The Importance of Lunar Telecommunications and its Use in Lunar Exploration

Kieron von Buchstab[a], Joshua Milam[b]

[a] *Faculty of Engineering, Carleton University, 1125 Colonel By Drive, Ottawa, Ontario, Canada K1S 5B6, kieronvonbuchstab@cmail.carleton.ca*
[b] *Faculty of Engineering, Carleton University, 1125 Colonel By Drive, Ottawa, Ontario, Canada K1S 5B6, joshuamilam@cmail.carleton.ca*

Abstract

In the near future, man is expected to begin civilising the moon. With this comes a plethora of hazards and considerations which must be accounted for to ensure the safety of lunar colonisers and their equipment. Most notable of these considerations are navigation, communication, and space weather prediction. All of these will require a telecommunication infrastructure to operate adequately. Navigation will require surface landers to communicate with lunar orbiters to navigate the surface of the moon, communication infrastructure will have to be established to ensure adequate communication beyond Line Of Sight (LOS), and space weather prediction will have to be implemented to protect lunar colonisers from solar radiation.

Students at Carleton University have been working on a Commercial Off The Shelf (COTS) ground station for the past few years. Due to the COTS nature of these ground stations, they are relatively cheap to produce. On top of this, the ground stations are relatively small in comparison to other ground stations, and are easily deployable. Due to the low manufacturing cost of these ground stations, they can be subject to heavy testing for a fraction of the cost of a typical ground station. This makes them good subjects for experimental and innovative testing. As well, due to their small volumetric footprint, multiple ground stations could be deployed on a single mission to the moon which would make them good subjects for construction of the lunar network.

With an array of ground stations on the lunar surface, one would be able to set up navigation systems and communication systems. Adequate communication infrastructure will allow communication beyond the LOS for use in exploring the lunar surface over long distances, and navigation systems will provide data for use in orbit determination, surface navigation, and precision landing of spacecraft.

It is clear that telecommunication infrastructure will be important for lunar colonists and future lunar civilizations. This paper aims to explore the constraints imposed on future lunar telecommunication systems, proposed testing of lunar ground stations and communication systems.

Acronyms/Abbreviations

Global Positioning System (GPS)
In Situ Resource Utilisation (ISRU)
Line Of Sight (LOS)
Low Frequency (LF)
Very Low Frequency (VLF)
High Frequency (HF)
Non-Line-Of-Sight (NLOS)
Commercial Off The Shelf (COTS)

1. Introduction

In the past decade, interest in lunar colonisation has become ever prevalent. With NASA going back to the moon in 2024 with the Artemis program and countless international landers being deployed on the lunar surface, the moon seems to be at the forefront of space exploration. While this is ever interesting, a lot of research is still underway concerning all aspects of lunar deployment and long term lunar colonisation. One area that lacks much research is the use and deployment of telecommunication systems on the lunar surface. This paper aims to explore multiple aspects of lunar telecommunications including current hazards faced by lunar colonists and how telecommunications can remedy them. First this paper will discuss the current risks associated with human inhabitants on the moon. Next it will discuss how telecommunication systems can aid in resolving these problems, and finally this paper will discuss the low cost ground stations being built at Carleton University and how they are being designed and tested to stand up to the harsh lunar environment.

2. Lunar Colony Constraints

The first lunar colonists will experience many firsts for human civilization. The colonists will also encounter various survival obstacles that will need to be overcome. Telecommunications can meet some of the lunar colonists' needs by providing information about solar radiation, location/abundance of water ice and navigational information via a lunar Global Positioning System (GPS).

Solar radiation is dangerous and can pose serious health risks to humans [1]. Thus, it will be important for lunar colonists to have accurate information regarding solar radiation levels at the Moon. Lunar satellites could be able to take solar radiation measurements and transmit the data down to lunar ground stations where colonists could access and interpret the measurements. From there, appropriate measures could be taken to mitigate. Human risk.

