Title: *Lunaris: Unveiling the Unknown* (3D Moon Analysis and Topography Assessment)
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Need

With the upcoming outburst of Moon-related missions, it would be desirable to expand the current knowledge of the Lunar topography as much as possible. 3D mapping the lunar surface offers a versatile data set that can immensely contribute to this objective. Apart from being the most detailed and accurate representation of the Moon to date, such information holds significant value in the planning of forthcoming lunar activities, as it enhances navigational capabilities and facilitates the identification of future potential landing and habitation sites, as well as scientifically intriguing areas to explore. Moreover, analyzing the chemical composition of the Lunar surface can produce another advantageous set of scientific data, which could further solidify the profile of the lunar surface. Combining the information received from the two science modules, locations of interest for space mining, more specifically, sites that are both situated in accessible terrain and rich in resources could be narrowed down.
The data obtained from this mission is planned to be published and made available for everyone, thus allowing more independent research to happen, furthering the development of the lunar ecosystem.

Mission Objectives

The objectives the initiative is aiming for are stated below:

Primary Objectives:

- To create a three dimensional map of at least 95% of the Lunar surface;
- To analyze and determine the chemical composition of at least 95% of the Lunar surface.

Secondary Objectives:

- To provide information about the Moon's geology which could help scientists better understand its formation and evolution;
- To enable the establishment of a system that provides a dynamic, up-to-date map of the Moon that will facilitate effective monitoring of changes, such as the growth of current lunar bases and the discovery of new features.

Concept of Operations

Space Segment:

The space segment will be made up of a constellation of two 6U CubeSats in a polar orbit around the Moon, located at an altitude of around 100 km from the lunar surface. The satellites will be placed 180 degrees apart from each other and will use their equipped LIDAR [1] and hyperspectral camera [2] to scan the Moon's topography and, respectively, the terrain's composition. This data will be stored on board until it is ready to be transmitted. One primary asset necessary for mission success is the Moonlight Constellation [4]. By making use of its services, the CubeSat will be able to obtain the necessary PNT data for the LIDAR device to function. This data is essential to operations, as without it, the LIDAR would not be able to know where the “images” it took came from. A previous plan was to use high sensitivity GNSS receivers in order to capture the needed PNT data from the Galileo Satellite, in turn boosting its signal to be more easily available on the Moon. This option remains viable if, due to further analysis, the current plan becomes unsuitable.

Ground Segment:

Another asset that will be used is the up and coming Lunar Gateway Station, which is vital for a successful operation. The data collected by the CubeSats and stored within the data storage unit will be transmitted to the Gateway through its S band receiver terminal, making it able to send a large amount of information within the transmission window. As a final step, the data that is sent to the Lunar Gateway will be transmitted to a terminal on Earth for use and research. [3]

