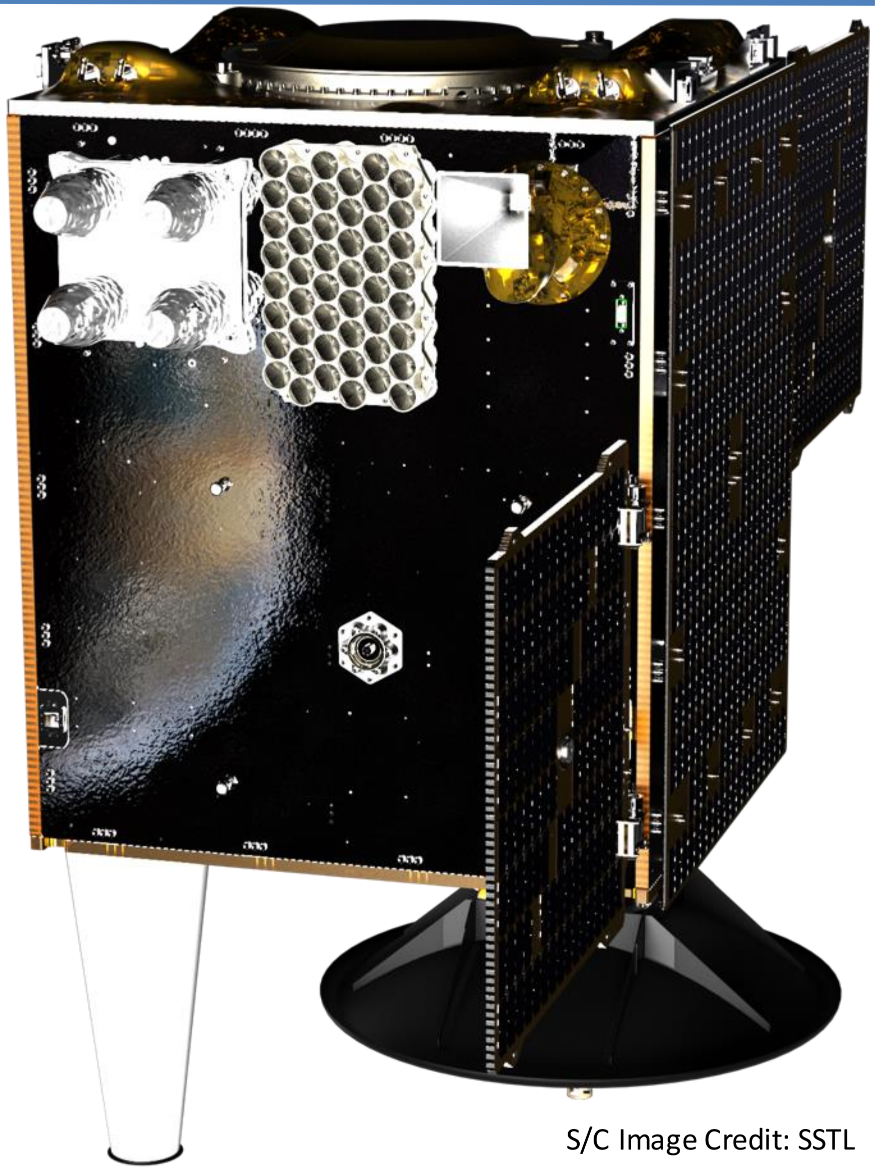




Based on orbit analysis provided by SSTL

Lunar Pathfinder Laser Retroreflector Array





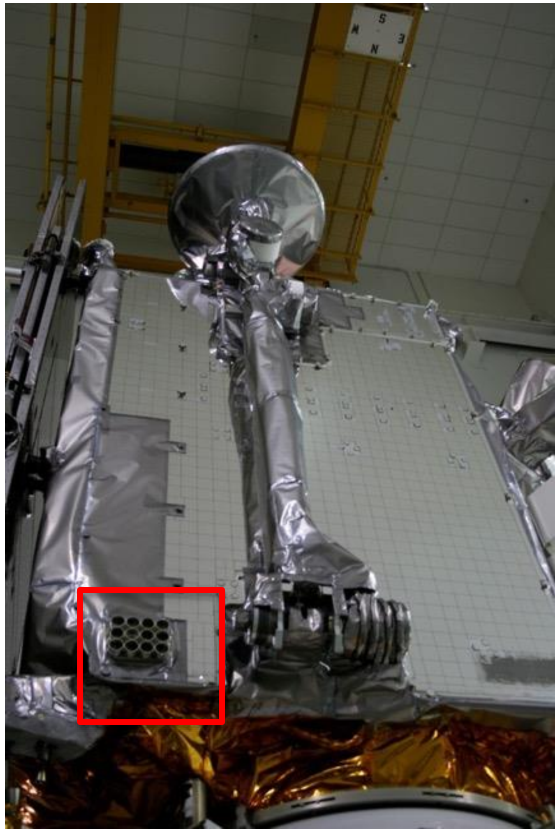
- 48 x 4.06 cm diameter uncoated unspoiled cubes
- Mass: 4.2 kg
- Volume: 262 X 383 X 53 mm^3
- Heritage KBR design