Water ice was first confirmed on the moon in mid 2018 by India's Chandrayaan- satellite [2]. The significance of water present on the Moon is immense for human lunar exploration. Water ice would enable lunar colonists to perform In Situ Resource Utilisation

(ISRU) which would enable local production of potable water, rocket fuel/oxidizer and gaseous oxygen for habitats [3]. The aforementioned resources are paramount for the success and stability of the first lunar colonies. Lunar ground stations would be able to transmit the location and abundance of ice water which would enable lunar colonists to perform the critical ISRU tasks mentioned above.

On Earth, we take for granted the navigational technologies that allow us to traverse our planet, whether it be in the air, over the ground or across the water. The system that allows humans to navigate successfully is GPS. The first lunar colonists will likely need a GPS similar to Earth's but tailored to the characteristics of the Moon. It will be critical to implement a lunar GPS because it would enable lunar colonists to navigate to locations of scientific importance and resource abundance. As well, it would allow lunar colonists to search for locations in which future development could occur. Lunar ground stations would allow for the receipt of navigational information provided by orbiting lunar GPS satellites, which would enable the above objectives to be successfully completed.

The needs faced by the first lunar colonists will likely be complex and unlike any of the needs faced on Earth. Telecommunications could provide some of the requirements mandated by enabling the receipt of data pertaining to solar radiation, location/abundance of water ice and navigational telemetry.

3. Solutions to Lunar Colony Constraints

As man ventures towards lunar colonisation, a large factor of success is how well man will be able to adapt to the lunar environment. There are many constraints imposed in colonising a moon. For one, without a dedicated satellite network, communication beyond line of sight (LOS) would be difficult. This would pose problems for lunar explorers looking to explore the bounds of the lunar surface. On top of this, without a dedicated satellite network simply navigating the lunar surface would be difficult. Establishing a ground station network on the lunar surface would help solve all of these problems. A ground station network is important for lunar exercises as they would provide communication systems and navigation systems.

Speaking first of communication, a large problem with communication networks on the lunar surface is that transmission beyond LOS is difficult without a satellite network. Communication beyond LOS is important for a variety of reasons. For one, many have proposed the use of autonomous robots to carry out operations on the lunar surface [4]. To do this, beacons would be required to triangulate robot positions such that their location could be accounted for. On top of this, the use of manual robots is being considered [4]. To operate these robots remotely over long distances would require telecommunication beyond LOS. NASA has investigated the use of low frequency (LF) and very low frequency (VLF) signals on the lunar surface [4]. Due to the electrical conductivity of the moon, these signals follow the curvature of the lunar surface and transmit beyond the LOS [4]. This allows for wide-range navigation beyond the LOS. In theory, two beacons could cover hundreds of kilometres and less than 10 would be required to cover an entire lunar hemisphere [4]. In comparison, hundreds of high frequency (HF) beacons would be required for the same task [4]. On top of this, LF beacons are typically more robust and reliable than HF beacons [4]. These communications are also important for astronauts. Those exploring lava tubes have no guarantee to be able to communicate with orbiting satellites, due to their position [4]. For tasks like this, non-line-of-sight (NLOS) beacons would be required, transmitting LF signals [4].

While communication is important, another large contributor to success on the lunar surface is the implementation of navigation systems. A large use case for ground stations would be in orbit determination for lunar satellites [5]. Not only this, ground stations would be useful in position determination for descending spacecraft. On top of this, these beacons could act as control towers to provide takeoff and ascent information to departing spacecraft. With these beacons in place, precision landing could be implemented to improve spacecraft landing procedures [5]. Currently spacecraft landing is done with sensors onboard the descending vehicle [5]. With lunar ground stations, relative landing site information could be provided much earlier in the descent trajectory than the vehicle would be able to gather with only its sensors [5].

