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SMALLSAT NAVIGATION VIA THE DEEP SPACE NETWORK, PART I: LUNAR TRANSPORT

Abstract

Launch costs present one of the greatest barriers to access to space, with large launch vehicles required for even relatively modest payload masses. On the other hand, spacecraft component miniaturization and the standardized CubeSat form factor have led to a renewed interest in smaller, more agile missions. Couple this interest with the proliferation of rideshare opportunities easing access to orbit for smaller payloads and it's no wonder that we have seen an explosion in the number of operational SmallSats in Earth orbit. Naturally, interest in SmallSat capabilities extends outside of low Earth orbit, with over ten SmallSats manifested as secondary payloads on the first SLS launch and the MarCO mission ride-sharing with InSIGHT. As with larger missions, near-term deep-space SmallSats will more than likely rely on telecommunications and tracking via NASA's Deep Space Network (DSN) or similar facilities. Given the predicted growth in the number of deep space missions, effective use of DSN resources will be more critical than ever, even with Multiple Spacecraft Per Antenna (MSPA) capability.

As a general rule, SmallSat missions are cost effective because rideshare opportunities are less expensive than dedicated launches and a common form factor encourages the development of compatible off-the-shelf components. A common misconception, however, is that these cost savings necessarily extend to all aspects of the mission, including operations and telecommunications. For example, costs for Mission Design and Navigation (MDNav) are directly tied to mission complexity as well as navigation requirements and are nearly insensitive to the actual size of the spacecraft. In fact, it is entirely conceivable that a SmallSat mission could levy more stringent MDNav requirements than a mission with a larger spacecraft. Accordingly, any savings in operational cost or DSN use will likely arise from careful assessment of the mission class, relevant risk posture, and any associated impacts on operational requirements. In particular, SmallSat missions will need to rely on increased use of one-way tracking with stricter limitations on two-way contact with the DSN. While all missions will eventually develop their own detailed navigation plans, a common set of references is needed to support SmallSat missions, especially in the early development phases. Our investigation will provide this initial survey of expected navigation performance for DSN radiometric data types, from traditional two-way Doppler and ranging capabilities to one-way equivalents, including delta-differential one-way range. In the first part of this paper, we examine transport within the Earth-Moon region.