Paper ID: 13809
student

SPACE PROPULSION SYMPOSIUM (C4)
Propulsion Technology (3)

Author: Mr. Daniel Guerrant
Colorado Center for Astrodynamics Research, University of Colorado, United States,
daniel.guerrant@colorado.edu

Dr. Dale Lawrence
Colorado Center for Astrodynamics Research, University of Colorado, United States,
dale.lawrence@colorado.edu
Dr. W. Keats Wilkie
NASA LaRC, United States, william.k.wilkie@nasa.gov

DYNAMICS AND CONTROL OF THE HELIOS SOLAR SAIL DEMONSTRATOR

Abstract

The heliogyro is a solar sail architecture that divides the sail into extremely high aspect ratio blades spun about a central hub. Spinning the blades provides centrifugal stiffening and obviates most of the sail support structure, maximizing acceleration. Pitching the blades—similar to a helicopter—provides attitude control and thrust vectoring. Additionally, the blades are stored and unspooled from reels, which greatly simplifies sail storage and deployment, non-trivial problems for folding sails. This allows heliogyros reach the extremely large sizes impossible with other architectures and opens up new classes of missions. Unfortunately, no one has studied the heliogyro in earnest since JPL considered it for a Halley's Comet rendezvous mission in the 1970's.

We propose a heliogyro demonstrator called HELIOS that capitalizes on the growing market of nanosatellite components and ride-share opportunities. Our sail would have six blades 0.8m wide and a 440m diameter yet still fit within the EELV Secondary Payload Adapter (ESPA) envelope. A collaboration between NASA Langley, JPL, and the University of Colorado, our mission concept would launch into LEO or GTO and demonstrate propellant-less orbit raising capability. It could accommodate small Earth science payloads and even utilize the sail as a sensor for charged particles and orbital debris.

Our work to date focuses on the structural dynamics of controlling long, thin blades that have extremely small bending stiffness and damping. We designed a simulation of the single blade dynamics along with a pitch control methods. These damp blade pitch maneuvers in less than ten minutes, well within mission requirements. We have examined this controller's robustness with realistic sensors both analytically and through simulation. We now have a relationship between sensor bandwidth and the blade material damping for closed-loop stability. We are planning experiments with a test article in a vacuum chamber for this summer to verify our conclusions. Furthermore, we have simulated using patches of thin-film electrochromic materials that modulate the local solar pressure for active control torque at the blade tips. By September, we will model the full spacecraft with the hub and all six blades. We plan to present a practical, robust controller capable of damping all structural modes for the entire spacecraft.

This work will alleviate the most significant concerns preventing heliogyro development and pave the way for a flight demonstrator such as HELIOS. From there, heliogyro missions to the entire solar system fall within technical reach and budgetary realities.