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ALTERNATIVE MISSION CONCEPTS FOR THE EXPLORATION OF OUTER PLANETS USING SMALL SATELLITE SWARMS

Abstract

Interplanetary space exploration has thus far consisted of single, expensive spacecraft missions. Mission costs are particularly high on missions to the outer planets and while invaluable, finite budgets limit our ability to perform extensive and frequent investigations of the planets. Planetary systems such as Jupiter and Saturn provide extremely complex exploration environments with numerous targets of interest. Exploring these targets in addition to the main planet requires multiple fly-bys and long mission timelines. In LEO, CubeSats have changed the exploration paradigm, offering a fast and low cost alternative to traditional space vehicles. This new mission development philosophy has the potential to significantly change the economics of interplanetary exploration and a number of missions are being developed to utilize CubeSat class spacecraft beyond earth orbit (e.g., NEOScout, LunaH-Map, Marco and BioSentinel).

This paper takes the CubeSat philosophical approach one step further by investigating the potential for small satellite swarms to provide extensive studies of the Saturn system. To do this, an architecture is developed to best replicate the Cassini Primary Mission science objectives using swarms of CubeSats. Cassini was chosen because of its complexity and it defines a well-understood baseline to compare against. The paper outlines the overall mission architecture developed and investigates the feasibility of the architecture in terms of mass, delta-V, link and power budgets, and sensor technology. The number of swarms needed, number of CubeSats per swarm, size of the CubeSats and overall science output are all presented. Aside from the primary objectives, additional science objectives beyond Cassini's capabilities are also proposed. These new mission objectives result from recent developments in sensor technology and the ability for CubeSats to take higher risk maneuvers.

Significant scientific returns can be achieved by the swarm based architecture and the risk tolerance afforded by the utilization of large numbers of low-cost sensor carriers. The results of this investigation are not constrained to Saturn and can be easily translated to other targets such as Jupiter, Uranus, Neptune or the asteroid belt.