Geology & Planetary Mapping
Winter School

# GEOLOGY, LANDING SITE SELECTION AND ROVER TRAVERSES IN COPERNICUS CRATER (MOON).

europlanet 2024
Research Infrastructure

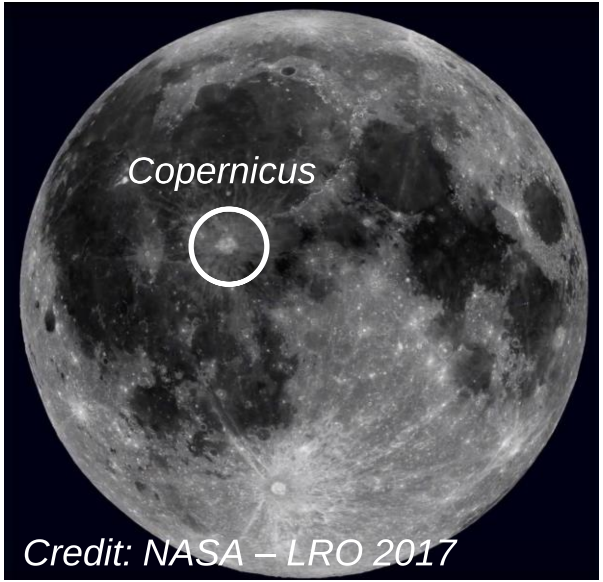
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 871149.

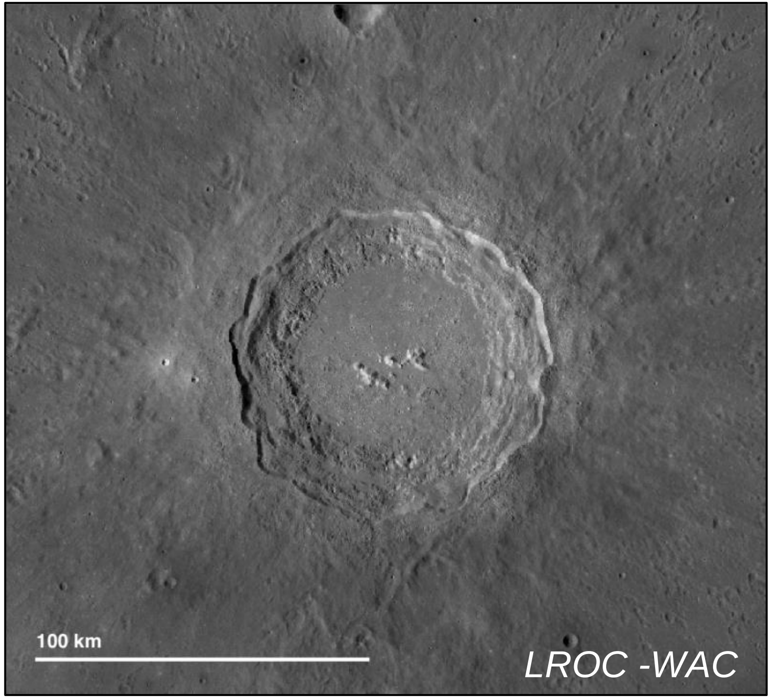
# WORKFLOW

1. Preliminary Study of the Area
2. Geologic Mapping
3. Scientific Stop Selection
4. Landing Ellispe Selection
5. Traverse Selection
6. Analysis

