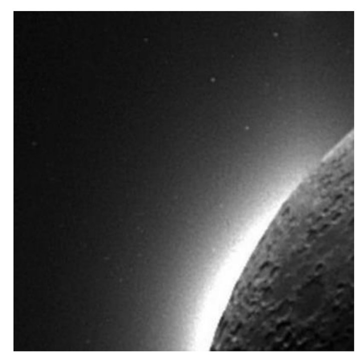
Satellite Research Centre
School of Electrical and Electronic Engineering

NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE

HORYU-VI Lunar Mission



Introduction: If the lunar regolith that covers the lunar surface rises due to charging and attaches to a landing spacecraft, rover, astronaut, etc. on the lunar surface, it may have a great effect on their activities. The Lunar Horizon Glow (LHG), which causes the lunar regolith to float and the sunlight to scatter forward due to the electrostatic field generated at the boundary between the day and night of the moon, has been described as a symbol of the charging of lunar fine particles. Discontinued, still wrapped in mystery. LHG observations using conventional lunar probes have limited observation opportunities and do not cover the various conditions of space weather that cause lunar charging.

Objective: To develop CubeSat for Lunar Horizon Glow observation.

1. The moon is the most accessible extraterrestrial frontier
2. The surface represents remarkable portion of conditions found in the solar system (ideal testbed)
3. Inspire domestic students, boost the local space industry, strengthen the international partnerships.

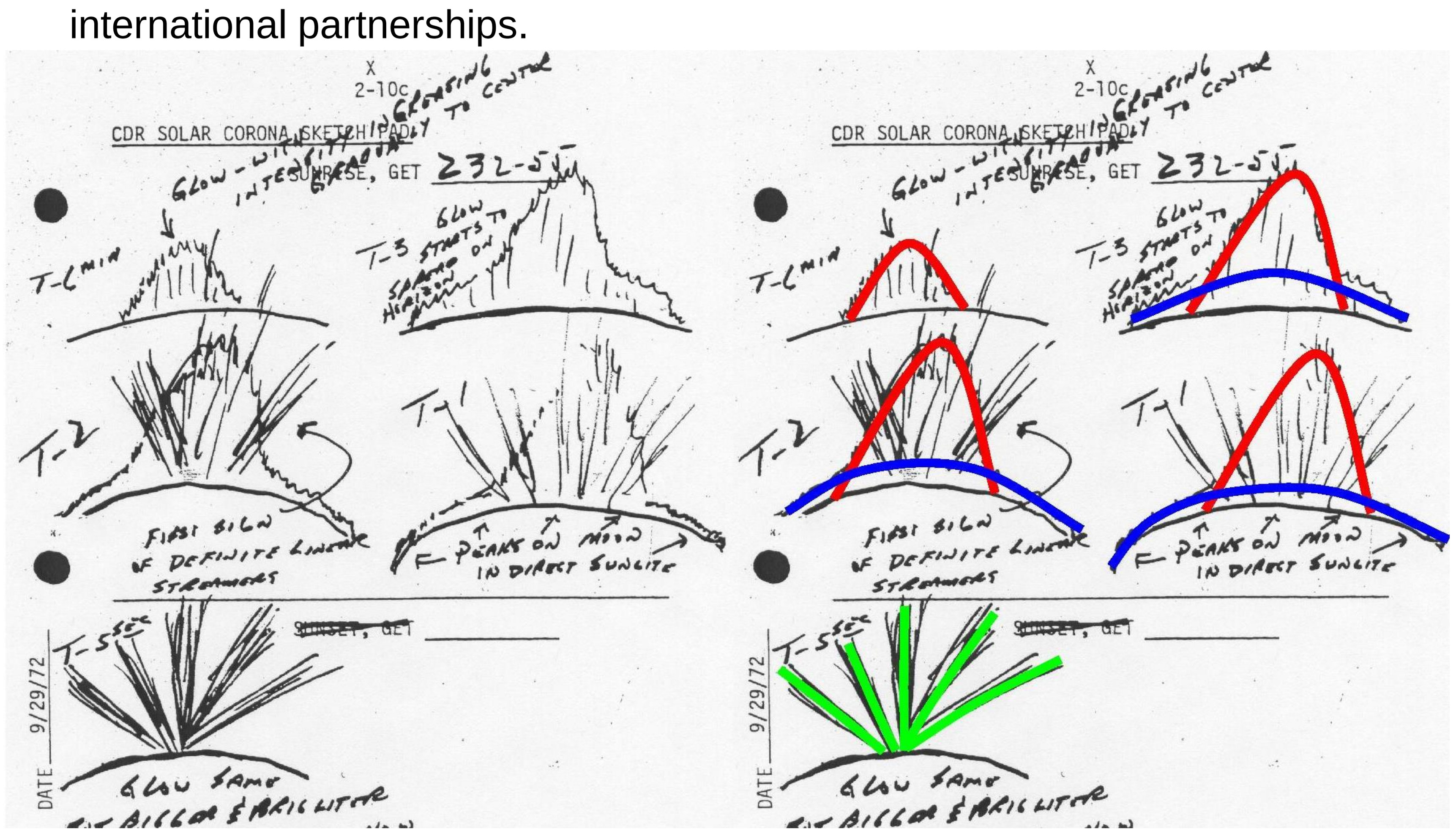
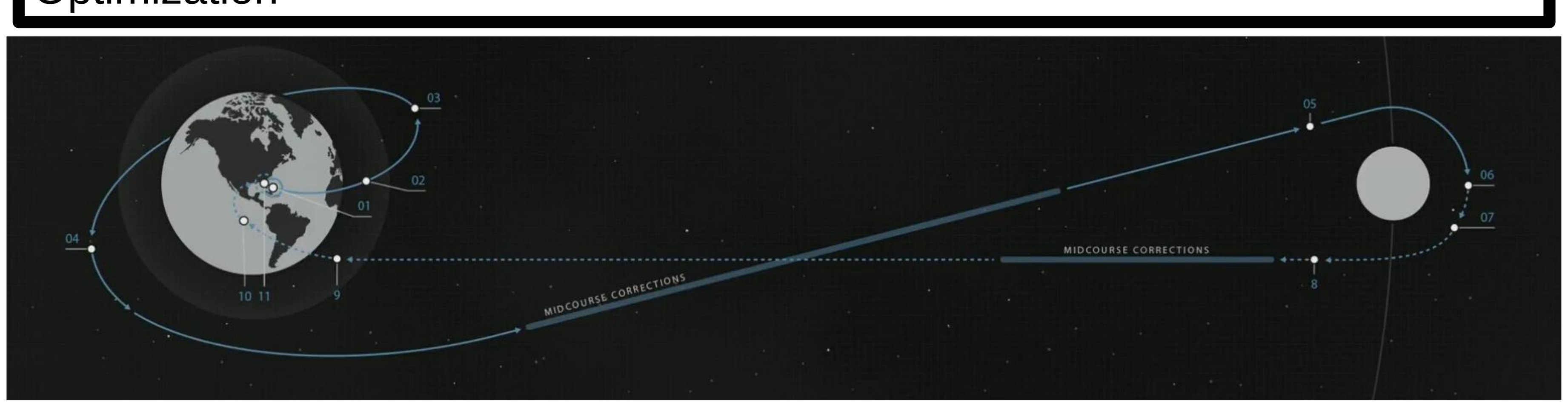