Communication and navigation systems are of utmost importance for success on the lunar surface. Without a dedicated satellite network, navigating the lunar terrain may prove difficult. This would make it difficult for lunar explorers to explore the bounds of the lunar surface. On top of this, communication would be restricted to LOS communications. By establishing a ground station network one could solve these problems. Potentially the largest factor of success in colonising the lunar surface will be how well man is able to adapt to the lunar environment but with a dedicated ground station network it may not be so hard.

4. Telecommunication Hazards

Over the past few years, students at Carleton University have been developing a Commercial Off The Shelf (COTS) ground station. The students have been developing this capability to experiment with the receipt of satellite telemetry. The very nature of developing a COTS ground station is advantageous because it enables a low production cost, low volumetric footprint and ease of deployment. One way in which the production cost of the ground station is kept low is by using additive manufacturing. More specifically, 3D printing is the type of additive manufacturing that has been widely deployed in the development of the ground station. From a cost perspective, 3D printing is advantageous because of the relatively inexpensive cost incurred, approximately $30/kg. With respect to test/evaluation schedules, a low production cost enables the ground station to undergo rigorous testing, including tests to failure of certain subsystems. Additionally, the low volumetric footprint of the ground station mandates that many of the mechanical systems must be relatively small in size. In many cases, these systems are too small to be machined in a reasonable amount of time and money. Our ground station is 597 mm wide, 434.6 mm high and 192.1 mm deep. This is desirable because the small size allows for maintenance without the need for equipment such as ladders or scaffolding. Additionally, the small size of the ground station allows for a one person maintenance crew, enabling a minimal, yet sufficient amount, of resources to be utilised. Another major aspect of having a ground station with a small volumetric footprint is ease of deployment. The ground station can be assembled/disassembled in a short time frame (approximately 8 minutes) with two person crew. Combined, these factors allow the ground station to be transportable and simple in deployment. The essence of developing a COTS ground station is desirable because it allows for a low production cost, low volumetric footprint and easy deployment.

7. Conclusion

In the near future, man is expected to colonise the moon. This paper first discussed the environmental problems faced by future lunar colonists in trying to colonise the moon, and then how telecommunication systems will solve these problems. Following this, the development of Carleton University's low cost ground station design was discussed. Despite the fact that much research is being done into lunar colonisation, telecommunication research is somewhat lacking in this perspective. With increasing programs and missions heading to the lunar surface, more research akin to this paper must be performed to ensure adequate telecommunication deployment and protocols within the lunar environment.

References

[1] G. M. Garnacho Saucedo, R. Salido Vallejo, and J. C. Moreno Giménez, "[Effects of solar radiation and an update on photoprotection]," *An Pediatr (Engl Ed)*, vol. 92, no. 6, p. 377.e1-377.e9, Jun. 2020, doi: 10.1016/j.anpedi.2020.04.014.

[2] A. Tabor, "Ice Confirmed at the Moon's Poles," *NASA*, Aug. 17, 2018. http://www.nasa.gov/feature/ames/ice-confirmed-at-the-moon-s-poles (accessed Sep. 17, 2023).

[3] "In Situ Resource Utilization - an overview | ScienceDirect Topics." https://www.sciencedirect.com/topics/earth-and-planetary-sciences/in-situ-resource-utilization (accessed Sep. 17, 2023).

[4] W. J. Waltz, M. L. Grande, and R. W. Moses, "Autonomous System Operations for Lunar Safe Haven Establishment and Sustainment," in *AIAA SCITECH 2022 Forum*, San Diego, CA & Virtual: American Institute of Aeronautics and Astronautics, Jan. 2022. doi: 10.2514/6.2022-2075.

[5] E. Anzalone, A. Iyer, and T. Statham, "Use of Navigation Beacons to Support Lunar Vehicle Operations," in *2020 IEEE Aerospace Conference*, Big Sky, MT, USA: IEEE, Mar. 2020, pp. 1–13. doi: 10.1109/AERO47225.2020.9172663.