# 1- PRELIMINARY STUDY

## From regional to local scale:



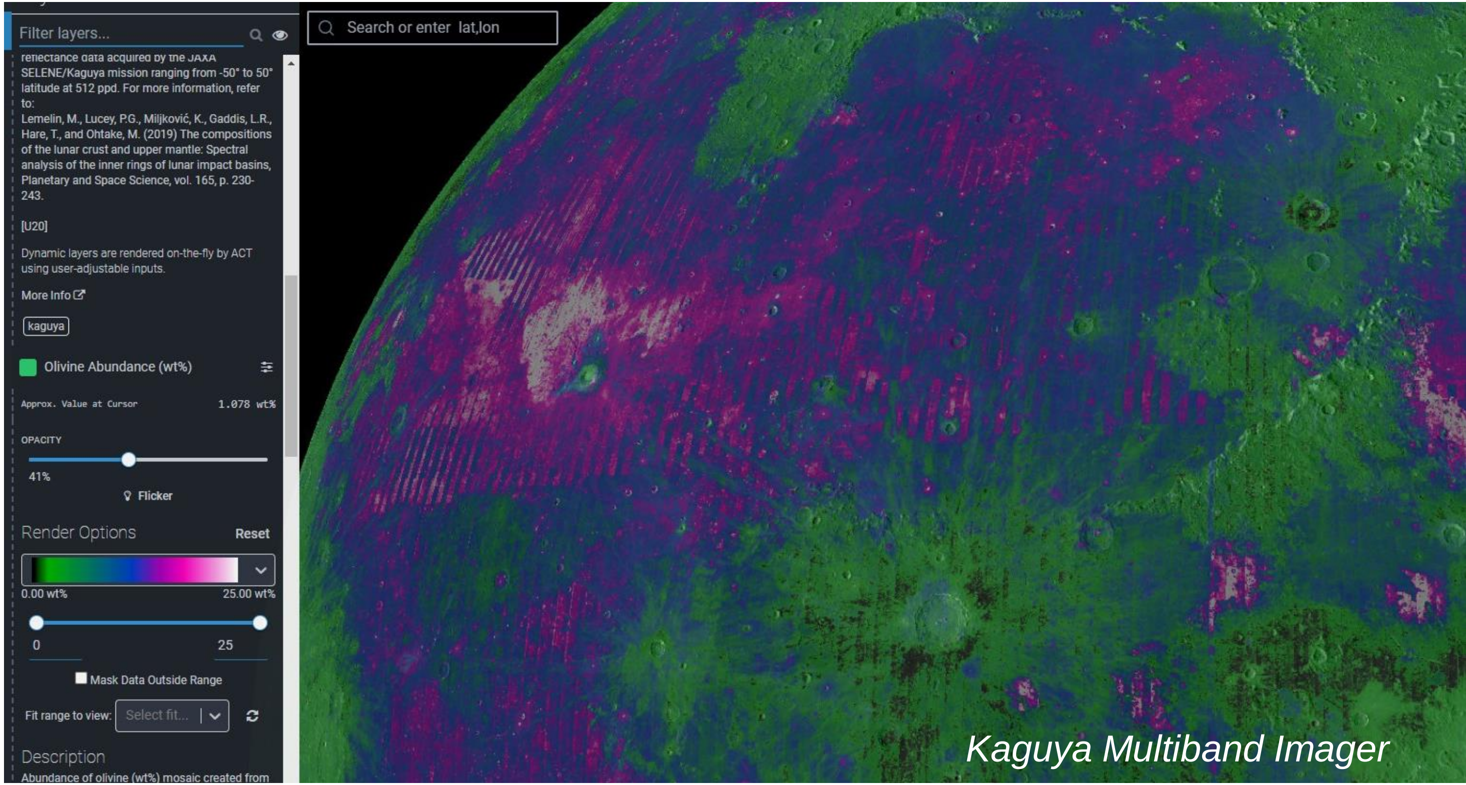




**Geomorphological Observations**

# 1- PRELIMINARY STUDY

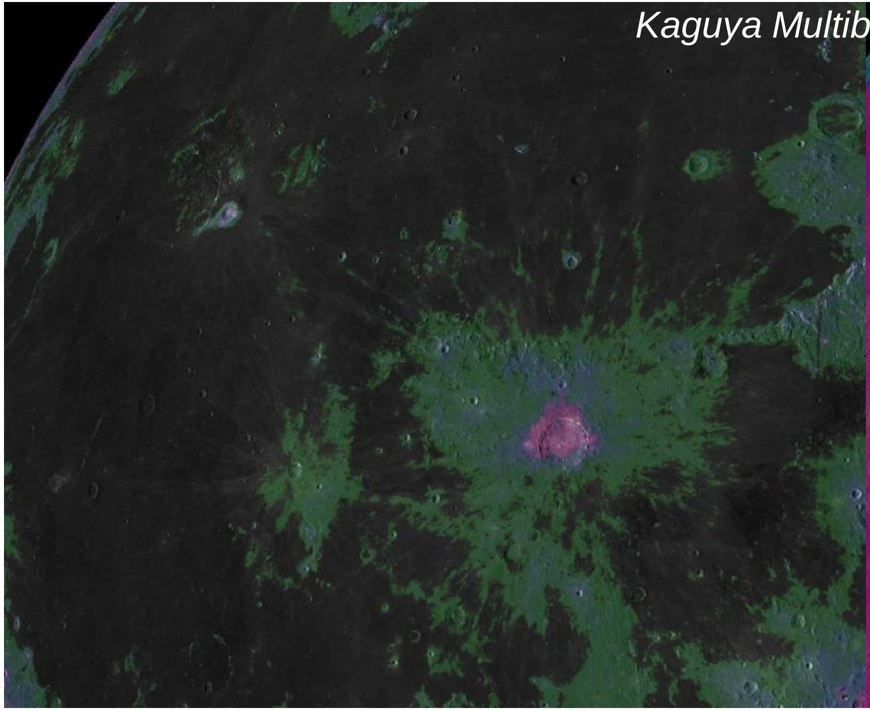
**Regional Spectral observations**

Olivine Content



# 1- PRELIMINARY STUDY

*Kaguya Multiband Imager*



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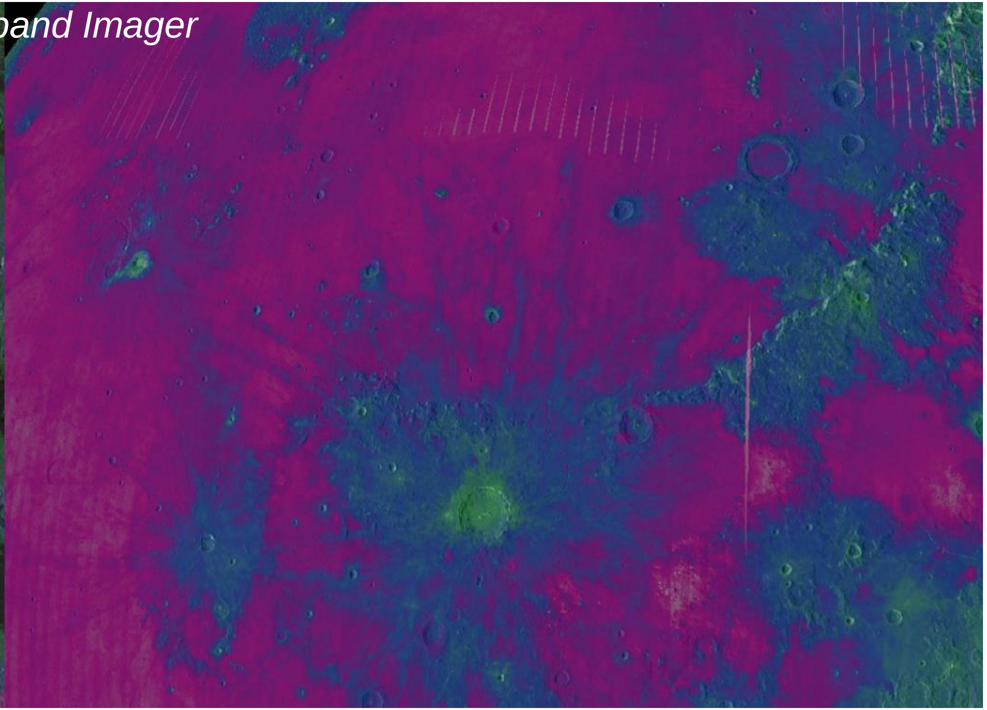
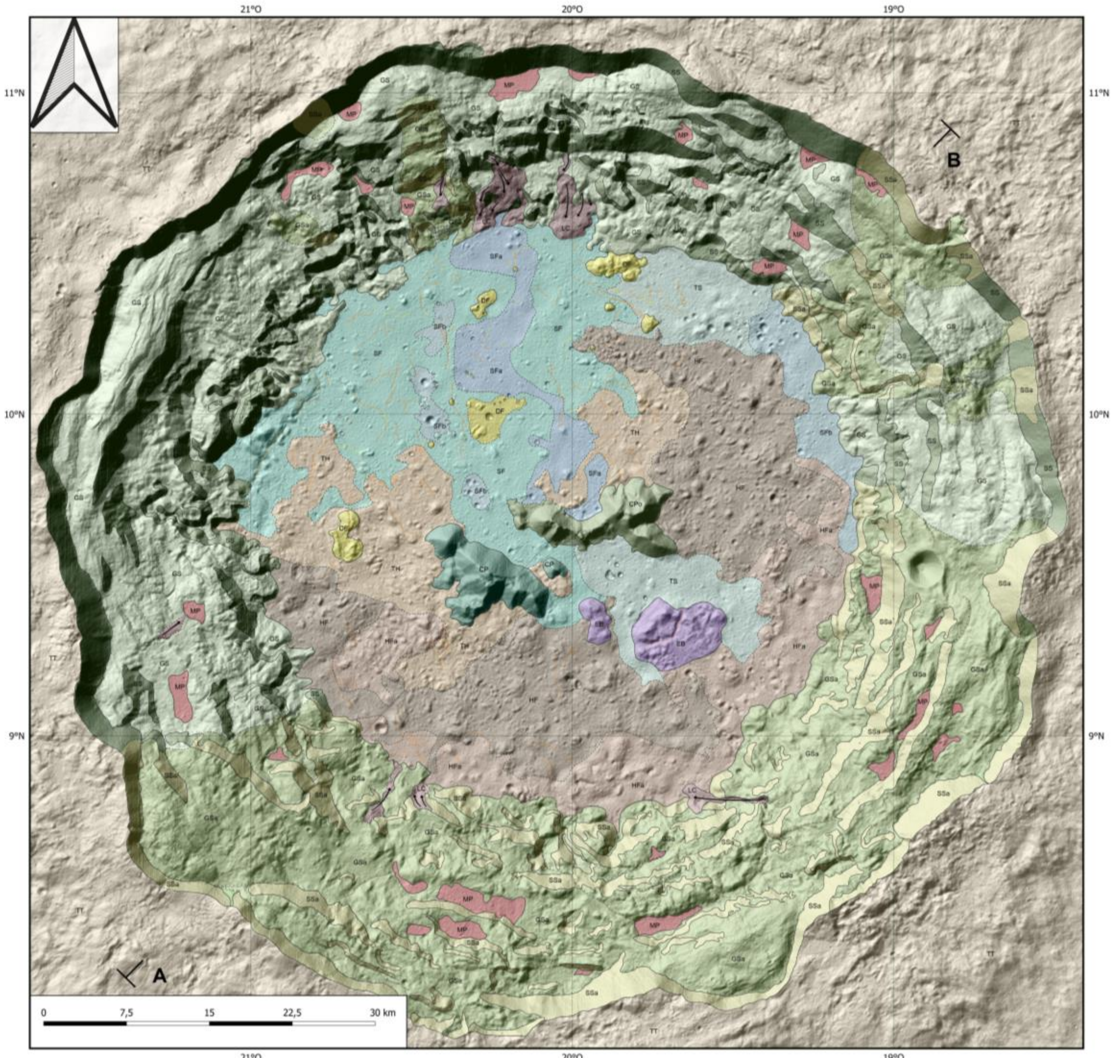


Iron Content

# 2- GEOLOGIC MAPPING




Tusberti et Al., 2023

# 3- SCIENTIFIC STOP SELECTION

## Do we have any scientific constrain?

ESA Strategy for Science at the Moon

| Topic | Major Research Topics | Campaign 1: Samples | Campaign 2: polar volatiles | Campaign 3: Geophysics | Campaign 4: plasma, exosphere, dust | Campaign 5: In situ geoscience | Campaign 6: Physiology & biology | Investigation 7: Physics and astronomy |
|---|---|---|---|---|---|---|---|---|
| Bombardment | Cataclysm? Inner solar system chronology – all planets? | | | | | | | |
| Structure from core to crust | How did the Moon differentiate? Why was the subsequent thermal and volcanic evolution asymmetric between the nearside and farside hemispheres? | | | | | | | |
| Rock diversity and distribution | Crust homogeneity & evolution (LMO, KREEP etc.)? | | | | | | | |
| Polar volatiles (ice) | Origins? Distribution? Abundance? Processes? Resources? | | | | | | | |
| Volcanism | How recent? Role of volatiles? Thermal evolution? Interior diversity? Resources? | | | | | | | |
| Impact processes | The Moon is a natural laboratory for impact events at all scales. The Moon and Earth were subjected to the same impact environment. | | | | | | | |
| Regolith | Formation and weathering processes? History of the Sun and Solar System? Resources? | | | | | | | |
| Atmosphere and dust | Exosphere formation and evolution? Dust levitation and transport? | | | | | | | |
| Earth-Moon formation | When? How? Subsequent evolution and processes on Moon & Earth? | | | | | | | |

