OPTIMIZING THE GLIDE TRAJECTORY TO AND AROUND EARTH-SUN L1

AUTHORS

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AFFILIATIONS

01 INTRODUCTION

- The Global Lyman-alpha Imagers of the Dynamic Exosphere (GLIDE), as seen in Figure 1, is a ride-share coupled to NASA's upcoming Interstellar Mapping and Acceleration Probe (IMAP) mission, which is scheduled to launch on SpaceX's Falcon 9 Full Thrust rocket in February 2025.
- The goal of GLIDE is to study variability in Earth's exosphere—the first atmospheric layer – by tracking the far ultraviolet light emitted from hydrogen, through solar flares.
- GLIDE will be released a few days after launch and must ultimately orbit the Lagrange L1 point. Lagrange points, shown in Figure 2, are positions where the gravitational pull of two large masses (e.g., the Sun and Earth) precisely equals the centripetal force required for a small object (spacecraft) to move with them. The Lagrange L1 point is about 1% closer to the Sun than Earth.
- The purpose of this research project is to optimize the GLIDE trajectory code to and around the Earth-Sun L1 point to minimize the required delta-v and reduce the expense of rocket propellant.

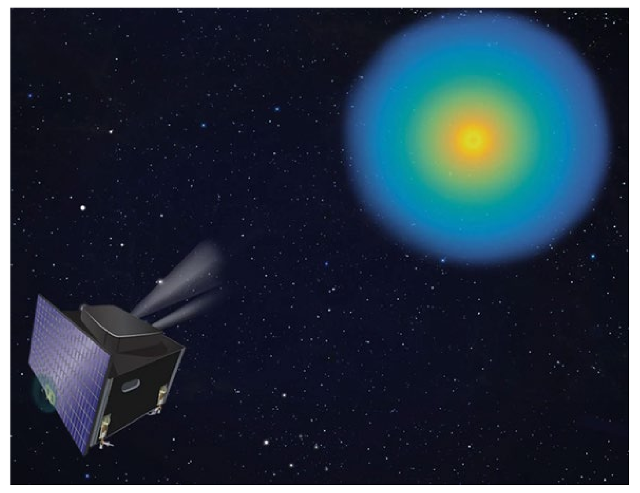

Figure 1: A rendering of the GLIDE spacecraft about the L1 point created by the principal investigator, Dr. Lara Waldrop.

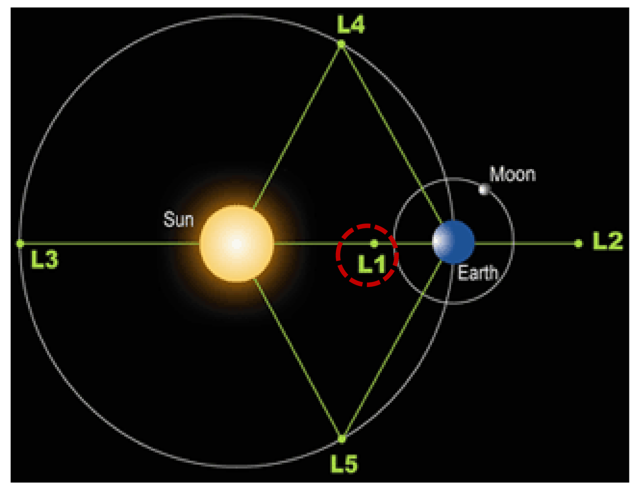

Figure 2: Lagrange points L1, L2 and L3 lie along the horizontal line connecting the two large masses. Points L4 and L5 form two equilateral triangles whose common base is the line between the two large masses.

02 DELTA-V

- A space mission is a series of different orbits. To maneuver, a spacecraft in orbit must use its rocket engines to change the magnitude or direction of its velocity. The GLIDE trajectory is illustrated in Figure 3.
- Delta-v budget is the summation of velocity changes required to leave one orbit and enter another.
- After entering the L1 point, Station-Keeping Maneuvers (SKM) are needed to maintain GLIDE in orbit at L1 for at least two years.
- Total delta-V depends on the initial state vector at release. SpaceX gave us 36 Target Interface Point (TIP) states over a 1-year window. Our focus is on TIP 13 since it corresponds to the nominal February 2025 launch window.