S/C Image Credit: SSTL

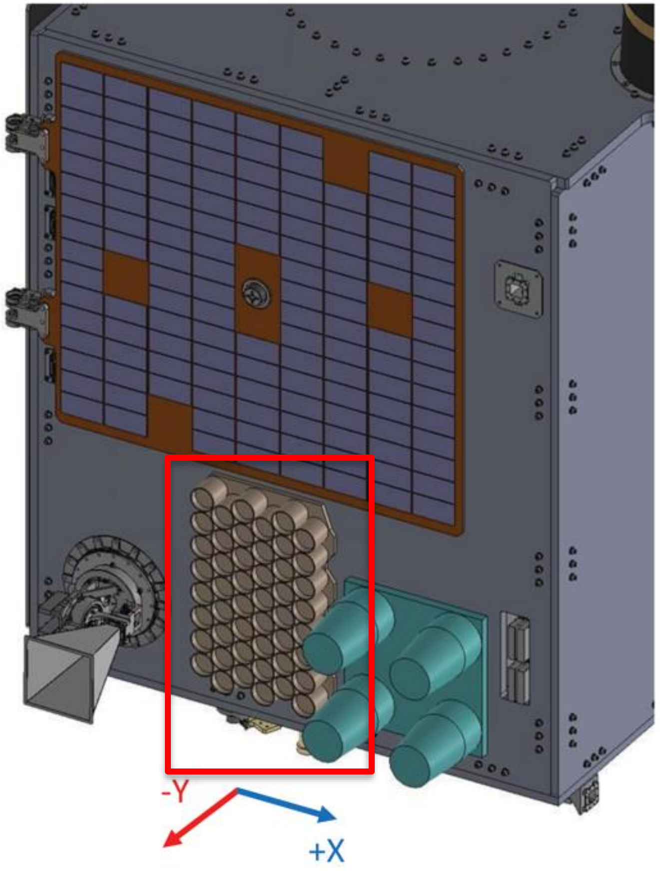
Leveraging Lunar Reconnaissance Orbiter (LRO) Experience

- LRO equipped with both passive LRA & active one-way Earth-to-LRO laser link
- Laser ranging to LRO was successfully demonstrated by the Grasse station
  - However, the small optical cross-section of LRO's LRR made ranging difficult and only possible under ideal conditions (weather, Moon elevation, dark background, etc.)
  - Therefore, only the one-way laser link was able to provide meaningful measurements for science
- ◆ Lunar Pathfinder LRA is ~12x the cross section of the LRO array that significantly improves the feasibility of successful range measurements.