# 3- SCIENTIFIC STOP SELECTION

TABLE 3.1 Primary Science Goals of Lunar Science Concepts and Links to Overarching Themes

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| | | Overarching Themes | | | | |
|---|---|---|---|---|---|---|
| **Science Concepts** | **Science Goals** | **Early Earth-Moon System** | **Terrestrial Planet Differentiation and Evolution** | **Solar System Impact Record** | **Lunar Environment** | **Implications for Life** |
| 1. The bombardment history of the inner solar system is uniquely revealed on the Moon. | 1a. Test the cataclysm hypothesis by determining the spacing in time of the creation of lunar basins. | X | | X | | X |
| | 1b. Anchor the early Earth-Moon impact flux curve by determining the age of the oldest lunar basin (South Pole-Aitken Basin). | X | X | X | | X |
| | 1c. Establish a precise absolute chronology. | X | X | X | | X |
| | 1d. Assess the recent impact flux. | | | X | X | X |
| | 1e. Study the role of secondary impact craters on crater counts. | | | X | | |
| 2. The structure and composition of the lunar interior provide fundamental information on the evolution of a differentiated planetary body. | 2a. Determine the thickness of the lunar crust (upper and lower) and characterize its lateral variability on regional and global scales. | | X | X | | |
| | 2b. Characterize the chemical/physical stratification in the mantle, particularly the nature of the putative 500-km discontinuity and the composition of the lower mantle. | | X | | | |
| | 2c. Determine the size, composition, and state (solid/liquid) of the core of the Moon. | X | X | | | |
| | 2d. Characterize the thermal state of the interior and elucidate the workings of the planetary heat engine. | X | X | | | |
| 3. Key planetary processes are manifested in the diversity of lunar crustal rocks. | 3a. Determine the extent and composition of the primary feldspathic crust, KREEP layer, and other products of planetary differentiation. | | X | | | |
| | 3b. Inventory the variety, age, distribution, and origin of lunar rock types. | X | X | | X | |
| | 3c. Determine the composition of the lower crust and bulk Moon. | X | X | | | |
| | 3d. Quantify the local and regional complexity of the current lunar crust. | | X | X | | |
| | 3e. Determine the vertical extent and structure of the megaregolith. | | | X | X | X |
| 4. The lunar poles are special environments that may bear witness to the volatile flux over the latter part of solar system history. | 4a. Determine the compositional state (elemental, isotopic, mineralogic) and compositional distribution (lateral and depth) of the volatile component in lunar polar regions. | | | | X | X |
| | 4b. Determine the source(s) for lunar polar volatiles. | | | X | X | |
| | 4c. Understand the transport, retention, alteration, and loss processes that operate on volatile materials at permanently shaded lunar regions. | | | | X | |
| | 4d. Understand the physical properties of the extremely cold (and possibly volatile rich) polar regolith. | | | | X | |
| | 4e. Determine what the cold polar regolith reveals about the ancient solar environment. | | | | X | |

National Research Council - USA

# 3- SCIENTIFIC STOP SELECTION

1. Bombardment history of the inner Solar System. (NRC Goal 1)
2. Structure and composition of the lunar interior. (NRC Goal 2)
3. Diversity of lunar crustal rocks (NRC Goal 3)
4. Lunar volcanism (NRC Goal 5)
5. Impact process (NRC Goal 6)
6. Regolith and weathering processes(NRC Goal 7)
7. Volatiles
8. IRSU

