Orbit Design Architectures for Lunar South Pole Coverage

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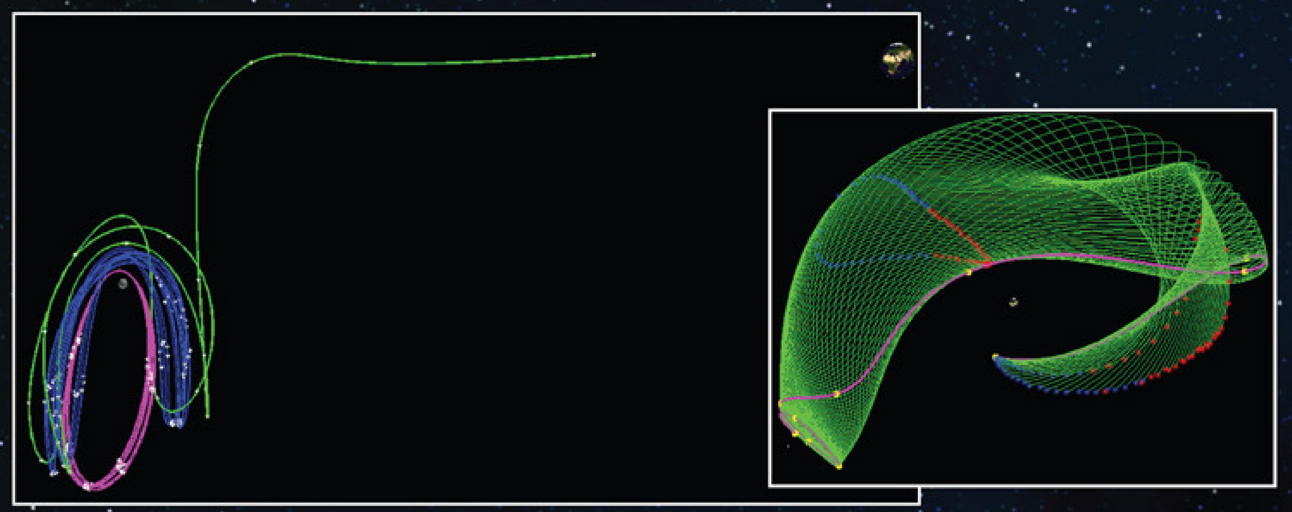
Explore . Discover . Understand

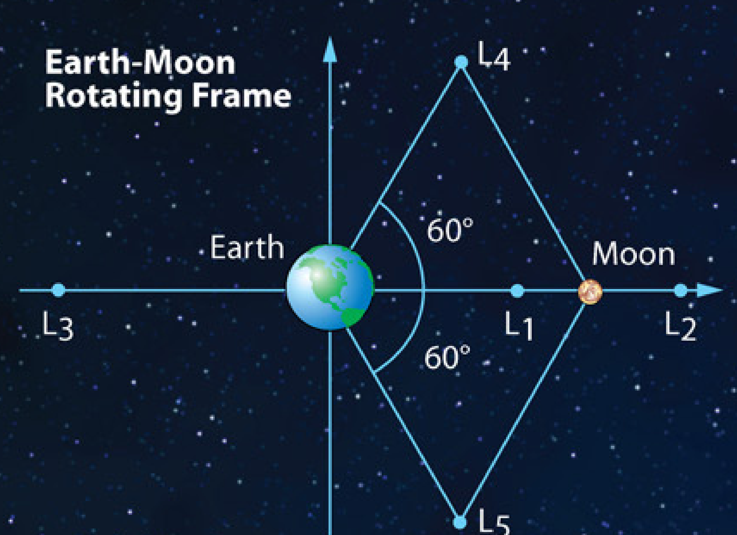
Project Overview

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 pole-sitters or even two-body, highly eccentric orbits.