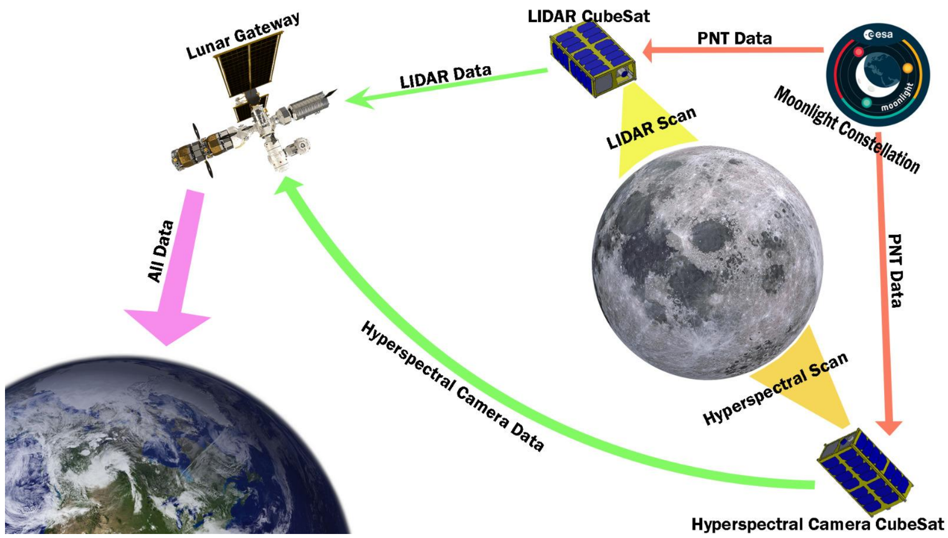

Figure 1: Graphical depiction of Concept of Operations

Key Performance Parameters

- Camera Resolution: A GSD of around 30 or even lower (calculated after a study of past missions that used hyperspectral cameras for Earth observation) is desirable. There are several CubeSat hyperspectral cameras that can be used with this precision at 100 km altitude, like the HyperScout M from Cosine, which has a GSD of 39 at 350 km altitude.
- Scanning Time: Taking into consideration similar missions around the Earth and the range and range resolution of the LIDAR system, it was concluded that a full scanning cycle of the Lunar surface in approximately one month is enough to produce a precise scan of the lunar surface. Using a polar orbit, it was calculated that the mission would complete a full scan in 28 days.
- Stability of Orbital Motion: In order to maintain a constant resolution for the images, the CubeSats need to always be at 100 km altitude. Any form of fuel-dependent propulsion would not leave enough room for the rest of the subsystems, as the payload and the data storage unit occupy a large portion of the available 6Us, and the fuel would not be

enough for the constellation's 5 year lifetime. Electric propulsion was chosen as an alternative, coupled with a frozen polar orbit that requires minimal station-keeping.

Space Segment Description:

The LIDAR [1] technology chosen as reference (occupying 2U of the available 6U) is currently under development by several companies (for example: Fibertek), meaning that in the foreseeable future it will be ready to use. This technology shows much promise, being able to scan a surface from up to 100 kilometers away in less than a second. ESA, in collaboration with Cosine, has developed various hyperspectral cameras, presenting variety in choosing the necessary technology. For calculations, the 1U HyperScout M hyperspectral camera from Cosine [2] was used as a reference. The use of a 6U structure is necessary to ensure that the payloads, a large enough data storage unit, and the rest of the subsystems will fit.
The data storage unit that will be used shall be capable of storing enough information to keep all the payload data until the transmission window. Currently, it is estimated that at least a couple of TBs will be required. An S-band antenna will be used in order to transmit all mapping data to the Lunar Gateway. A precise link budget is planned to be calculated in order to ensure that the required communication can be established.[3][4]

CAD Representation of the CubeSats:

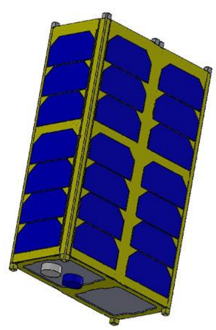

Figure 2: LiDAR CubeSat

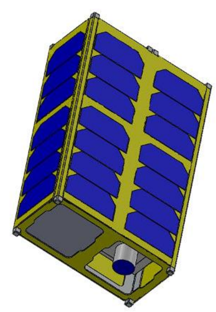

Figure 3: Hyperspectral CubeSat

Overview of power consumption, volume and mass budget
For the power, mass, and volume budgets, reference modules from Endurosat and other COTS companies, as well as the HyperScout M hyperspectral camera from Cosine [2] were used. For the LIDAR, calculations were based on a concept for a future CubeSat LIDAR module from Fiberlink. [1]
A rough approximation of the maximum eclipse power consumption was calculated, and it has been estimated that with two 8-cell Battery Packs, the battery's state of charge reaches about 80%.This means that even without the power generated from the solar arrays, the power budget is positive, and both CubeSats can function normally.

Subsystem	Component	Mass [g]		Qty.	Dimensions [mm x mm x mm]	Power consumption [W]	
		LIDAR CubeSat	Hyperspectral camera CubeSat			LIDAR CubeSat	Hyperspectral camera CubeSat
ADCS	Central Unit	414.4		1	94 x 94 x 27	1.2	
PAYLOAD	LIDAR	2500	-	1	100 x 100 x 200	15	-
	Hyperspectral camera	-	1200	1	100x100x100	-	9
	Data Storage Module	1000		1	100 x 100 x 200	29	
STRUCTURE	6U Structure	570		1	100 x 100 x 300	-	
	Harness	269		-	-	-	
EPS	Solar Panel 6U	400		2	15 x 174 x 335	-	
	Solar Panel 3U	130		2	15 x 87 x 335	-	
	EPS PDM	280		1	90.2 x 95.7 x 25.2	-	
	8-cell Battery Pack	1100		2	90.2 x 95.7 x 68	-	
OBC	OBC	120		1	83 x 94 x 23	0.5	
COMMS	S-band Antenna	60		1	97 x 80 x 5	-	
	S-band Transmitter	140		1	90 x 96 x 23	4.5	
		TOTAL	TOTAL			TOTAL	TOTAL
		8613.4	7313.4			50.2	44.2
				Approximate orbital period (h)		2	
				Approximate eclipse period (h)		0.7	
				Energy consumption during eclipse (Wh)		35.14	30.94

