# Space Mission Preliminary Analysis

Lunar Far Side Radio Communications

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## Abstract

Report discusses the possibility of communicating with lunar far side using relay satellite positioned in libration points.

**Introduction**

In 1960's during the Apollo program, six successful Lunar landing missions were dedicated for studying properties of our natural satellite. NASA astronaut and geologist Harrison Schmitt, proposed for Apollo 17, the objective to visit Tsiolkovsky Crater on far side of the Moon. One of the reasons for abandoning this ambitious mission goal is due the impossibility of Earth-Moon radio communication on the far side.(Kenneth Silber (2009). Down to Earth: The Apollo Moon Missions That Never Were. *Scientific American*)

Absence of terrestrial radio waves propagation on Lunar far side certainly is a challenge for any mission, but it may also be advantage for radio astronomy as noted in Wikipedia:

"Because the far side of the Moon is shielded from radio transmissions from the Earth, it is considered a good location for placing radio telescopes for use by astronomers. Small, bowl-shaped craters provide a natural formation for a stationary telescope similar to Arecibo in Puerto Rico." (Wikipedia (2016). Far side of the Moon.)

Interest for Lunar mining is on increase in China, which have already announced further missions that would explore the far side. China's plan for communication is Lagrange point transponder satellite rather than in Lunar orbit.(The Conversation. 2016. China's plan to be first to far side of the moon could unveil inner lunar secrets)

Technical challenge in obtaining effective communication depends primarily radio frequency output power, antenna gain and attitude of the spacecraft. Other variables the should be taken into account are carrier frequencies and modulation techniques to be used for communications. Historically for purpose of Earth-Moon communication during the Apollo program, Unified S-Band was used for transmission of “1) voice 2) telemetry 3) television 4) biomedical data 5) ranging” (Peltzer, K. E, 1966) as discussed in NASA technical paper Apollo Unified S-Band System, the reuse of this already developed and in-mission tested technology is probable. Aside the attitude control, which will ensure that antennas are always pointed into desired direction, station keeping and compensations of orbital perturbations should also be considered. The attitude control must be precise enough to enable orientation of antennas, this implies freedom over three axis, pitch, roll and yaw. The three degrees of freedom can be obtained using twelve UDMH monopropellant thrusters. Aside for rotation the thruster can also provide power for translation maneuvers where small changes in velocity is needed. The sensitive radio equipment is prone to temperature changes so thermal radiators would be required to dissipate absorbed solar energy via radiation to space, this is especially important for L4 or L5 satellites because of their excessive exposure to Sun. For Lagrange 2 thermal radiation is also important because the satellite is exposed to long periods of lunar nights and days, so the heating of radio components also must take place during the lunar nights. If communication between the relay satellite and spacecraft orbiting the Moon is required, Doppler frequency shift is another variable that can cause loss of performance. If the satellite is to provide communication with radio telescope, the interference of communication channel with radio observation poses a problem. The way to overcome this is by implementing selective band filters on the telescope. By using narrower band for communication the less obtrusive will it be for the radio observation. As a joint mission, it is encouraged for spacecraft to be equipped with other scientific instruments, such as optical and infrared devices for surveying the far side, measuring magnitude of lunar albedo and other.

During the Apollo program there was a proposal for communicating with far side by in-mission deployed transponder satellite or even with the spent S-IVb stage of Saturn V rocket which would serve that purpose before eventually impacting lunar surface.

The communication of Earth to the far side of the Moon would take place across two transponder satellites positioned on Lagrange points in Earth-Moon system. Each of these satellites is carrying radio transponder consisting of the: receiving antenna, input filter, low noise amplifier, frequency translator, output filter and transmission antenna. Putting the satellite in Halo orbit around Lagrange points will ensure fixed positions of Earth and Moon with the respect to the satellite. First satellite located at either L4 or L5 would ensure communication from Earth to the second satellite located on L2 which would finally transpond data to the far side. Point to point far side surface communication could also be achieved through L2 satellite. For communication with Earth high gain directional antenna is prefered, while for point to point far side communication omni directional antenna is sufficient because of the proximity of the L2 point with respect to the lunar surface and the wide area that needs to be covered. Satellites on Lagrange points have previously been used and still are, as shown in SOHO fact sheet: “SOHO moves around the Sun in step with the Earth, by slowly orbiting around the First Lagrangian

Point (L1), where the combined gravity of the Earth and Sun keep SOHO in an orbit locked to the Earth - Sun line."(SOHO Fact Sheet, ESA). Progression of the mission would follow from launch to the LEO parking orbit, followed by TLI burn to put the spacecraft on the trajectory intersecting desired Lagrange point and finally end with the retrograde, halo orbit insertion maneuver. For launch operations, a heavy launch vehicle, such as Delta IV Heavy would be sufficient to lift the satellite to LEO parking orbit at altitude of 200 kilometers, together with the additional propulsion stage that would execute the TLI burn. After the TLI the propulsion stage would be jettison, and the spacecraft would continue alone on its cislunar trajectory toward Lagrange 4. Two of such launches would be necessary to setup a network of satellites required for communication. The usual way to transferring spacecraft to the Moon/Lunar Lagrange point is Hohmann transfer, which is previously described, however there are are other alternatives such as three body low thrust transfers discussed in paper (Kyle Wolma, The Use of Lagrange Points for Lunar Exploration, Settlement, and Support). The low thrust transfer may be used to reduce the total weight of the upper stage. The method of such way of travel is progressive firing of thrusters at perigee to gradually increase semi major axis or orbit until it reaches desired position.

Redundancy should also be considered as the future human exploration missions would rely on such satellite and loss of signal and lack of contingency may prove fatal for the crew. The length of the mission on a far side must end before the expected time of service of the communication satellites, or if permanent human settlement is planned that satellites finishing their service must be replaced with their newer versions in order to maintain the link. For the L2 point satellite the major problem is the power supply as this Lagrange point is introduced to the long Lunar nights, to overcome this issue satellite should be put into halo orbit around the point itself. This will ensure that solar arrays get enough power satellite operation and for the charging of the batteries. Such motion across halo orbit on L2 could also provide certain locations where satellite is in good view of Earth and thus communication with far side would be possible without L4 satellite. As for case where the L2 satellite is completely eclipsed by the Moon with respect to Earth. L4 or L5 transponders would be necessary.

## Alternatives

Possible alternative to this approach, but far more costly and ambitious, a long term project, could be near side Earth-directed radio station connected with far side via telecommunication cable, similarly what today on Earth exists as a submarine optical cables. Benefit of such lunar ground network is because during the same mission of laying a communication cable, a power cable could also be laid. Two solar array power stations of opposing sides of the Moon could provide power to each other during long lunar nights. Theoretically maximum length of cable connecting the stations would be half of its equatorial circumference which is 5,457 kilometers, neglecting the variations of lunar surface.

## Discussion

Nonetheless, interest for far side cannot be disputed, and interest will remain to grow primarily from scientific and economic standpoints the building of the radio telescope and lunar mining, respectively. The sooner the humanity establishes the communication channels to the Moon the sooner the benefits that moon has to offer will be exploited.

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