- Orbits investigating:
  - Halo orbits
  - Vertical orbits
  - Highly Eccentric Orbits (HEO's)
  - Other orbits
- General method of investigation:
  1. Start with Circular Restricted Three-Body Problem (CR3BP) between the Earth & Moon
     - This model provides the basis for orbit design, but does not account for effects like gravitational perturbations and solar radiation pressure
  2. Differentially correct (TOF & periodic constraint)
  3. Full ephemeris Purdue University software (GENERATOR)
  4. High fidelity GSFC software (Astrogator, SwingBy, FreeFlyer, etc.)
- Potential scenarios will be narrowed by analyzing stationkeeping costs, transfer costs, and total coverage time



This diagram shows that five equilibrium points, L_1-L_5, exist in the gravitational model (L_1-L_5 also denoted as Lagrange points or libration points).

Equations of Motion

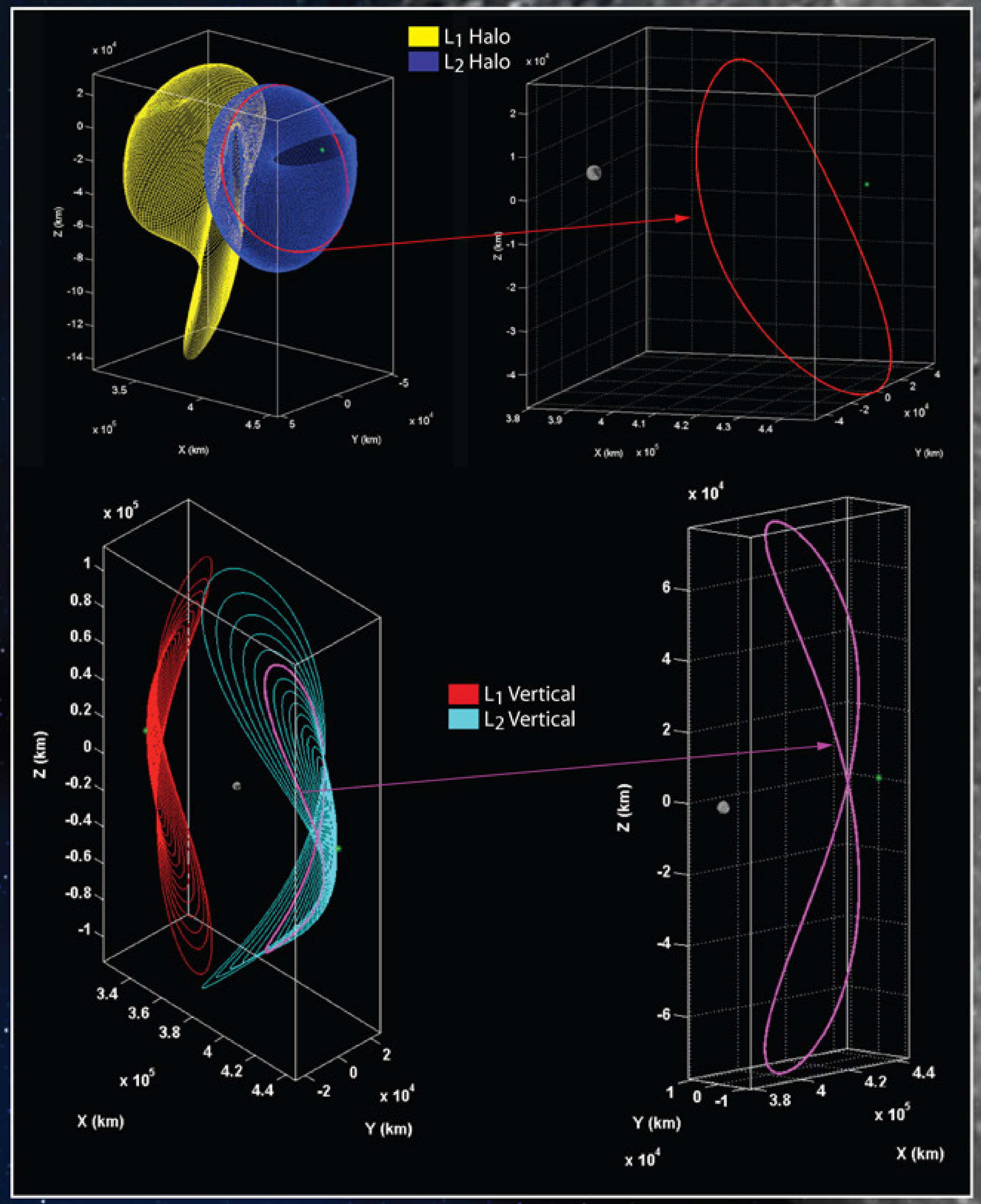
$$\ddot{x} = 2\dot{y} + x - \frac{(1-\mu)(x+\mu)}{d^3} - \frac{\mu(x-(1-\mu))}{r^3}$$