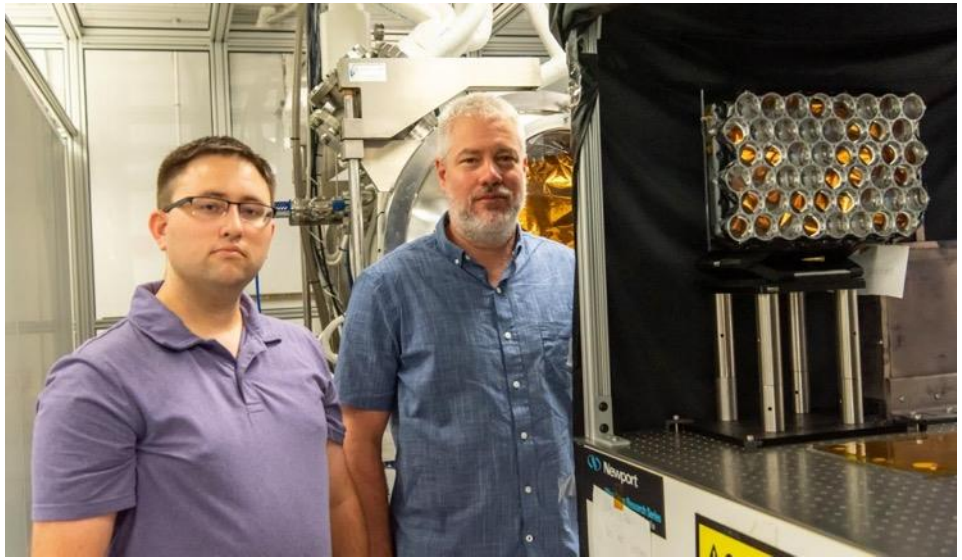
LRO

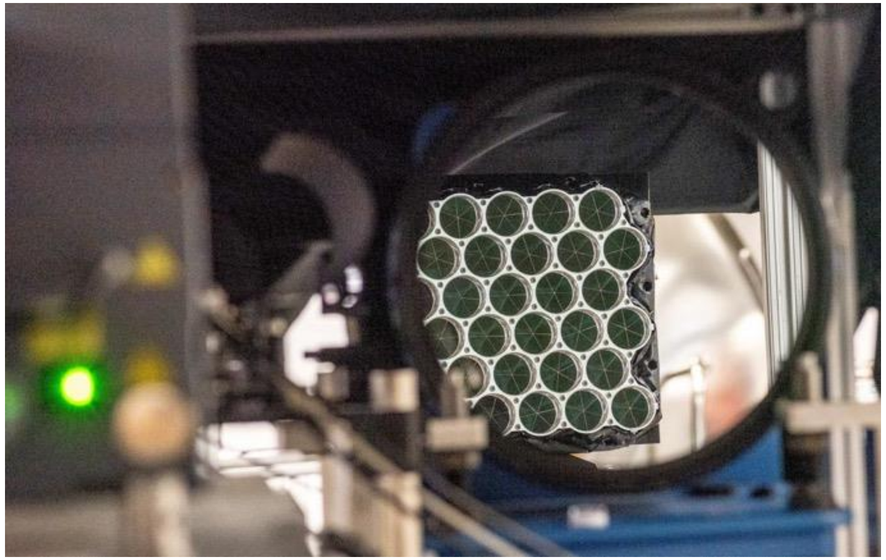


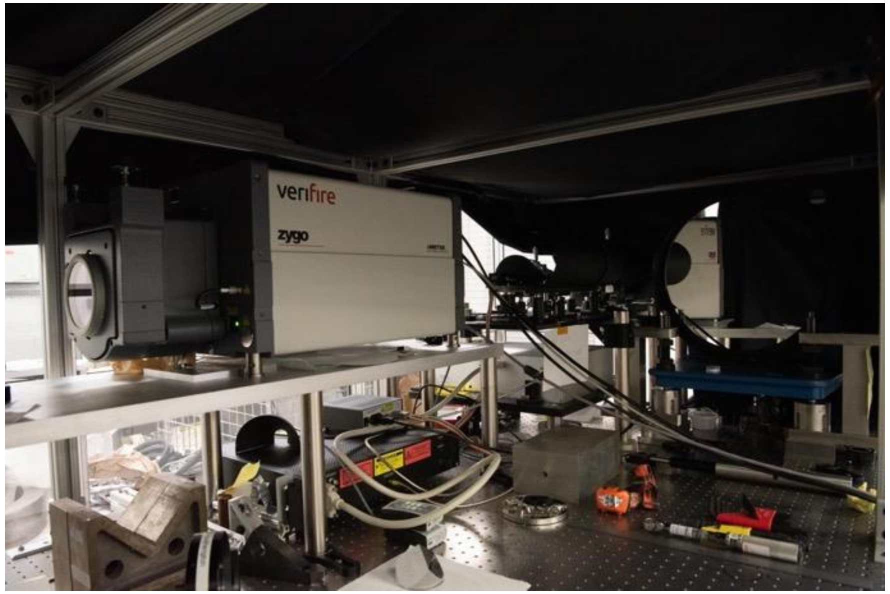
Lunar Pathfinder

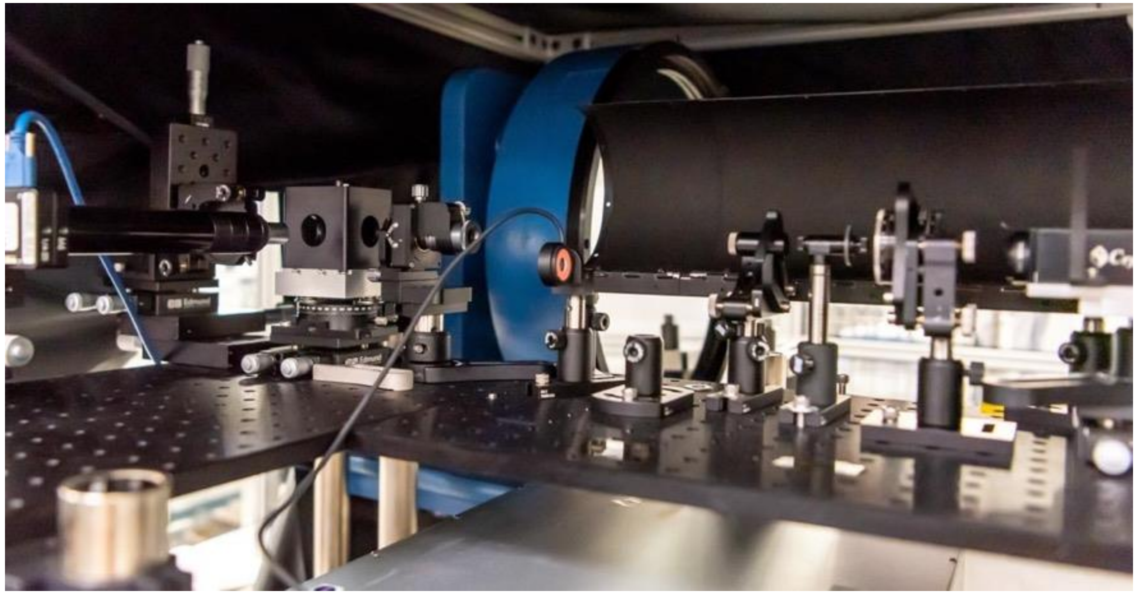