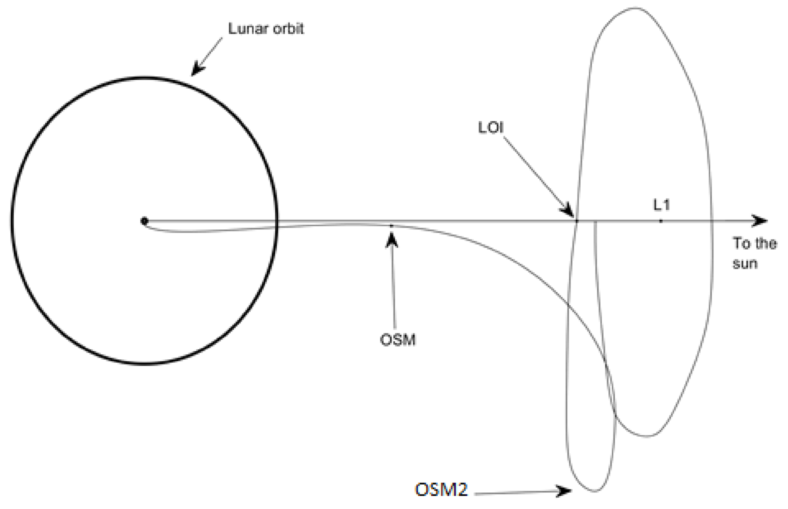

Figure 3: A schematic view of the GLIDE trajectory to the Earth-Sun L1 point. To enter into orbit the spacecraft needs initial burns at Orbit Shaping Maneuver 1 (OSM1) and Lissajous Orit Insertion (LOI), an OSM2 burn is optional.

03 METHODOLOGY

- To determine the trajectory of the spacecraft from a set of possible state vectors at release (given by SpaceX), we used MONTE (Mission Analysis, Operations, and Navigation Toolkit Environment), the Jet Propulsion Laboratory's astrodynamic computing platform.
- Once initial trajectory and burns were computed, we used MONTE's COSMIC (Computer Optimization System for Multiple Independent Courses) application for trajectory optimization and design. It works by minimizing the total delta-V of a series of independently propagated trajectory segments.

04 RESULTS

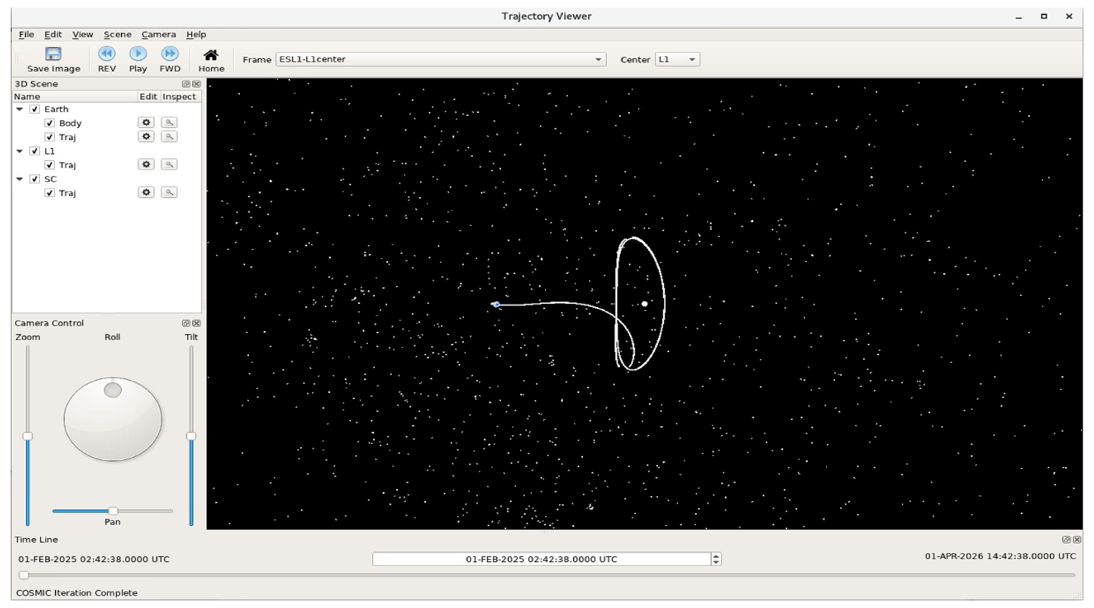

Figure 4: The COSMIC application running the different trajectory iterations at L1. The timeline of our mission is also included.