$$\ddot{y} = -2\dot{x} + y - \frac{(1-\mu)y}{d^3} - \frac{\mu y}{r^3}$$

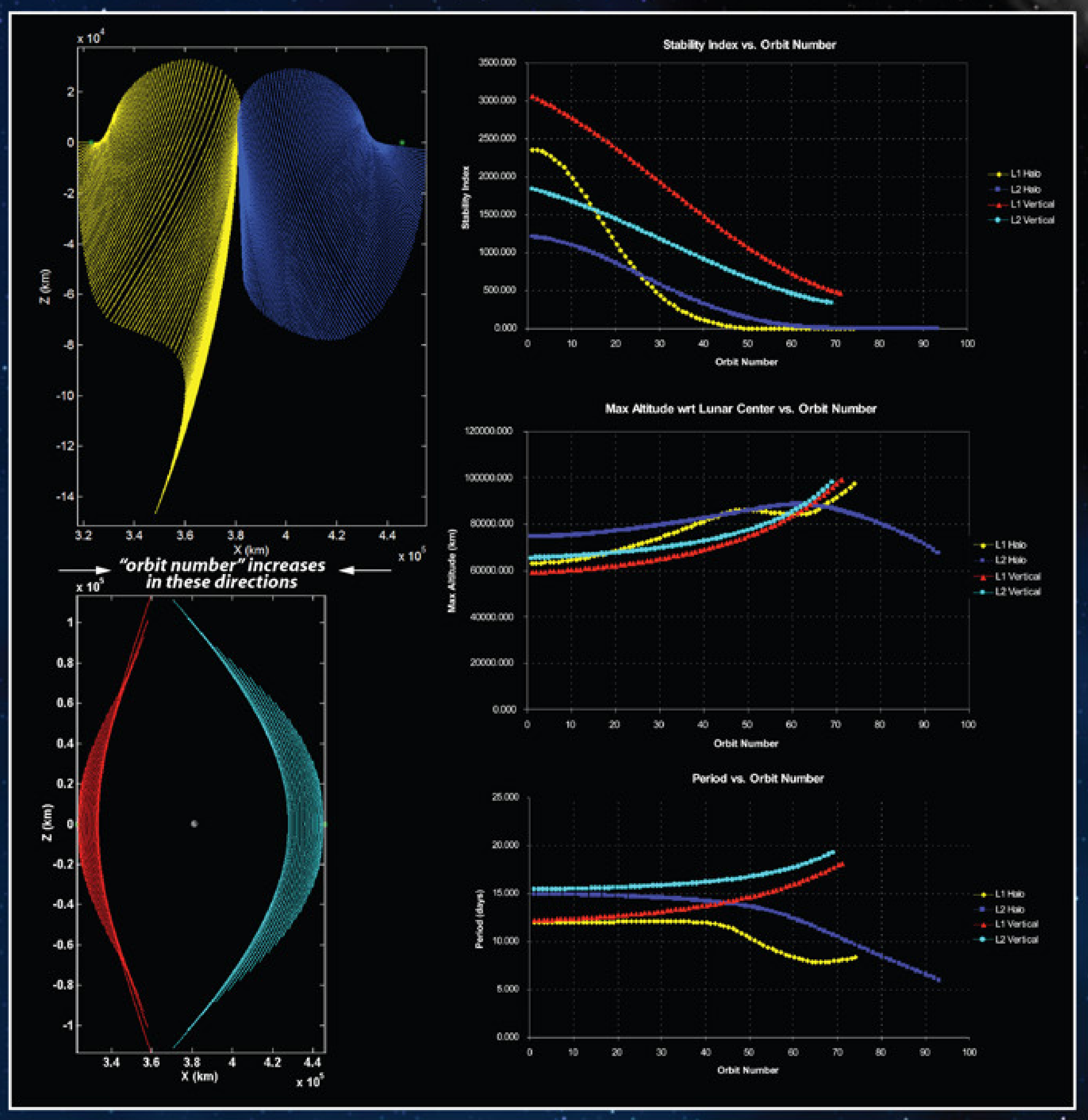
$$\ddot{z} = \frac{-(1-\mu)z}{d^3} - \frac{\mu z}{r^3}$$