Table 1: Power, Volume and Mass budget

Orbit/Constellation/Description

The constellation is justified by the fact that the 3D mapping and surface analysis components cannot both fit within the space of a single 6U CubeSat. Moreover, by using two separate 6U satellites, if one of them were to malfunction or be damaged in some way, it would be much cheaper to replace a single one (with a single payload) than both payloads (if this mission were to be integrated in a bigger frame, ex: 12U).

In order to extract accurate data from the LIDAR technology and hyperspectral camera, a LLO (Low Lunar Orbit) was chosen for the mission, preferably at a height of 100 kilometers.The two Cubesats will operate in a polar orbit.These types of orbits are necessary for the mission, as using the LIDAR and the camera installed on both satellites, the full surface of the Moon will be covered in multiple cycles, obtaining data related to the topography of the Moon and its surface resources. However, LLO polar orbits could become unstable due to the existence of lunar mascons that alter the Moon's gravity field. In this regard, a frozen polar orbit was chosen, in which a spacecraft can stay indefinitely, only suffering small changes in its inclination that can be corrected using the ADCS subsystem. There are two frozen orbits that present the required parameters, situated at inclinations of 76 and, respectively, 86 degrees. Both orbits fit within the requirements of the mission. In order to reach the frozen orbit at an altitude of 100 kilometers, it was calculated that a delta V of 13.196 km/s would be necessary. It is estimated that the constellation’s lifetime will be about five years. Developing a second generation of this constellation which would replace it after the end-of-life.has been considered.

Implementation Plan

There are several facilities available at Politehnica University of Bucharest that will aid in the development of this project, such as mechanical and electrical laboratories, as well as several software tools. Moreover, there are several places the students involved in this project can ask for assistance from: companies with branches in Romania such as GMV, THALES, and Deimos, as well as Romanian native companies such as COMOTI, INCAS, and Romanian InSpace Engineering (RISE) that would be willing to help with information, facilities, and testing. Moreover, ROSPIN (Romania's leading space NGO) is working on a CubeSat as part of an ESA Project and would extend their know-how.

The following facilities would be required: a clean room - for building, assembly, and integration of the CubeSat; a Vibration Testing Facility; a Vacuum Chamber; and a Shock Testing facility - for various satellite environmental tests. Access to these can be obtained.

Risk factor

Number	Risk	Impact
1	Delays in the schedule of the Lunar Gateway and Moonlight missions would in turn delay the proposed mission, given the current set-up.	Low
2	Malfunctions of the Lunar Gateway and Moonlight constellation during the missions' lifetimes could lead to loss or corruption of vital data. In the worst of scenarios, a complete connection cut-off to the proposed mission's satellites could take place.	High
3	The window of data transmission to the Lunar Gateway might be too small. There is no way to predict the likelihood of this happening at this time, but measures will be taken in order to prevent it. There will be extensive calculation on the orbit to make sure it gives as large of a window as needed for data transmission.	Medium
4	Lack of funding for building the mission could prove fatal towards the ambition, however several opportunities for sponsorship will be available.	Low
5	If the data transmission component on one of the CubeSats were to suffer a malfunction, part of the constellation would become unusable. To prevent this, redundancies for all crucial equipment will be included during the design process.	Medium

Table 2: Risk factors

Mission Implementation

Figure 4: Gantt Chart (Mission phases defined according to ESA)

References

[1] Mark Storm, He Cao, Doruk Engin, Michael Albert, "Cubesat Lidar Concepts for Ranging, Topology, Sample Capture, Surface, and Atmospheric Science" (2017). Proceedings of the 31st Annual AIAA/USU 2017 Conference on Small Satellites.
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[2] Cosine, "The HyperScout product line" (2020)
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[3] NASA, Gateway Mission Overview (5/24/2023)
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[4] ESA, Moonlight Webinar Presentation (3/9/2022)
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