Title: LWISAT: Lunar Water Index by Spectral Measurement through a CubeSat Constellation

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Organization: LWISAT

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Goals and Needs

The conquest of space has been delayed due to many factors, but one that stands out is the answer to the question: how much water does the moon contain? According to Van Der Heijden y Stinson [1] water is one of the most valuable and threatened resources for life.

Until last year, the Stratospheric Observatory For Infrared Astronomy (SOFIA) [2] obtained the first quantifiable data on water in a lunar crater. The Artemis mission has the objective of establishing interplanetary human presence to expand the scope of humanity. To create base camps, on the moon's surface, there is not yet a baseline on the amount and location of water

LWISAT: Lunar Water Index by Spectral Measurement through a CubeSat Constellation will become the next research step in the task of solving the quest for lunar water. It will go beyond previous missions' efforts. The general objective of this endeavor is to develop a remote sensing water index supplied by a 10 nano-satellite constellation deployed in a lunar orbit. By generating the lunar water index, the precision in interplanetary and mining missions would increase. Besides, it would decrease the cost of exploration and analysis due to the fact that there is already a baseline for high-quality spectral band diagrams of different potential water deposits.

A new era of deep space exploration will unravel as this mission explores new locations of water deposits and it will update recorded data with higher resolution than has been obtained up to date in other missions. This endeavor could create synergies with missions such as ISRU or Flashlight.

The advantage of having this data is that it helps not only astronauts living in the base camp, but also the companies that support the mission. One of the main stakeholders that will benefit from LWISAT is *NASA*, among other space agencies, but especially the scientists working on the Artemis mission. In this context, LWISAT's development goal is to explore, identify and quantify water on the moon. Adapting LWISAT mission requirements for hostile non-terrestrial environments could work for future water management missions in other celestial bodies.

Mission Objectives

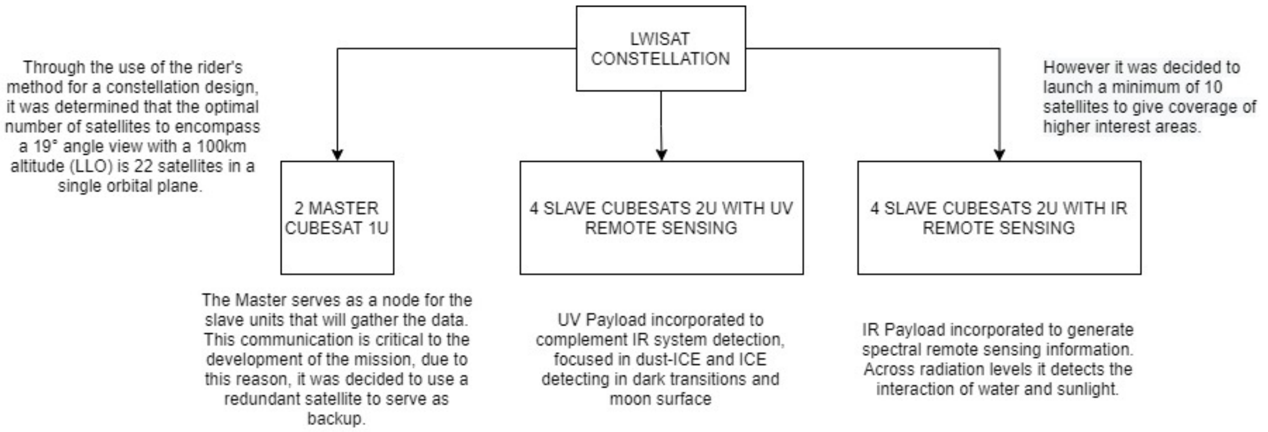
General Objective:
Develop a remote sensing water index supplied by a nano-satellite constellation in a lunar orbit

Specific Objectives:

- Determine the lunar area for water measurement.
- Define spatial and temporal resolution to fulfill scientific needs
- Generate a high-quality spectral band diagrams of different potential water deposits
- Provide databases to support deep space exploration by other missions about water resource searching on the moon's surface.

Concept of operations including orbital design.
Developing a constellation has its benefits, such as: precision. Having satellites with different functions working collaboratively, will provide precise and exact information about the Lunar Water Index. Another advantage is the increased area coverage; there is more accuracy in the data as there are several satellites focused on analysing common areas.