Initial Design Process

- Regenerate entire L_1 and L_2 families in CR3BP
  - Using a numerical differential corrections procedure, there exists an entire family of orbits about the libration points



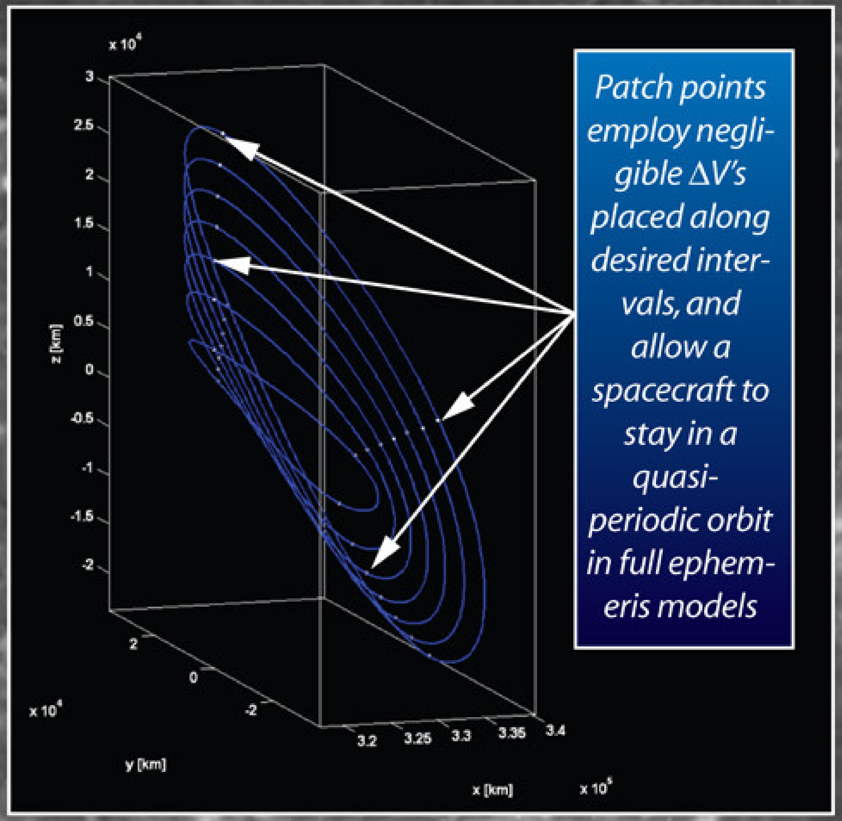
- Build up a table of relevant ***orbit properties*** and a table of ***initial conditions***



