Libration Point Navigation Concepts Supporting Exploration Vision

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Abstract

Farquhar[1] described several libration point navigation concepts that would appear to support NASA's current exploration vision. One concept is a Lunar Relay Satellite operating in the vicinity of Earth-Moon L2, providing "Earth-to-lunar far-side and long-range surface-to-surface navigation and communications capability." Reference [1] lists several advantages of such a system in comparison to a lunar orbiting relay satellite constellation. Among these are one or two vs. many satellites for coverage, simplified acquisition and tracking due to very low relative motion, much longer contact times, and simpler antenna pointing. An obvious additional advantage of such a system is that uninterrupted links to Earth avoid performing critical maneuvers "in the blind." Another concept described is the use of Earth-Moon L1 for lunar orbit rendezvous, rather than low lunar orbit as was done for Apollo. This rendezvous technique would avoid large plane change and high fuel cost associated with high latitude landing sites and long stay times. Earth-Moon L1 also offers unconstrained launch windows from the lunar surface. Farquhar claims this technique requires only slightly higher fuel cost than low lunar orbit rendezvous for short-stay equatorial landings. Farquhar also describes an Interplanetary Transportation System that would use libration points as terminals for an interplanetary shuttle. This approach would offer increased operational flexibility in terms of launch windows, rendezvous, aborts, etc. in comparison to elliptical orbit transfers. More recently, other works including Folta[3] and Howell[4] have shown that patching together unstable trajectories departing Earth-Moon libration points with stable trajectories approaching planetary libration points may also offer lower overall fuel costs than elliptical orbit transfers. Another concept Farqhuar described was a Deep Space Relay at Earth-Moon L4 and/or L5 that would serve as a high data rate optical navigation and communications relay satellite. The advantages in comparison to a geosynchronous relay are minimal Earth occultation, distance from large noise sources on Earth, easier pointing due to smaller relative velocity, and a large baseline for interferometry if both L4 and L5 are used.

Barton et al.[2] studied the use of GPS for navigation enroute between the earth and the moon. Assuming modest modifications that would improve GPS receiver sensitivity by approximately 10 dB and a high-gain directional receiver antenna, they showed that GPS signals viewed over the earth's limb would support post-translunar injection (TLI) navigation out to about half the lunar distance. They also showed GPS navigation could support a mid-course trim burn for at least several hours after TLI, but if the trim burn

was more than 8 hours after TLI, there was not enough GPS information to estimate the post-burn state. In recent work for a 10 by 50 Earth radius (RE) polar inclination science mission, we have shown that when the side lobes of the GPS satellites' transmit pattern are also considered, as many as three GPS satellites may be visible even at 50 RE, just short of Earth-Moon L1, as Figure 1 shows, and at least one GPS satellite is available for much of the apogee region.

In this work, we examine the navigation accuracy achievable for an L1 lunar rendezvous scenario, see Figure 2, from a lunar navigation infrastructure based on the concepts described by Farquhar and Barton, with possible augmentation by geosynchronous tracking and data relay satellites. Among many issues with any lunar navigation infrastructure is the source of ephemeris information for the space segment. Therefore, we also examine the use of autonomous onboard navigation for the various relay satellite concepts.