SCIENTIFIC GOALS
Of the selected targets

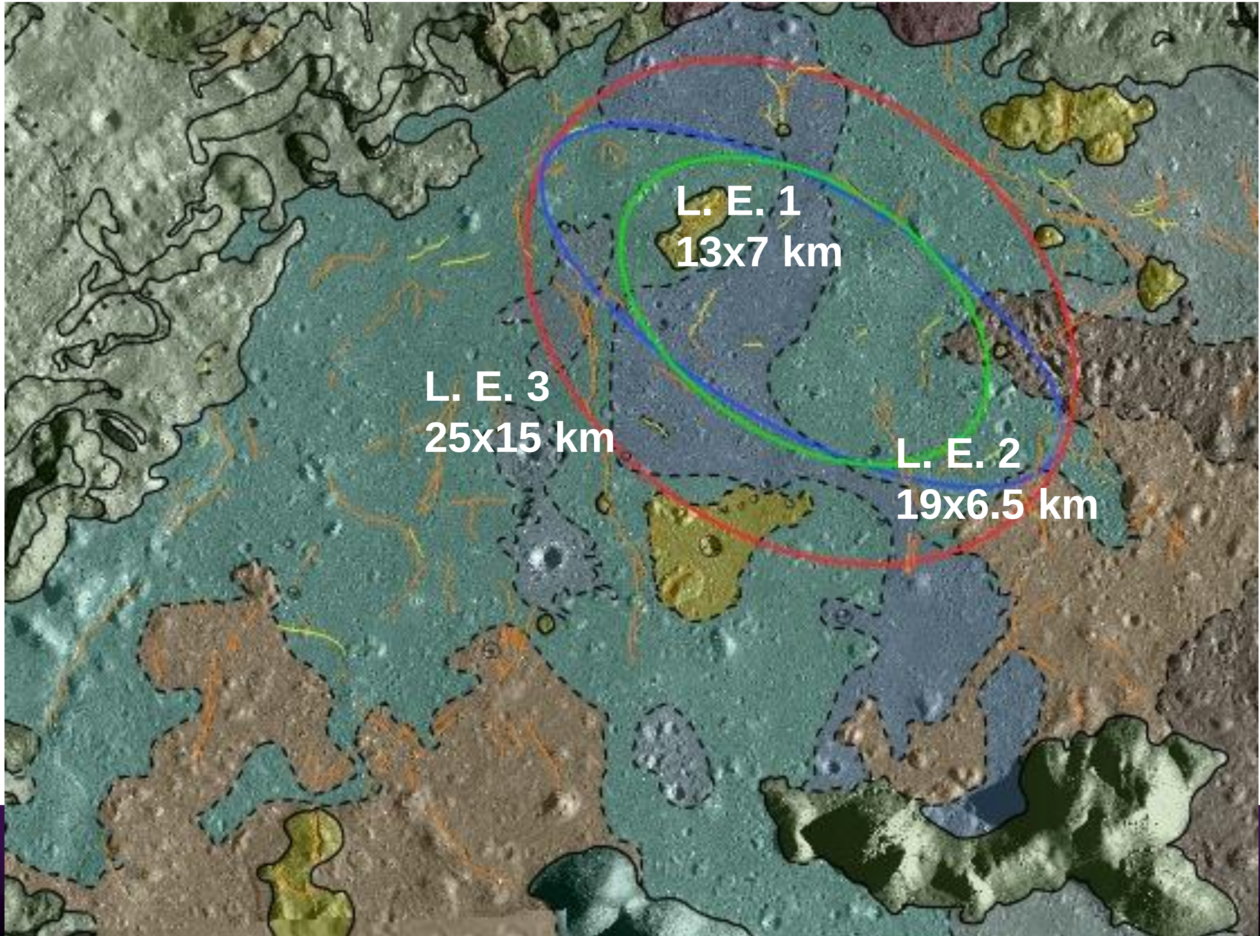
# 4- LANDING ELLIPSES SELECTION

**Do we have any engineering constrain?**

- Latitude/Longitude
- Dimension and Orientations
- Slope
- Boulders/craters abundances
- Dust Coverage
- Thermal Inertia
- Albedo
- Radar Reflectivity

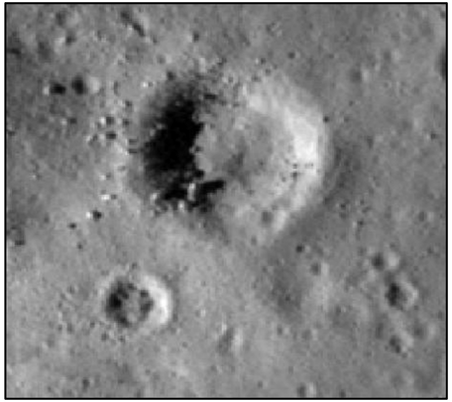
- They vary from mission to mission
- They mainly depend on the «Entry Descend and Landing parameters» (EDL)