LRA Characterization at NASA Goddard Space Flight Center

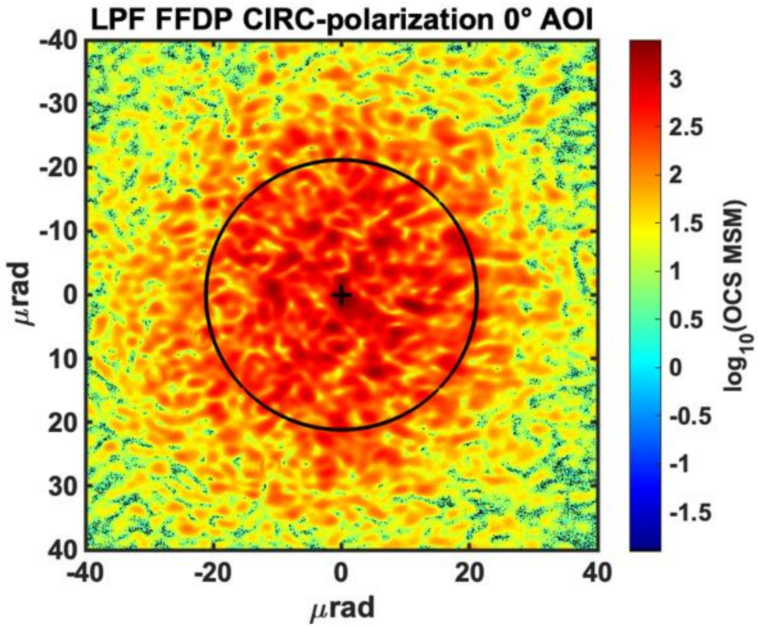


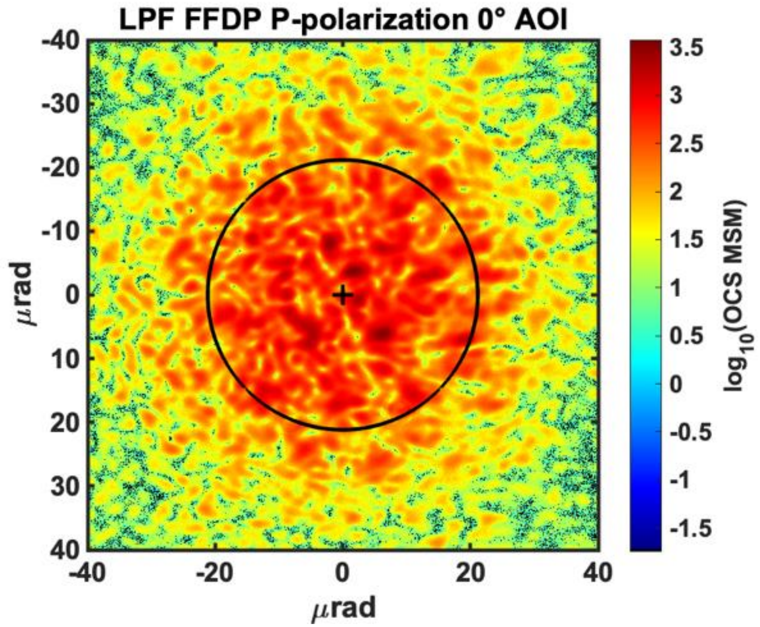


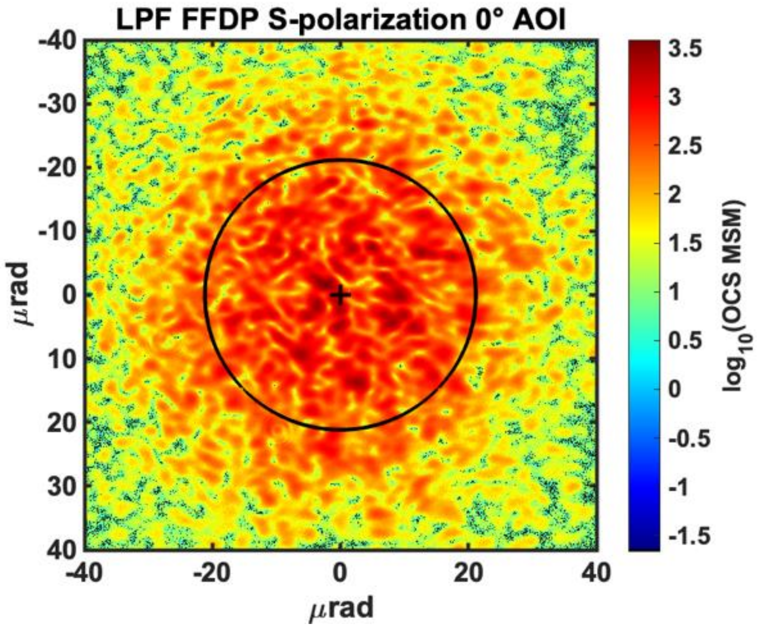




Measured Far Field Diffraction Pattern (FFDP)