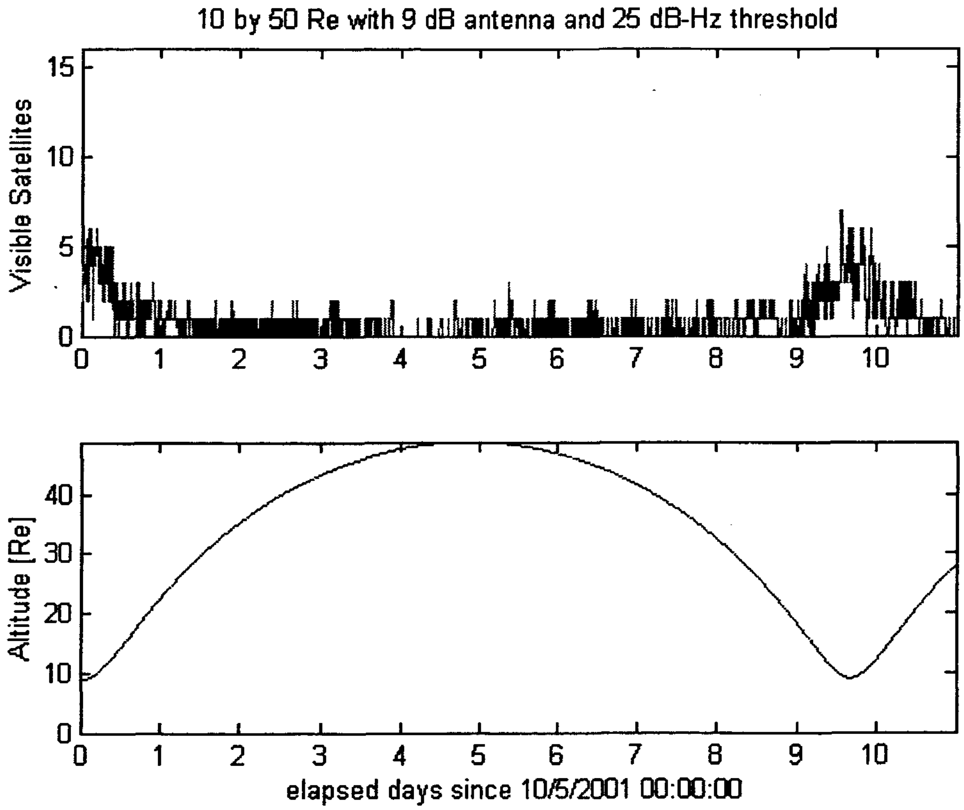

Figure 1: GPS visibility, assuming modest improvements in receiver sensitivity and high-gain directional receiver antenna.

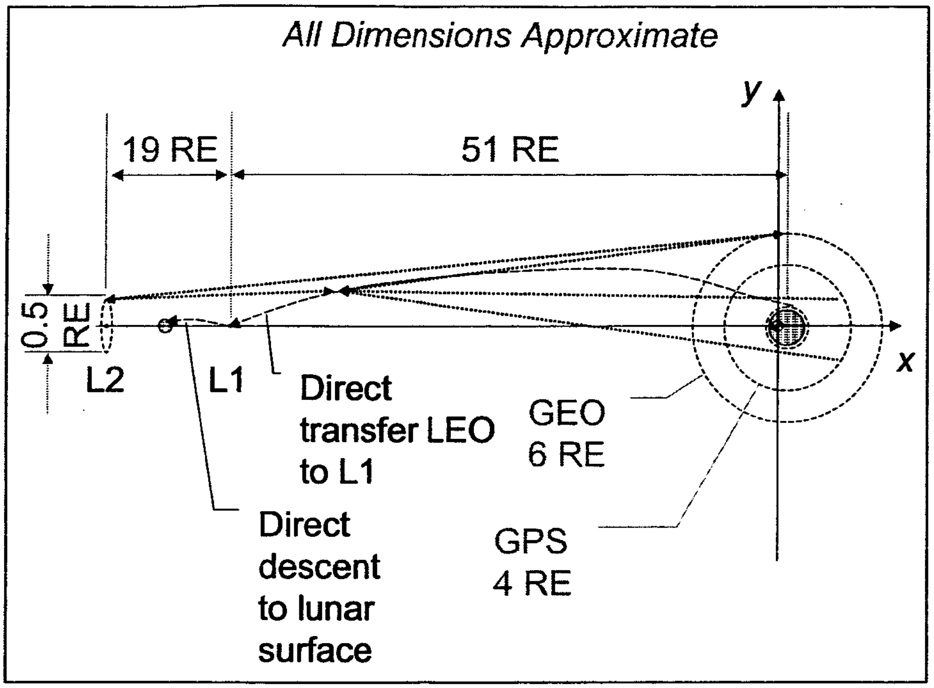

Figure 2: A lunar rendezvous scenario showing Cislunar transfer, L_1 orbit position, Moon, and L_2 orbit .

References

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