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UW CubeSat

L4/L5 Mission Proposal – Write-up/Outline

Mission Overview:

* Launch CubeSat from SLS on route to or on return from the Moon
* CubeSat will use its own propulsion to then path to either L4 or L5 (Earth-Sun)
* Upon reaching the target location, CubeSat will begin to survey for asteroids in the immediate area

Mission Purpose:

* Explore Earth-Sun’s L4 and L5
  + Relatively unobserved, due to general sunward direction (always in daylight)
  + L4 and L5 are balance points between the gravity of the Earth and the Sun and the rotational forces of orbit, 60 degrees ahead and behind the Earth in its orbit.
  + Only two known Trojan asteroids, one at each
  + No mission has spent significant time at these points
  + Result implications:
    - No new asteroids discovered -> low hazard for “parked” spacecraft performing space-based observations (particularly of the Earth)
    - Many asteroids discovered -> Convenient point of interest for study/exploitation of asteroids
* Improve techniques for remote detection of asteroids and other small rocky bodies

Initial Conditions, Assumptions and Assessment of Feasibility:

* Initial conditions taken from publicly available NASA documentation: ICPS Disposal State
  + GMAT was then used to propagate forward those initial conditions to the point where the spacecraft would be just outside the Moon’s sphere of influence
    - Finding velocity and position relative to the Earth
  + Assumption: We assumed that these parameters were generalizable to any day of the month (i.e. any position of the Moon relative to the Earth in its orbit), so that we can set any launch window and optimize Delta-V needed to reach L4 or L5.
* Assumption: We assumed the spacecraft will be equipped with a Pulsed Plasma Thruster capable of sustaining an (conservative estimate) acceleration of 5\*10^-5 m/s^2, with sufficient fuel for a total Delta-V of 1 km/s.
  + Keeping 40% of fuel in reserve for maneuvers and corrections, leaves a maximum Delta-V-to-target requirement of no more than 600 m/s
* Assessment of Feasibility using new orbit propagator
  + Propagator Function and Features:
    - Three-body propagator
      * Earth and Sun orbit a shared barycenter located at the origin
        + Orbits assumed circular and co-planar
      * Earth and Sun apply gravity on one another
      * Spacecraft can be placed anywhere with any initial velocity
      * Spacecraft mass assumed to be negligible compared to major bodies
        + Earth and Sun apply gravity on spacecraft, but the spacecraft does not apply gravity to Earth or Sun.
      * Motions restricted to orbital plane of the earth (XY only, no Z)
      * Calculations done in Cartesian coordinates in an inertial frame
      * Rotated into a non-inertial frame in which the Earth and Sun appear stationary for display purposes and analysis.
    - Numerical approximation
      * For every timestep, positions and velocities of all objects are recorded
      * Gravitational accelerations based on relative position and mass are calculated
        + For spacecraft, acceleration due to thrust is also calculated, if applicable during timestep
      * Integration: Accelerations are multiplied by the length of the timestep and added to current velocity.
      * Integration: New velocities are multiplied by the length of the timestep and added to current position.
      * Accuracy of this technique improves with shorter timesteps
      * Assumption: A timestep length of 480 seconds was used for most of the analysis to provide a good balance between accuracy and computation time for timescales of a year or multiple years.
  + Assessment:
    - Trial-and-error techniques were used to find combinations of initial conditions and thrust applications to minimize Delta-V needed for a successful encounter with the target
      * Encounters were judged to be successful if the spacecraft passed within 0.05 AU of the target center at a velocity relative to the target of no more than 50 m/s
        + Assumed that a corrective burn during such an encounter could achieve capture without having to carry additional reserve fuel
      * System for noting initial position of spacecraft: days in the lunar month
        + Took lunar month as synodic month: 29.5 days
        + Took day 0 as collinear with Earth and Sun and outside the Earth’s orbit (full moon position)
        + Counting positively counter-clockwise and negatively clockwise to maximum/minimum at ±14.75 days (new moon position)
    - Data:
      * Initial Assessment: All values estimated

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| --- | --- | --- | --- | --- | --- |
| Starting Position (Day) | Delta-V to Best Encounter | Time to Encounter | L4/L5? | Relative Speed During Encounter | Successful? |
| ±14.75 | 230 m/s | 1 yr | L4 | 3044 m/s | N |
| -10 | 526 m/s | 2 yr | L4 | 2060 m/s | N |
| -5 | 350 m/s | 2 yr | L5 | 6.1 m/s | Y |
| 0 | 865 m/s | 1 yr | L4 | 2562 m/s | N |
| +5 | 409 m/s | 1 yr | L5 | 11.8 m/s | Y |
| +10 | 877 m/s | 20 yr | L4 | 0-400 m/s | N\* |

\*(Captured in horseshoe very early, but approaches center too slowly)

* Prompted additional assessment between -8 days and +8 days
* From this data, seems reasonable to reach L5 within mission parameters, but possibly not L4.