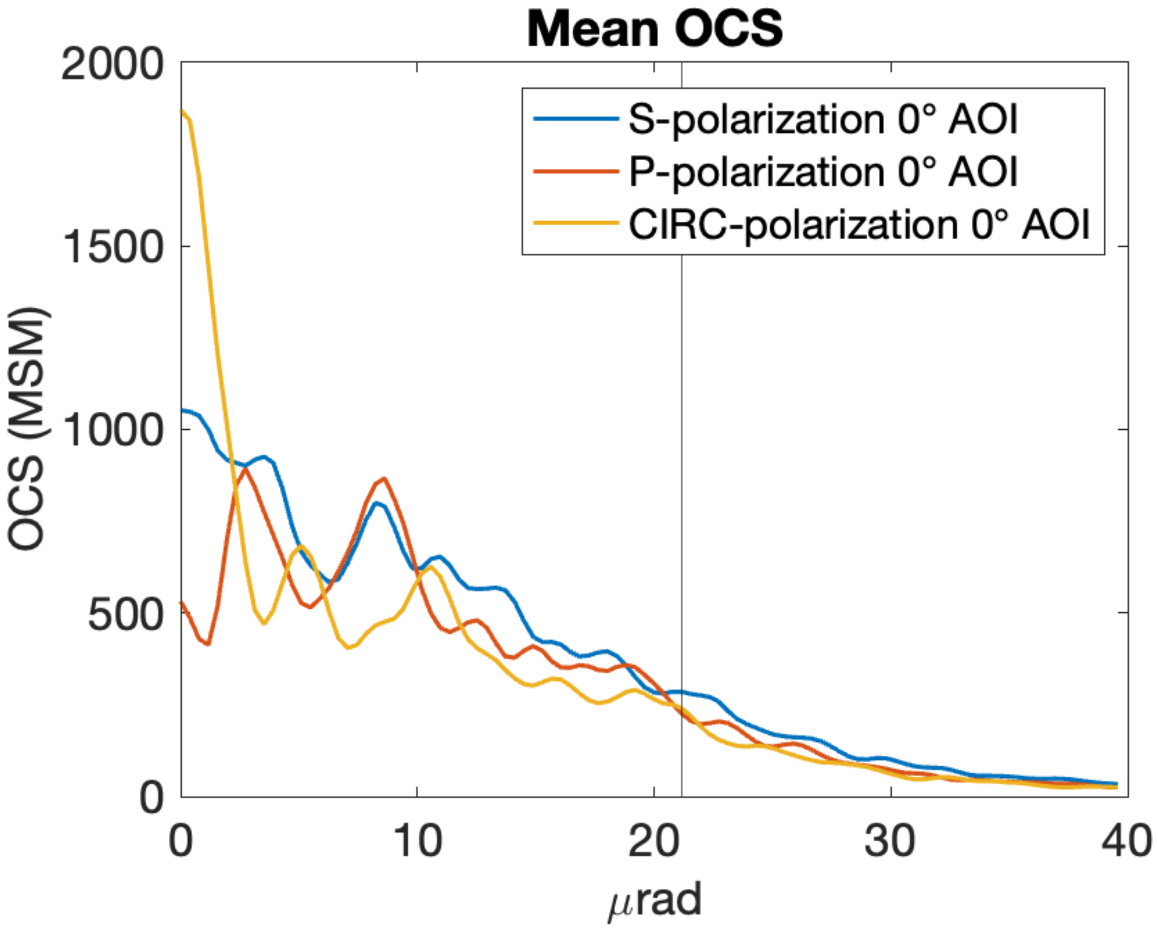


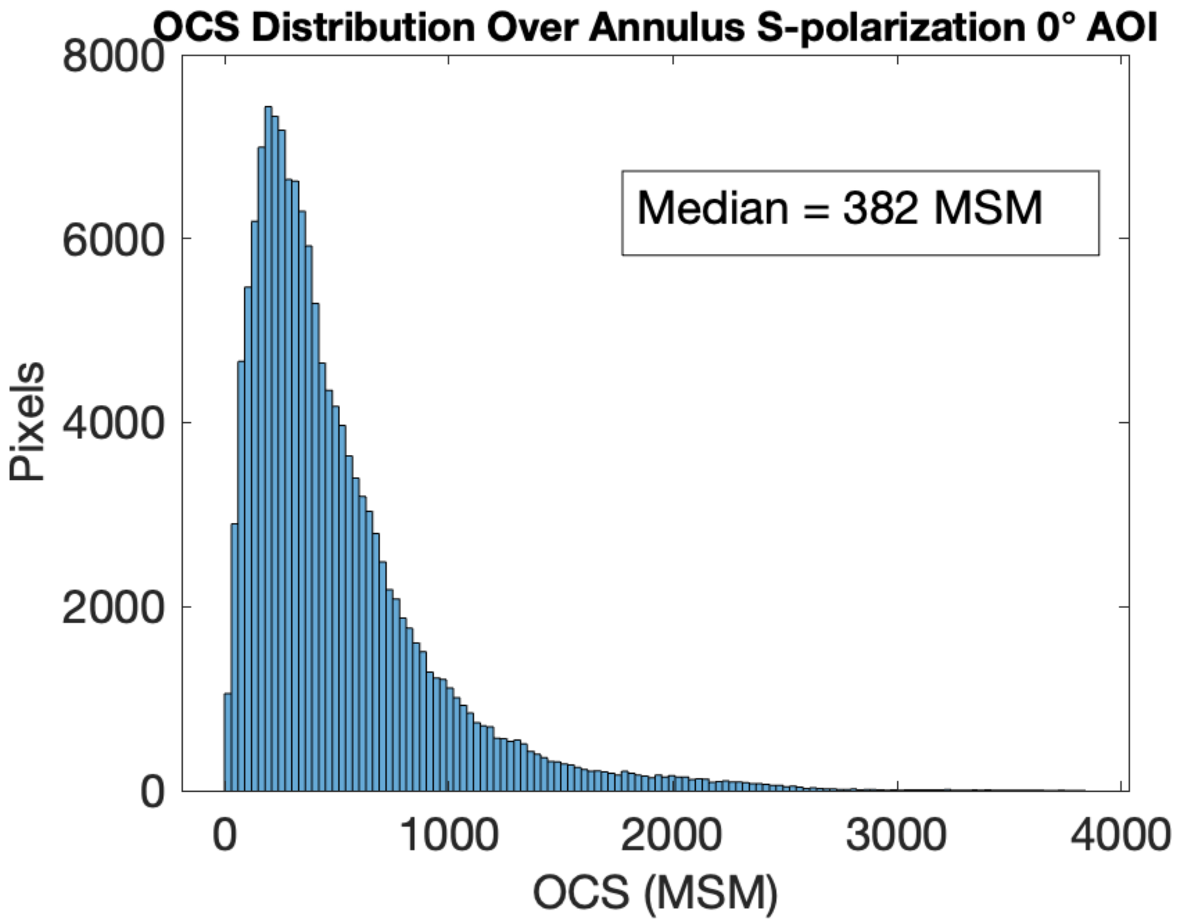




Preliminary - pending