Power and Thermal Characterization of a Lunar Weather Station and Laser Space Communications Network Node. A.S. Gileadi, San Jose State University, Avraham.Gileadi@sjsu.edu, San Jose, CA, 95125.

Introduction: With the advent of new launch capabilities and new crewed missions, it is expected that surface-based mission concepts will change significantly, especially for the Moon. Deep space communications infrastructure is about to see an expansion in capabilities and technology. A new emphasis on optical communications is driven by the increased bandwidth needs of scientific missions. Communication systems that can receive, store, and retransmit data are needed to support a system that is inherently intermittent. The equipment proposed by this paper stands where the new realities meet. A lunar communications station would require continuous power for operations and would be installed near significant lunar infrastructure. Dual optical modules would provide communications relay capabilities in a predictable location with good visibility. Scientific equipment such as seismometers could also be included, enabling advanced warning of potential ejecta hazards from nearby meteoroid impacts. Any long-duration lunar system needing to sustain operation through the long and cold lunar nights requires an innovative approach. This project compares the use of regolith as thermal insulation for temperature sensitive components with a more conventional insulation approach.

For the first time in fifty years, the world is once again pursuing crewed space missions outside of low Earth orbit. With the advent of new launch systems including SLS, Starship and others, as well as a renewed public interest in space, the options for research opportunities and capital investment available to students and entrepreneurs appears on track to reach an all-time high. These new systems bring with them new capabilities, expanding the envelope of what kinds of missions are possible. At the same time, the development of enabling technologies that will be used for space missions have also been advancing at a rapid pace.

Free-space optical communications (or laser communications) have already demonstrated deep-space downlink speeds as high as 622 Mbps with an uplink speed as fast as 20 Mbps, and come with a significant reduction in size, weight, and power requirements [1]. There are already plans to augment NASA's Deep Space Network (DSN) with laser communications modules [2]. This technology also has scientific research potential as the architecture could be used to significantly improve the accuracy of laser ranging of the Moon [3]. Currently, ranging of the Moon is performed using high powered lasers from terrestrial observatories and retroreflectors on the lunar surface, an effort made significantly harder because of the refraction from Earth's atmosphere. When using a Moon-based system, laser light would only have to transit the atmosphere once, a substantial improvement. The likelihood of installation of a laser communications system on the lunar surface seems high considering the plans NASA has for the Moon.

NASA has plans to establish an outpost on the Moon that can be used as a proving ground for technologies to be used in deep-space exploration. These plans include extended duration missions on the lunar surface. One of the hazards that astronauts will face on the lunar surface will come from meteoroid strikes. Meteoroids strike the lunar surface with enough momentum to kick up ejecta that can land far from the impact side. As the Moon has little gravity or atmosphere, the hazards from ejecta can be as serious as those posed by the meteoroids themselves. Currently, the primary method of determining the location of impacts uses terrestrial based telescopes that look for bright flashes on the lunar surface, an indication of a meteoroid impact [4]. An improvement on this method would be to station multiple satellites in lunar orbit to look for impact flashes. Observations could be used to provide early warning of hazards from ejecta to astronauts and facilities. A further improvement would be to station multiple seismometers on the lunar surface to triangulate the exact size and location of impacts. The technologies and methods for surfaced based seismometers have been studied extensively in the context of a lunar geophysical network [5]. Significant meteoroid strikes are happening all the time on the Moon [4]. Together with data from lunar orbiters, a seismometer network can provide high accuracy ejecta "weather" forecasts to countries conducting lunar operations.

Despite the advances in technology, the cost to deliver payloads to the lunar surface is likely to remain a primary mission selection consideration. The system studied in this thesis project addresses cost in the following ways. It combines two systems that are likely to be in high demand on the Moon in the future: an optical communications network node and a geophysical network node. The result is a reduction in cost, size, and complexity as significant components can be shared between the systems. Furthermore, the system is intended to be delivered as cargo as a part of a crewed mission, eliminating the need for a dedicated launcher and lander. This last consideration also reduces risks associated with proper installation of the seismometers.

The primary problems considered by this paper are the cold temperatures, and the availability of sunlight and their effect on permanently installed hardware. Hardware installed in the mid and low latitudes will have to survive for 336 hours (14 days) without sunlight whereas hardware installed at the south pole will only have to endure for 60-100 hours without sunlight [6]. It follows that all landing sites for planned crewed missions to the lunar surface will be at the south pole [7], so thermal and power considerations will be evaluated for this environment. Because a robust communications and seismometer network will require multiple installations, the environment of the low / mid-latitudes will also be considered. It is also a hope that the knowledge gained from this project can translate to the development of continuously inhabited lunar human habitation systems. Understanding the power and thermal requirements for hardware to survive for long durations on the lunar surface will be an important consideration for the hardware proposed by this paper, and for any long-duration extra-terrestrial surface installation.

References:

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