Lunar Optical Communications[1]

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Summary

Numerous studies have shown that NASA's Deep Space Network (DSN) is woefully inadequate to support the current pace of space exploration [1]. Proposals are on the table for extensive infrastructure build-out using RF communications, which is ultimately bandwidth constrained. Optical communication offers unregulated, near-infinite bandwidth that can easily support the needs of humans at the Moon and beyond. Although not part of the proposed lunar network architecture, optical communication systems should be considered; these systems are operational now, quickly proliferating near earth space (e.g. StarLink), and offer very high bandwidths.

Lunar optical communication was first successfully demonstrated in 2013 by NASA's Lunar Laser Communications Demonstration (LLCD) between the LADEE satellite orbiting the moon and three earth-based ground stations [2]. This demo heavily leveraged Commercial Off The Shelf (COTS) 1.5 μm optical components that are widely-available from telecom suppliers. The comm signal format used for LLCD was Pulse Position Modulation (PPM) with a ½-rate convolutional code and it operated error-free at up to 622 Mbps for the return link and 20 Mbps for the forward link. One of the ground stations, White Sands Test Facility (WSTF) in New Mexico, achieved a real-time comm link with better than 1 photon per bit efficiency. The physical link was also closed by ground stations with at JPL's Table Mountain Facility (TMF) in California and ESA's Optical Ground Station (OGS) at Tenerife.

After this demonstration, NASA and other non-U.S. space agencies embarked on deploying optical comm systems for near-earth. Several such systems, such as NASA's Laser Communications Relay Demonstration (LCRD) [3] and ESA's European Data Relay System (EDRS) [4], are operating today. Industry has also caught on and there are several near-earth optical comm systems in service, including SpaceX's StarLink. Optical comm standards have also emerged, including some proposed by the Consultative Committee for Space Data Systems (CCSDS). CCSDS optical comm standards include a high photon efficiency standard using PPM [5] for Lunar and deep space applications, which has been successfully used for the Deep Space Optical Communications (DSOC) program [6].

The upcoming Orion Artemis II Optical Communications (O2O) system will provide operational 1.5 μm optical comm using CCSDS-compatible PPM waveforms for the first crewed Artemis mission [7].

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The system will provide up to 250 Mbps return link and 20 Mbps forward link from/to the Moon next year and will support live video during the mission as well as other applications. O2O will employ optical ground stations located at WSTF and TMF to form the Earth end of the link. Additional ground stations are being considered to support this mission and build out the optical ground station infrastructure.

Optical comm is technologically ready to make a huge impact on deep space comm networks, offering a way to aggregate local RF data over high bandwidth optical trunks and provide high data rate services for humans in deep space. Demonstrations are behind us and operational syste4ms are here now. The terrestrial telecom sector provides a pipeline of COTS components and sub-systems from which to build systems. Industry is now offering off-the-shelf, space-qualified optical comm terminals for near earth systems, some of which could be leveraged or modified to be compatible with longer range links. It is time that this technology be considered as a part of the Lunar and deep space comm architectures.

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