final calibration

Optical Cross Section (OCS) Distribution





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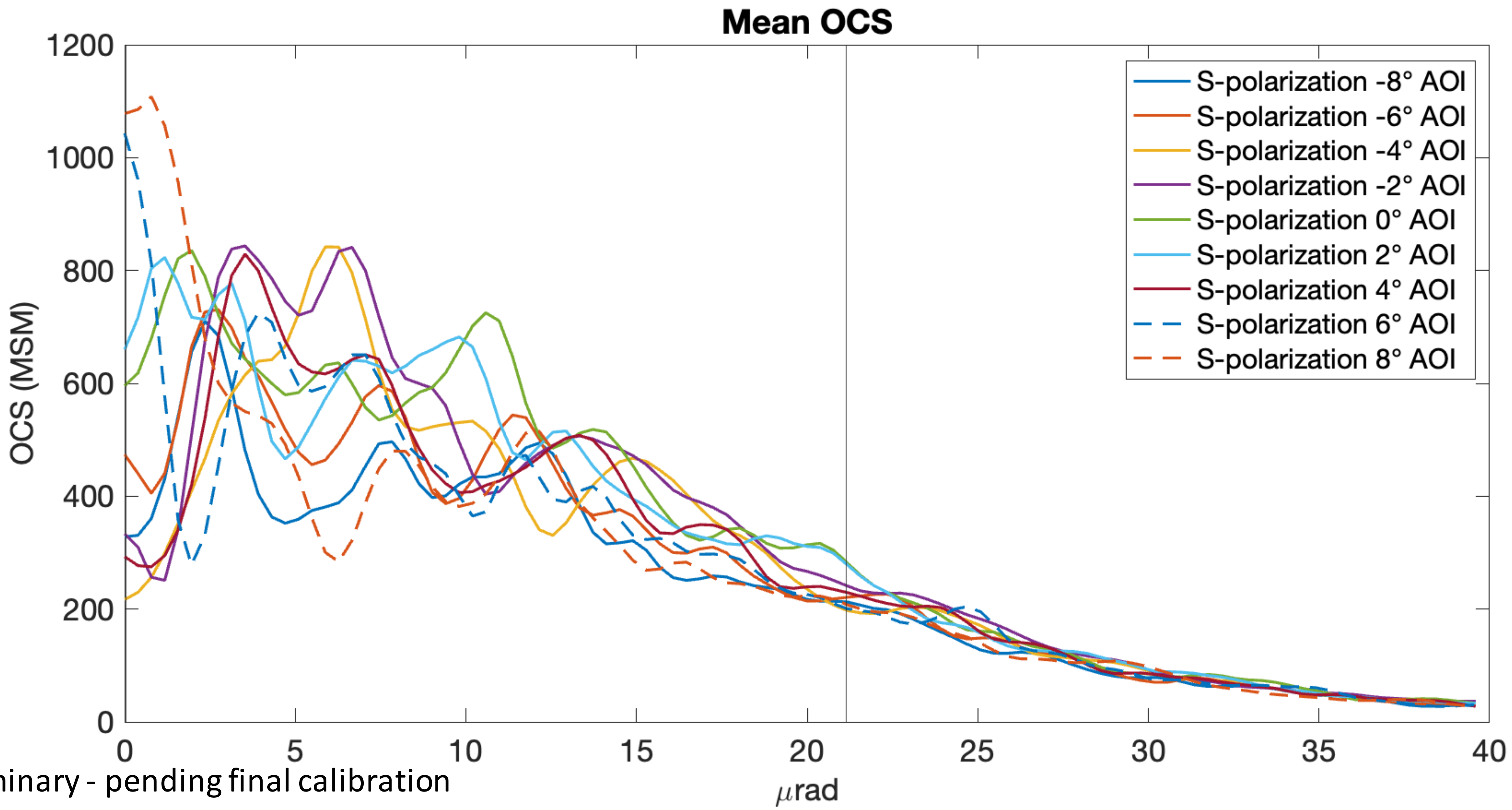
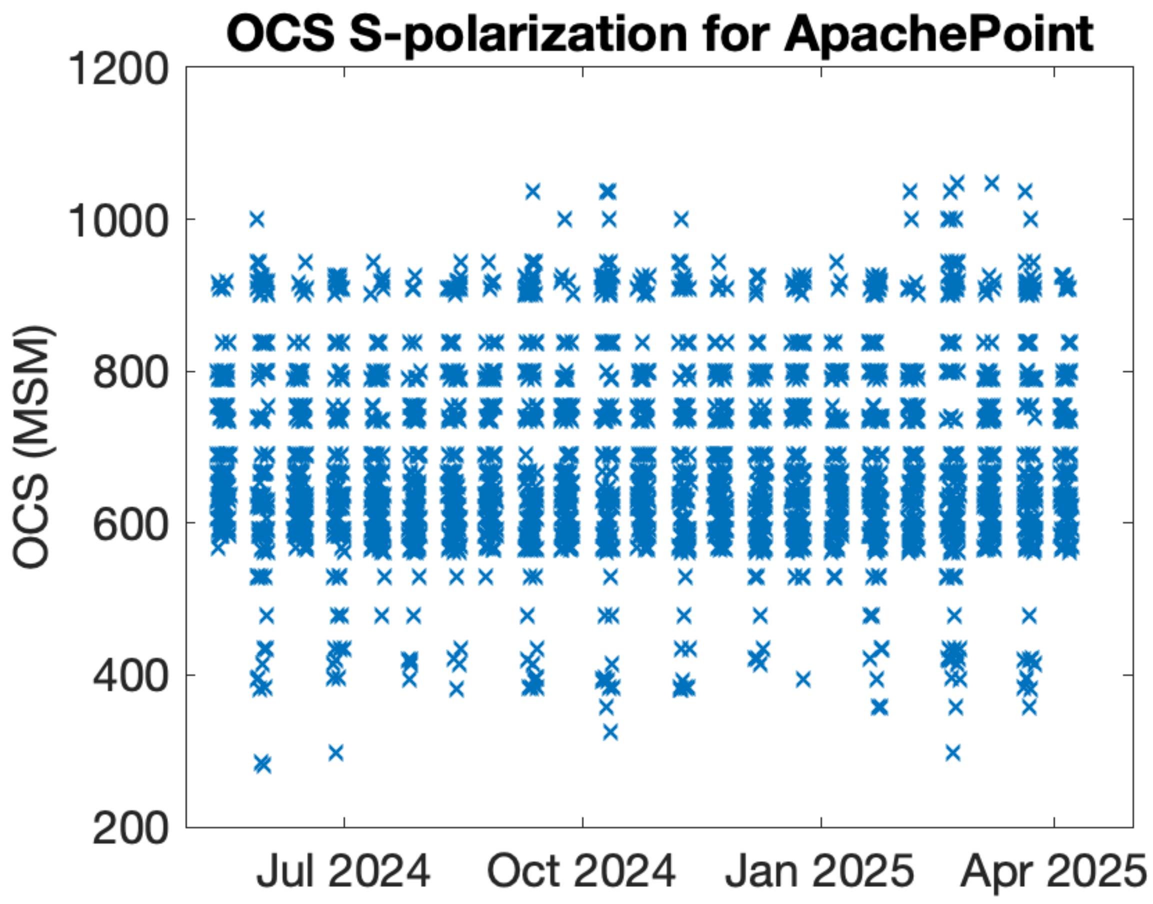
Annulus = 0.5-21.2 μrad