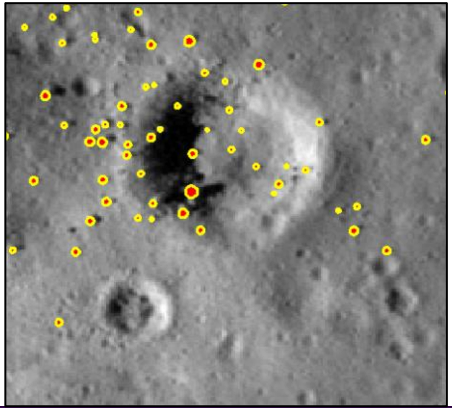
# 4- LANDING ELLIPSES SELECTION

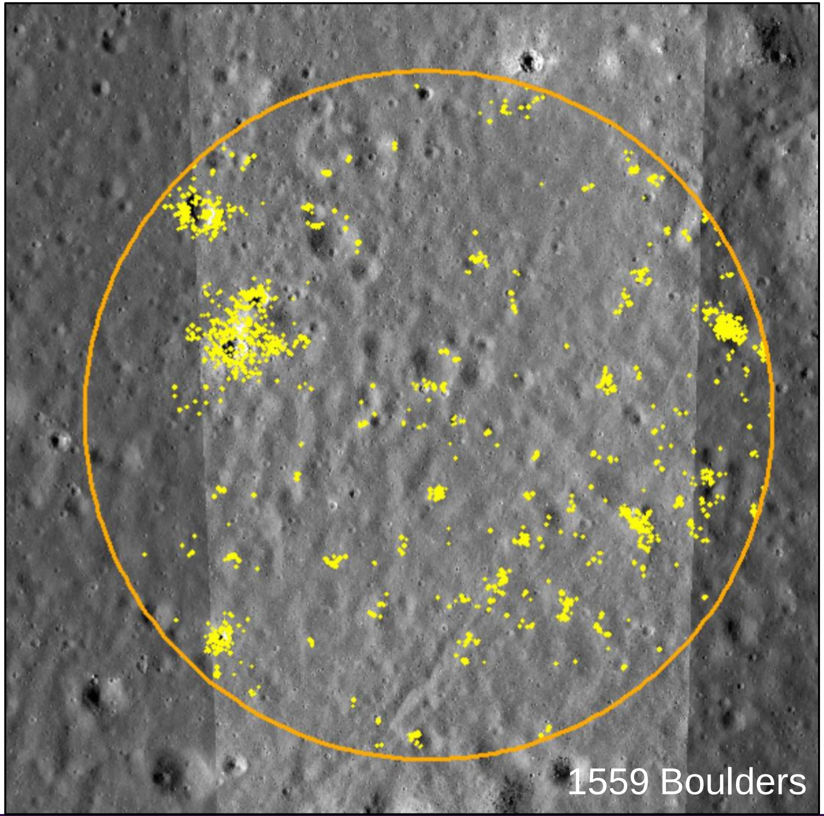


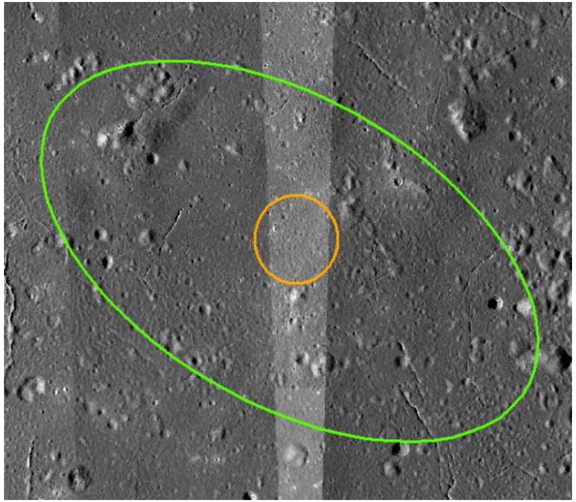

**3 concentric and Conservative