Figure 1. LWISAT constellation description

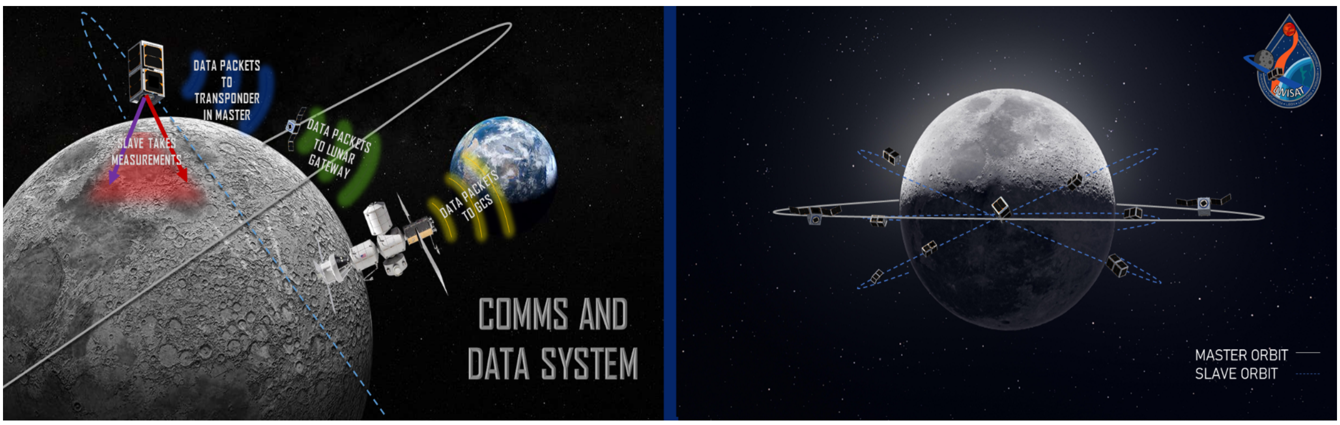


This mission will be focused on the south pole of the Moon, ($1250km^2$)[3], due to its extreme temperature and the abundance of hydrogen located in the poles [5],[6]. For the trajectory of the Delta-V, it depends on the launch location and its launcher, so it presents a small variation range. However an approximation depending on the type of mission that is projected, the Delta-V ranges between 3.5 km/s to 4 km/s, with a difference range of 0.5 km/s.

This mission is going to follow Artemis' timeline so the launch dates may vary. This is a high cost space mission, not only because of the goal that it wants to achieve but also because of the innovation of this mission. Because of this goal, it is expected for this constellation to operate for at least 2 years in order to gather enough data to generate the lunar water index. The cost range for these constellations falls between 50 to 100 million dollars.

The LWISAT constellation will be deployed into LLO from the Lunar Orbital Gateway (LOP-G). At launch, the whole constellation will be turned off. With the usage of deployment springs, the cubesats will be activated. This will happen when the constellation is in space [7].

Figure 2. Concept of operations of the system



Key Performance Parameters
In this section technical parameters are described to carry out the mission.

Table 1. Parameters & Specifications for electrical and structure component

Subsystem	Parameters & Specifications
Electrical Power System	Voltage, Current and Temperature Monitoring. State of charge above 20% at all times.
Comms	RF communications (using X-band). Frame and data package count of at least 10,000 packages of information. Voltage and current in operational levels at all times.
ADCS	Star Tracker for attitude determination. Reaction Wheels for attitude control. High accuracy Gyroscope XYZ (+- 0.5°/s). System current in operational levels at all times.
Structure	Manufacturing process consideration to ensure proper tolerances. (+- 0.1 mm)

*Electrical variables must be in line with datasheets and calculation specifications

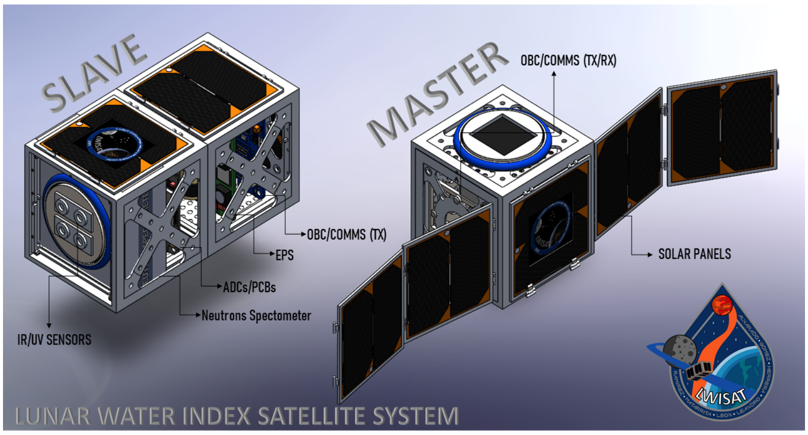
Table 2: Materials of choice for each subsystem

Subsystem	Materials
Structure	Al 7075, Al 5052
Electrical Power	GaAs Panels, Li-ion Batteries
Thermal Protection	Silicone and polyurethane
Radiation Protection	MLI blankets conformed by kapton and metalized PET

Lastly, the data achievement of LWISAT, is to obtain the spectral information in a spatial resolution of approximately 15 m, reaching the best quality on this type of remote sensing systems. To reach that, each LWISAT satellite must have the temporal resolution appropriate to attain the system in the most rigorous way.