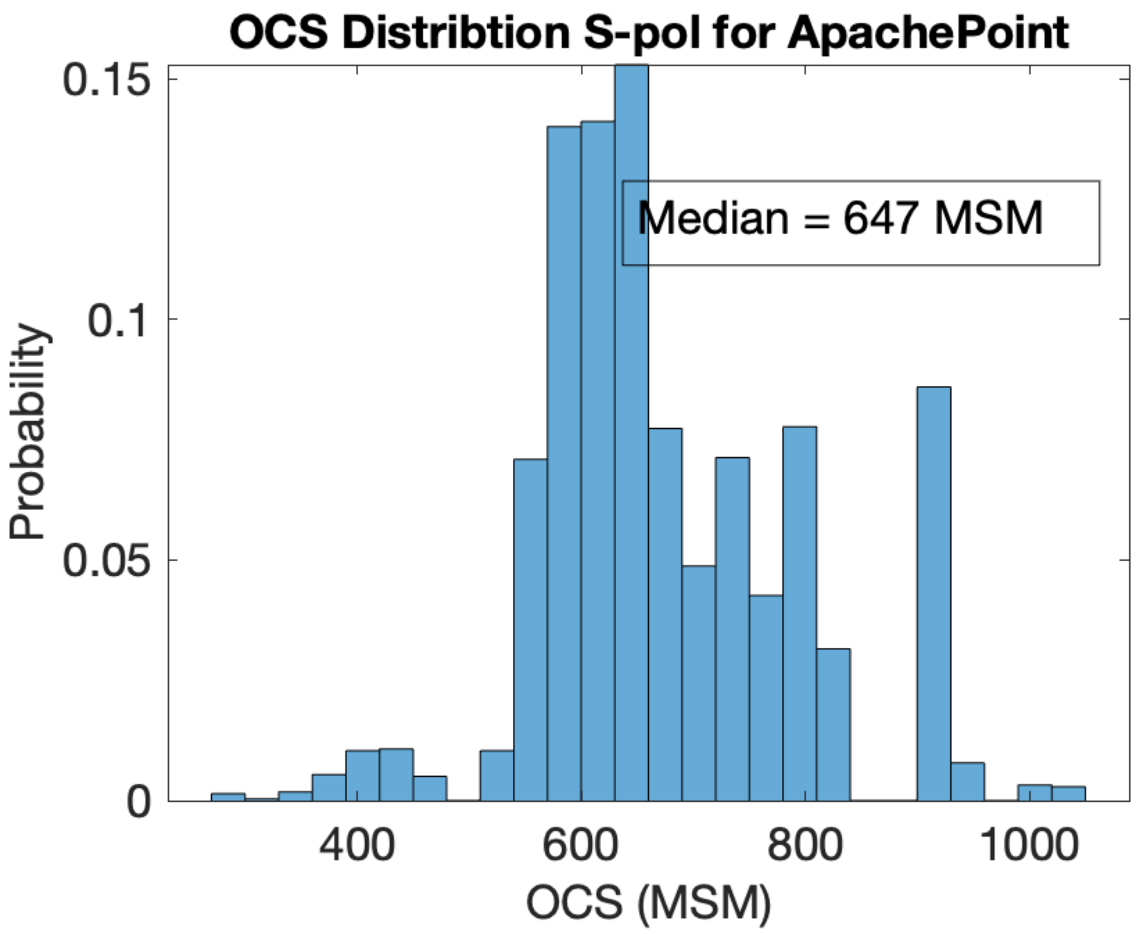
Angle of Incidence (AOI) Dependence



Preliminary - pending final calibration

Lunar Pathfinder Visibility





Preliminary - pending final calibration

Summary

- Lunar Pathfinder LRA Cross Section should enable ranging from all current LRR stations.
- Regular Earth pointing experiment windows provide many tracking opportunities.
- Lunar Pathfinder will demonstrate for the first time simultaneous three ranging technologies (radio, GNSS, and laser) on a lunar orbiting satellite.
- If successful, will open new possibilities for precision orbit determination and navigation on and around the Moon.

Photo Credit: SSTL