Potential landing Ellipses**

# 4- BOULDER COUNTING



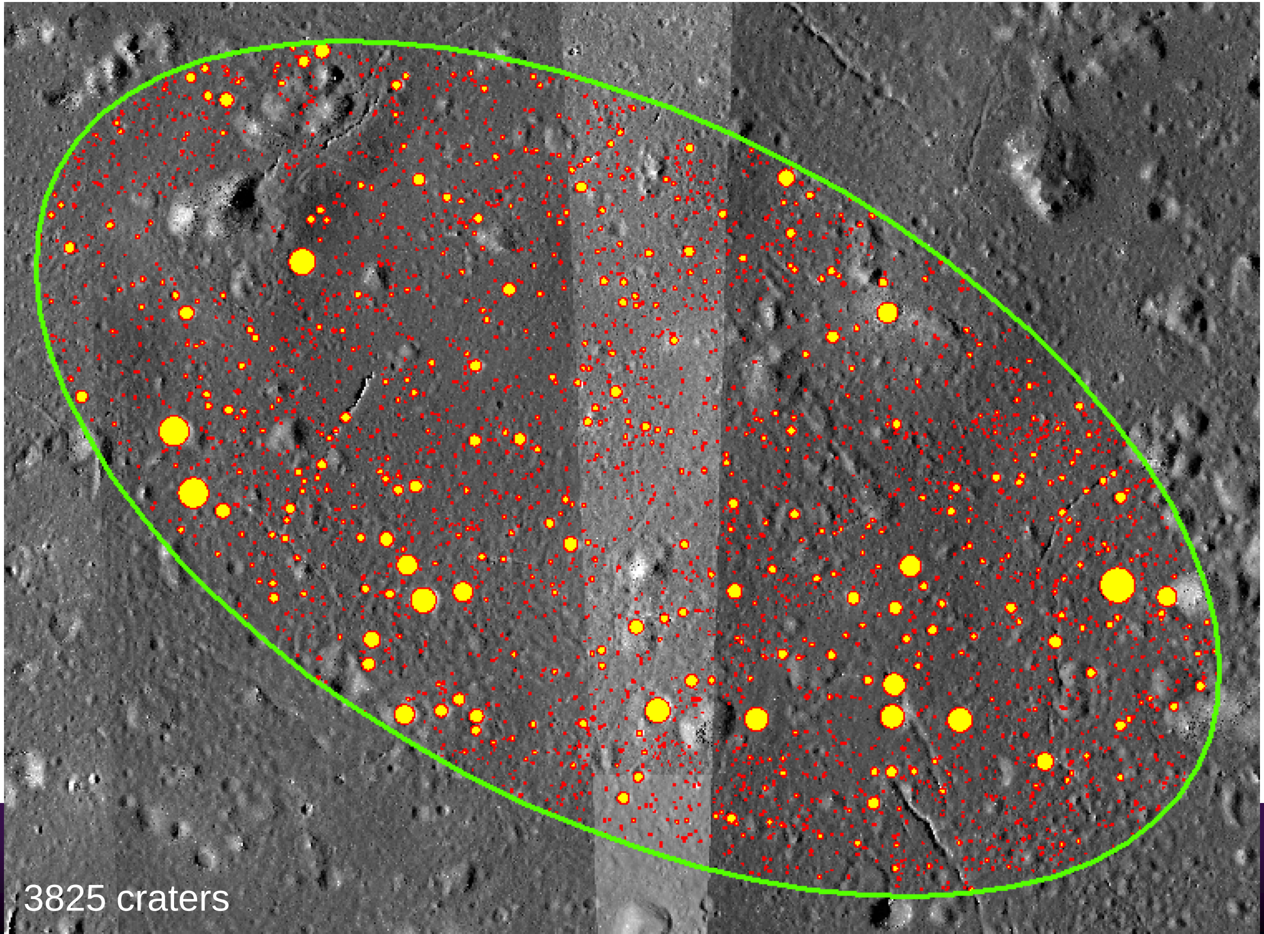




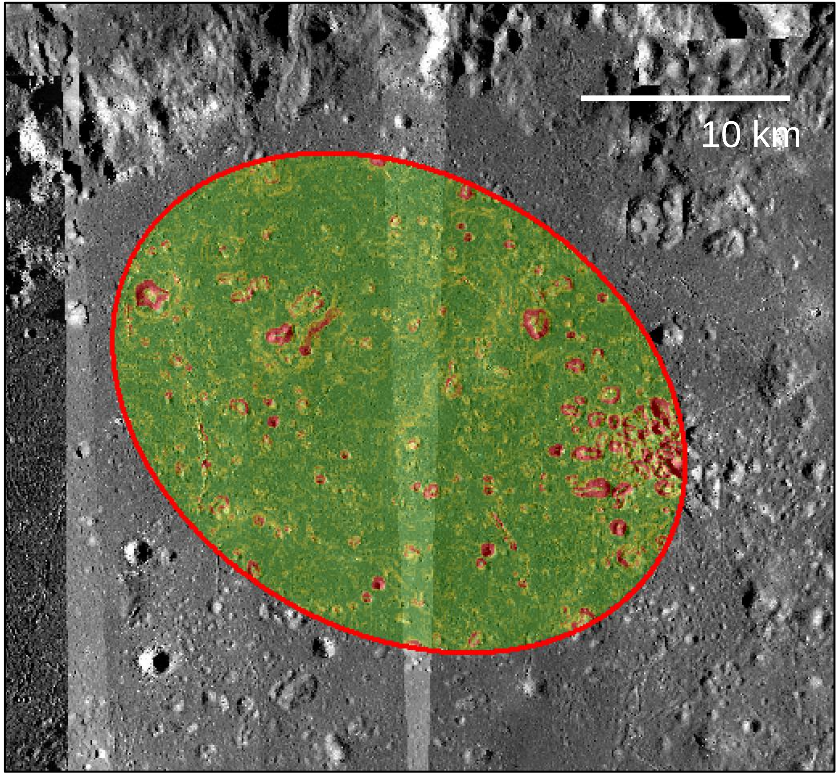
**1.9 x 10$^{-4}$** Boulders per Square meter