Space Segment Description
Firstly, the slaves take the information of the moon measuring with its sensors, and then carry out the scientific process and remote sensing. Then, the data is sent to the Masters [8],[9] using it as a base. An adjusted version of the electronic design of the transponder on board the PROCYON for communication in deep space, adapted to the envelope and the power requirements of LWISAT. Afterwards, the masters send the information to the LOP-G (Lunar Orbital Gateway) and finally, the pertinent space agency receives this data, they decide if they send the information to a GCS (Ground Communication Station) or they keep it in the same LOP-G. These communications are carried out through a solid-state power amplifier and X-band transponder (8.2 and 12.4 GHz for deep space exploration probes).

Figure 3: CubeSat Design Concept



On-board Instruments

LWISAT will work with an UV-IR remote sensing system. The support of this type of instruments is going to allow for the detecting of the water refractive index on the moon surface -on the light and non-light parts- and determinate the range-change of natural light conditions. For this hybrid optical type of measurement, LWISAT needs the following requirements for 15m^2 spatial resolution according to ground sample distances.

Lighting Surface: Infrared Spectrometer capable to penetrate moon surface with a wavelength from 0.60 **μ**m to 3.00 **μ**m for the water recognition deposits.

Range-Change surface: An UV-IR hybrid Deuteron-Halogen spectrometer, capable of detecting and determining water index on liquid deposits and dust-ice reaction with U-V radiation. Minimum D-H Spectrometer requires 175-3300 nm.

Dark Surface: A full UV laser with a spectrometer in-system capable of detecting dust-ice and ice deposits on the moon surface, in order to map water in post-processing.

Table 3. Instruments of choice, range and information gather for different regions

Remote sensing region	Optical Instrument proposed	Detecting	Wave range
Light surface	Infrared Spectrometer	Liquid water	0.60-300 $/\mu m.$
Range-Change surface	UV-IR Hybrid deuteron-halogen spectrometer	Liquid Water/Dust-ice	175-33000 nm
Dark surface	Full UV spectrometer	Water/Dust-ice/Ice	not specified yet

Data Handling

After collecting the analog information given by the spectrometer, it will pass the information to the input interface. There, it is going to be organized and processed by the microcomputer inside of the cubesat. Regarding the ADCS, it will use a Star Tracker which uses celestial bodies maps to determine the attitude and the Reaction Wheels to correct and control this same attitude. After the data is delivered to the LOP-G, it will be post processed to generate the index. This data will be shared with various space agencies in order to develop a baseline for future missions not only on the moon, but for interplanetary travel.

Additional Considerations

Satellites must endure extreme conditions not solely when in space but also during its launch. These conditions range from vibrations, acceleration, humidity, temperature, radiation, and space debris [10], [11]. Taking this into consideration, the CubeSats must be designed, manufactured and assembled in a way so that it can achieve long-term durability, high thermal resistance, and high mechanical resistances.

Implementation Plan

This mission will be partnered primarily with *NASA* and supported by *JAXA*. These two agencies will provide the financing and development of an informatics operating system that will offer access to first-hand and premium data for the quantification and location of the water reserves that aid LWISAT. This will work as an essential point of cooperation for missions such as ISRU and the Lunar Flashlight mission for the Artemis program.

Institutions like *Space System Laboratory (SETECLab), Asociación Centroamericana de Aeronáutica y el Espacio (ACAE), Tecnológico de Costa Rica, TECspace, Universidad de Costa Rica, Universidad del Valle de Guatemala (UVG),* and *Invenio* will help with consulting and support. The *Agencia Espacial Costarricense (AEC)* is essential for the communication and connection of LWISAT to other agencies. The LWISAT Team will be in charge of the Engineering Systems Development. To implement this project, it is planned to use the second payload of the SLS in the Artemis program, as it is ideal for missions in deep space.

Our mission is in phase with the timeline of the Artemis mission, specifically Artemis 2. LWISAT will begin to work, waiting for Artemis 3 where results are already expected and give support to the following missions. Likewise, LWISAT results are subject to NASA's mission timeline, which gives a period of time of approximately 6 years between 2024 to 2030.

References

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