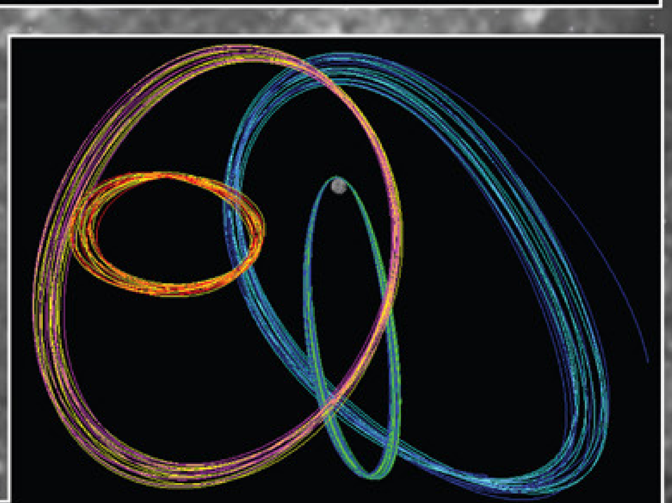
- Use CR3BP results to design different types of scenarios:

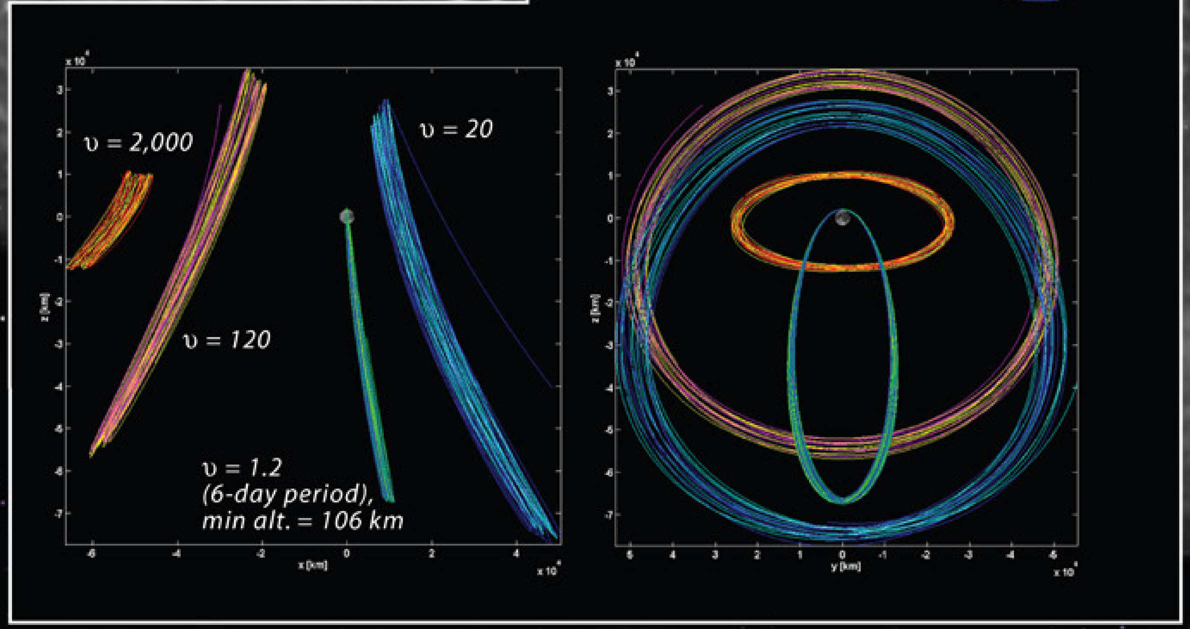
1:1 L1 to L1 (same orbit)
1:1 L1 to L2
1:1 L2 to L2 (same orbit)
2:1 L1 to L2
2:1 L2 to L2

- Grab "patch points" for these orbits, and apply periodic and time-of-flight (TOF) constraints to different orbits