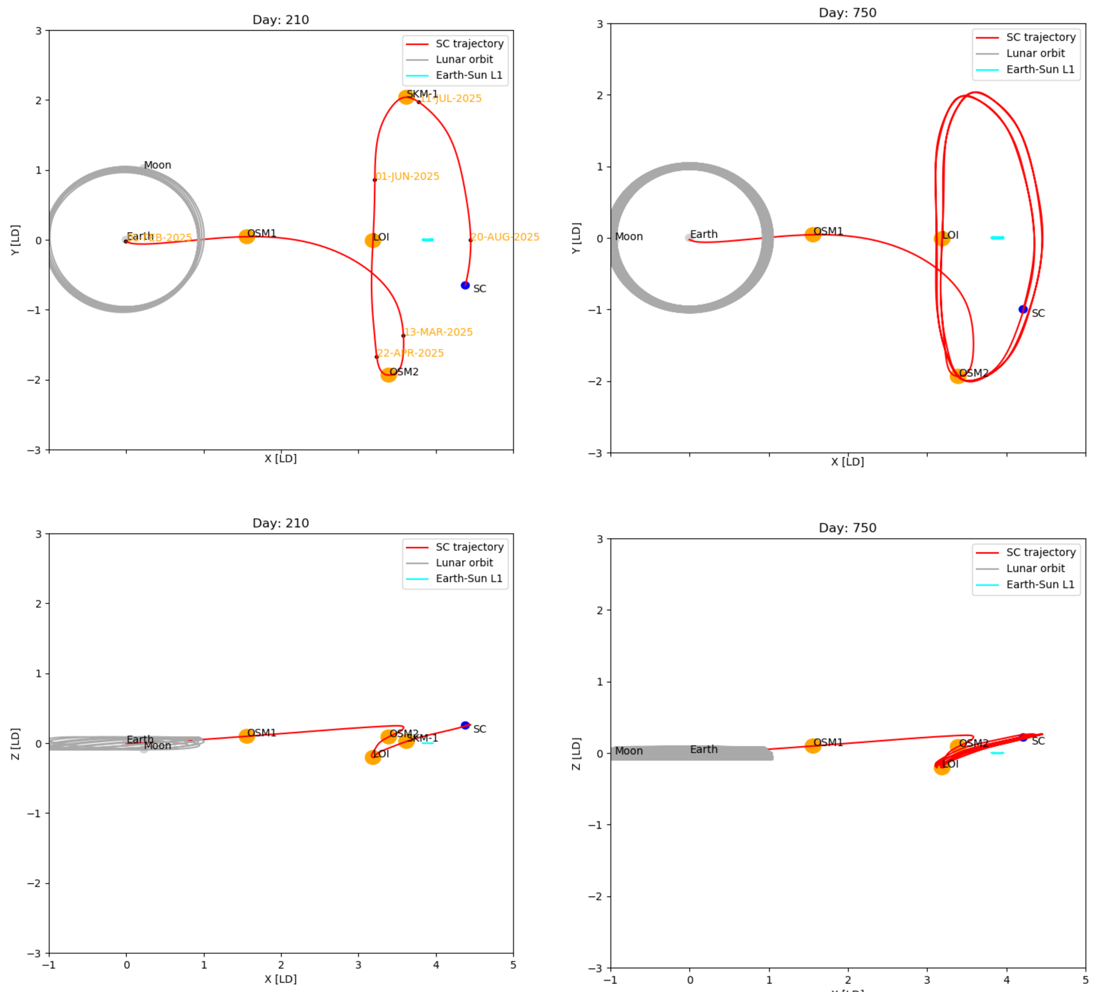

Figure 5: The GLIDE trajectory at days 210 and 750, with views in the X-Y (ecliptic plane) and X-Z directions (plane perpendicular to ecliptic). On day 210 the spacecraft is in transit to complete its first orbit around the point L1; the dates of the expected burns are also included. At day 750 the spacecraft has completed almost two orbits around L1 (one orbit is about six months), and eight station keeping maneuvers (four per year).

Number of burns: 11

OSM1:	06-FEB-2025	02:42:39.0000 UTC	9.069095589423396 m/s
OSM2:	06-APR-2025	14:42:38.0010 UTC	0.0 m/s
LOI:	20-MAY-2025	11:02:37.6028 UTC	13.272226782570625 m/s
SKM-1:	03-JUL-2025	23:02:37.6028 UTC	0.05296696664594916 m/s
SKM-2:	30-SEP-2025	23:02:37.6028 UTC	0.00021463290401404583 m/s
SKM-3:	28-DEC-2025	23:02:37.6028 UTC	1.5595678910419825e-05 m/s
SKM-4:	27-MAR-2026	23:02:37.6028 UTC	1.386063883377259e-05 m/s
SKM-5:	24-JUN-2026	23:02:37.6028 UTC	4.7180234615420006e-05 m/s
SKM-6:	21-SEP-2026	23:02:37.6028 UTC	0.0 m/s
SKM-7:	19-DEC-2026	23:02:37.6028 UTC	0.00019193838997142796 m/s
SKM-8:	18-MAR-2027	23:02:37.6028 UTC	5.296452474603185e-05 m/s

======== Total burn DV: 22.394825511011064 m/s

Figure 6: Table output for TIP state 13 displaying the total number of burns to get GLIDE into orbit and the station keeping maneuvers necessary to keep the spacecraft in orbit around L1 for two years. The total delta-V comes out to approximately 22.4 m/s.

05 CONCLUSION

- A key goal in deep space-missions is to minimize the required delta-v to reduce the size and expense of the rocket.
- In this project we optimized the GLIDE trajectory code to and around the Earth-Sun L1 point to minimize the required delta-v. The work done here will be implemented in the GLIDE mission.
- For the nominal TIP state, the total delta-V value over a two-year mission was approximately 22.4 m/s. Station-keeping required less than 0.05 m/s per year—other TIP states lead to higher station keeping cost.
- Since delta-v depends on the position and motion of celestial bodies the delta-v expenditure varies according to the launch window. For future work we need to run simulations for the remaining 36 TIP states to minimize their delta-v expenditure.

06 REFERENCES

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