Orbit Design Architectures for Lunar South Pole Coverage

Daniel J. Grebow*, Martin T. Ozimek*, K.C. Howell**, David C. Folta***

*Graduate Student, Purdue University, West Lafayette, IN
**Professor of Aeronautics and Astronautics, Purdue University, West Lafayette, IN
***Flight Dynamics and Analysis Branch, NASA Goddard Space Flight Center, Greenbelt, MD

Project Overview

Analysis and definition of Earth-Moon and lunar south pole orbits to meet the vision for space exploration.

Placing a facility at the South Pole of the moon poses questions concerning the orbital architecture of the communicating satellites. Constant communication can easily be achieved with Earth-Moon libration point orbits. We analyzed different architectures for nearly rectilinear halo orbits, vertical orbits, and other three-body variations for lunar coverage of the South Pole. Using invariant manifold theory, we also analyzed the transfer and stationkeeping costs for these orbits. Libration point orbits may be a cheaper alternative to polar-sitters or even two-body, highly eccentric orbits.

- Orbits investigating:
  - Halo orbits
  - Vertical orbits
  - Highly Eccentric Orbits (HEOs)
  - Other orbits

- General method of investigation:
  1. Start with Circular Restricted Three-Body Problem (CR3BP) between the Earth & Moon
  2. This model provides the basis for orbit design, but does not account for effects like gravitational perturbations and solar radiation pressure

- Differentially correct (TOF & periodic constraint)
- Full ephemeris Purdue University software (GENERATOR)
- High fidelity GSFC software (Astrogator, SwingBy, FreeFlyer, etc.)
- Potential scenarios will be narrowed by analyzing stationkeeping costs, transfer costs, and total coverage time

Initial Design Process

- Regenerate entire L₁ and L₃ families in CR3BP
- Using a numerical differential corrections procedure, there exists an entire family of orbits about the libration points
- Build up a table of relevant orbit properties*

- Use CR3BP results to design different types of scenarios:
  - 1:1 L₁ to L₁ (same orbit)
  - 1:1 L₁ to L₂
  - 1:1 L₂ to L₂ (same orbit)
  - 2:1 L₁ to L₂
  - 2:1 L₂ to L₂

- 'Grab' patch points* for these orbits and apply periodic and time-of-flight (TOF) constraints to different orbits
- Run in full ephemeris Purdue University flight software (GENERATOR) See resulting configurations
- Check total coverage

High Fidelity Modeling

Full ephemeris vertical orbit with targeting

Future Work

- Study scenarios in more detail with Astrogator
  - In-depth coverage analysis
  - Transfer costs
- Determine ΔV costs for inserting into orbit scenarios
- Stationkeeping
- Analyze the capability and ΔV costs of several different methods

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