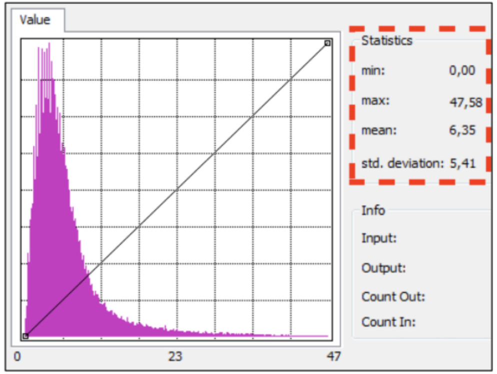
# 4- CRATER COUNTING




**53** Craters per Square Kilometer

# 4- SLOPE ANALYSIS




**1.31%**

Forbidden Areas



3825 craters

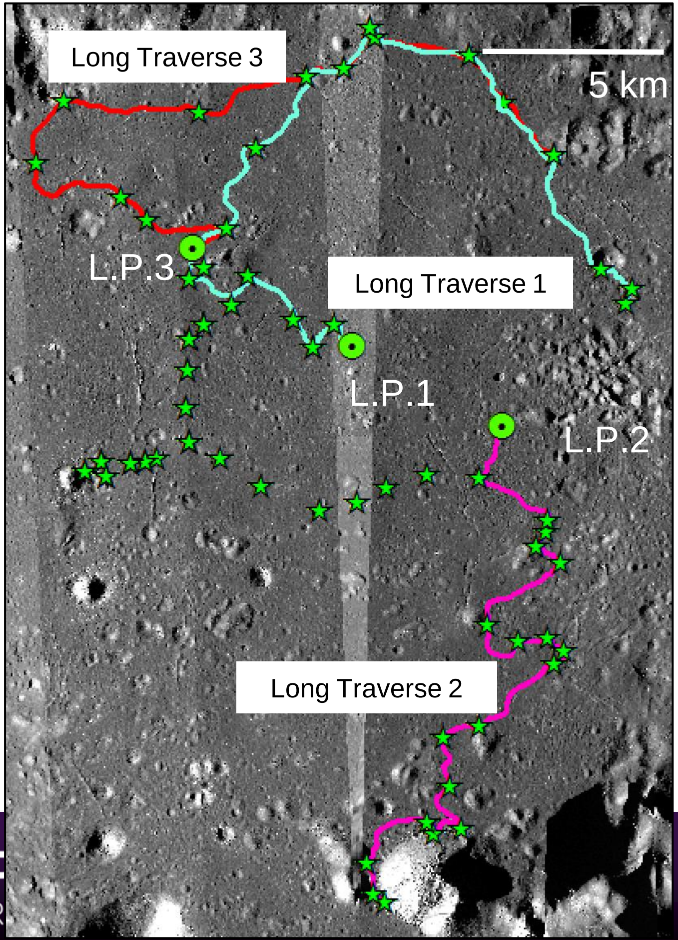
# 5- TRAVERSES SELECTION

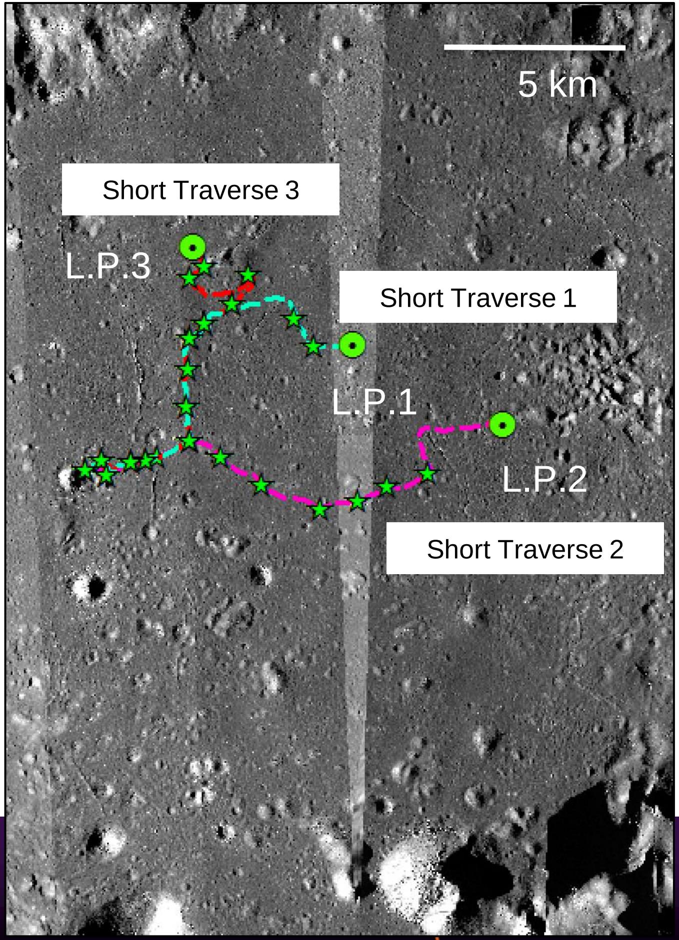
**Do we have any engineering constrain?**

- Maximum path lenght = 32km
- Ground Clearence = 30cm
- Maximum Steepness = 16°

- Subdivide the Targets in subgroups and try to connect them
- Being conservative
- Avoid Obstacles
- Draw a shorter version of the path for each traverses (B-Plan)

# 5- TRAVERSES SELECTION



# 6- TRAVERSE ANALYSIS

## Kind of analysis extimation

| Target (T) activities | Time (Earth hours) | References |
|---|---|---|
| Panoramic image using 3D imager | 8 | *Potts et al., 2015* |
| Position rover for in situ target | 0.5 | *Potts et al., 2015* |
| GPR analysis | On while traversing | *Shearer & Tahu, 2010* |
| Position arm-mounted APXS | 0.5 | *Potts et al., 2015* |
| APXS analysis | 3.0 | *Arvidson & May, 2010* |
| Position GRS | 0.5 | *Potts et al., 2015* |
| GRS analysis | 1.0 | *Wieczorek et al., 2015* |
| Position microscope camera (LRAC) | 0.5 | *Potts et al., 2015* |
| Microscope Camera (LRAC) | 1.0 | *Arvidson & May, 2010* |
| Surface imager (MSL MastCam) | 0.5 | *Shearer & Tahu, 2010* |
| Sample collection | 3.0 | *Potts et al., 2015* |
| Sample Transfer to bad and storage | 1.0 | *Potts et al., 2015* |

## Time exitmation

| Traverse | 1-analysis timing (Earth days) | 3-analysis timing (Earth days) |
|---|---|---|
| Long Traverse 1 | 8.5 | 18.5 |
| Short Traverse 1 | 6.5 | 15 |
| Long Traverse 2 | 10 | 22 |
| Short Traverse 2 | 6 | 12.5 |
| Long Traverse 3 | 7 | 15 |
| Short Traverse 3 | 7 | 16 |

# 6- TRAVERSE ANALYSIS

| Instrument | Interior Structure-Tectonism | Primordial crust | Volcanism | Cratering Model Ages | Impact processes | Subsurface structures | Volatiles | Regolith and ISRU |
|---|---|---|---|---|---|---|---|---|
| Panoramic and Context Cameras | • | • | • | | • | • | | |
| Microscope camera | | • | • | • | • | | | • |
| VNIR Spectrometer (0.3-0.9 μm) | | | • | • | • | | | • |
| NIR-SWIR Spectrometer (0.7-3.5 μm) | | • | • | • | • | | • | • |
| TIR spectrometer (7.0-14.0 μm) | | • | • | • | • | | | • |
| XRF | | • | • | • | • | | | • |
| XRPD | | • | • | • | • | | | |
| Gamma Ray Spectrometer | | • | • | | • | | | |
| Neutron Spectrometer | | | | | | | • | • |
| LIBS | | • | • | • | • | | • | • |
| α-Spectrometer (dust, Radon, outgassing) | | | | | | | • | • |
| Magnetometer | • | | | | • | • | | |
| GPR | • | • | • | | • | • | • | • |
| Seismometer | • | | | | • | • | | • |
| Radiation dosimeter | | • | • | | | | | • |
| Heat flow probe | • | | | | | | • | |
| Laser Range finder | • | | • | | | | | |
| Laser scanner | • | | • | | • | | | |

Massironi & Ferrari 2019


THANK YOU ALL