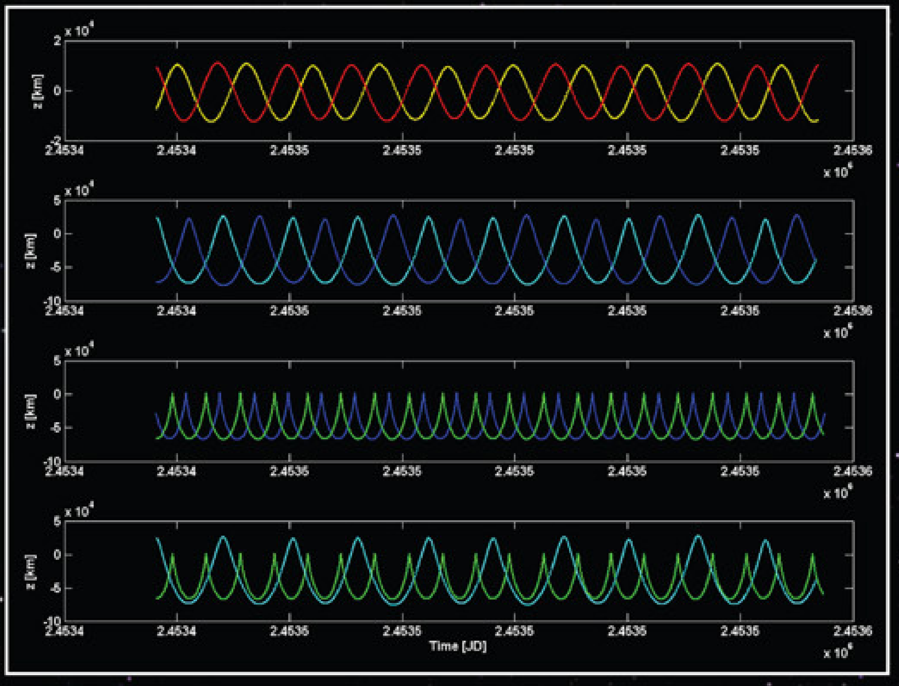


- Run in full ephemeris Purdue University flight software (GENERATOR) *See resulting configurations*

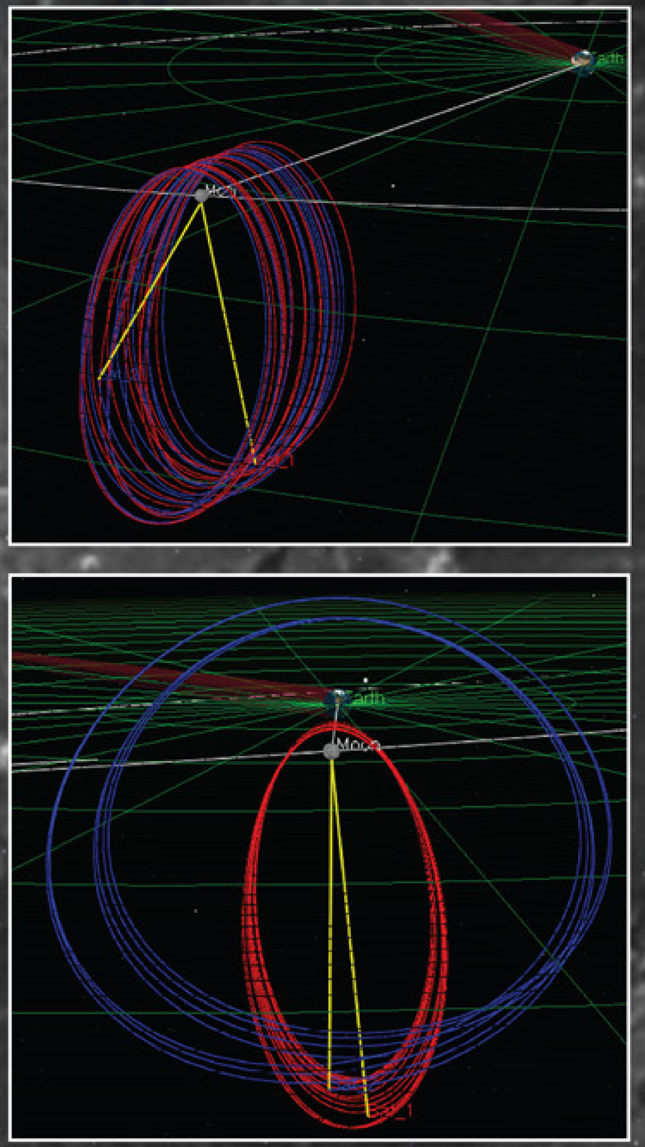




- Check total coverage



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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