ASTRODYNAMICS SYMPOSIUM (C1)
Mission and Constellation Design (5)

Author: Dr. Daniel Grebow
Jet Propulsion Laboratory - California Institute of Technology, United States, daniel.grebow@jpl.nasa.gov

Mr. Martin Ozimek
United States, mozimek@purdue.edu
Prof. Kathleen Howell
Purdue University, United States, *(email is not specified)*

ADVANCED MODELING OF OPTIMAL LOW-THRUST LUNAR POLE-SITTER TRAJECTORIES

Abstract

Recently, Grebow et al. discovered low-thrust trajectories in the Restricted Three-Body Problem (RTBP) that maintain direct line-of-site with the lunar south pole for very long periods. The trajectories might be used to support communications for a sustained human presence at the south pole, one current interest of NASA. The results have general implications, however, including long-term exploration of the polar regions of other planets, as well as planetary moons.

NASA is investigating the coverage capabilities of a small 500 kg spacecraft with an NSTAR thruster. Originating in International Space Station (ISS) orbit, the mission is characterized by three phases: (1) spiral out to the Moon, (2) optimize pole-sitting position, and (3) spiral down to an end-of-life lunar stable orbit. The end-of-life orbit corresponds to a frozen orbit, serving as part of a larger constellation for continued surveillance and lunar operations.

The RTBP study successfully implemented all three phases. The results indicate that the motion seems to be confined to a deformed surface corresponding to the halo orbit families. Though these types of solutions have been useful in the design of missions like ISEE-3, WIND, SOHO, MAP, and Genesis, clearly the nature of the pole-sitter trajectories requires further validation with higher fidelity models. This investigation proposes the transition of preliminary designs to include the effects of lunar librations, planetary ephemerides, solar powered thrust-modeling, shadowing, solar radiation pressure, and actual departure from the ISS.

Methodology

The problem will be solved with collocation including path constraints to restrict the spacecraft to a bounded region below the actual lunar south pole. The algorithm removes unnecessary arcs, automatically determines when it is necessary to thrust, and appropriately aligns the thruster. Direct transcription is a natural transition from collocation to optimize the coverage time.

Expectation of Results

Currently, the actual performance under higher fidelity models is unknown. In the previous study, several parameters were computed for a feasible and optimized mission. (See Table 1.) Of particular note, lunar librations are expected to result in a decrease of the minimum elevation angle of 13° from the lunar south pole. Since the initial goal of 365 days was far exceeded in the RTBP study, a comparable total time for phase two under the new model will also be emphasized.

References

Table 1: Preliminary Performance Characteristics of Pole-Sitter Mission.

		Feasible	Optimal
PHASE 1	Fuel Mass Consumed (kg)	22.13	13.58
	Total Time (days)	42.81	34.14
PHASE 2	No. of Thrust Arcs	35	35
	Fuel Mass Consumed (kg)	264.19	273.09
	Total Time (days)	**447.04**	**554.18**
	Min. Elevation Angle (°)	**13.0**	**13.0**
PHASE 3	Fuel Mass Consumed (kg)	1.76	1.41
	Total Time (days)	2.36	2.37

Grebow, D., Ozimek, M., and Howell, K., "Design of Optimal Low-Thrust Lunar Pole-Sitter Missions," Paper No. AAS 09-148, *19th AAS/AIAA Spaceflight Mechanics Meeting*, Savannah, Georgia, February 8-12, 2009.