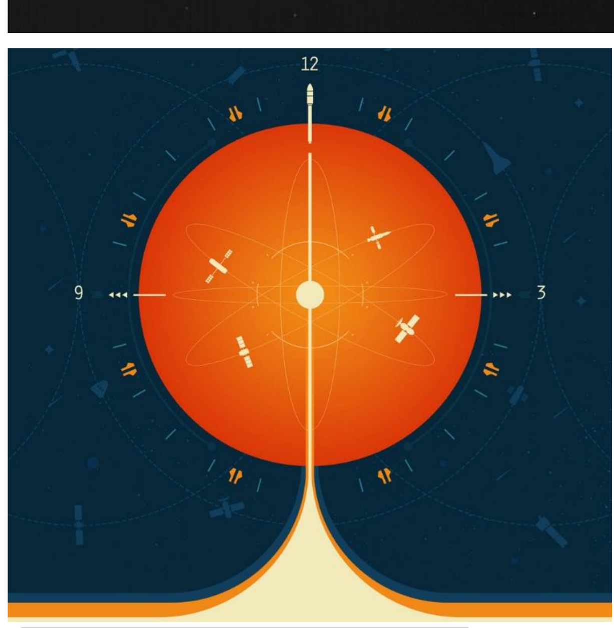
Fig. 1: Sketches of sunrise with "horizon glow" and streamers viewed from lunar orbit during Apollo 17.

1. Coronal and Zodiac Light
2. Lunar Horizon Glow due to Exospheric dust
3. (possibly) Crepuscular rays formed by shadowing and scattered light

NTU Contribution:

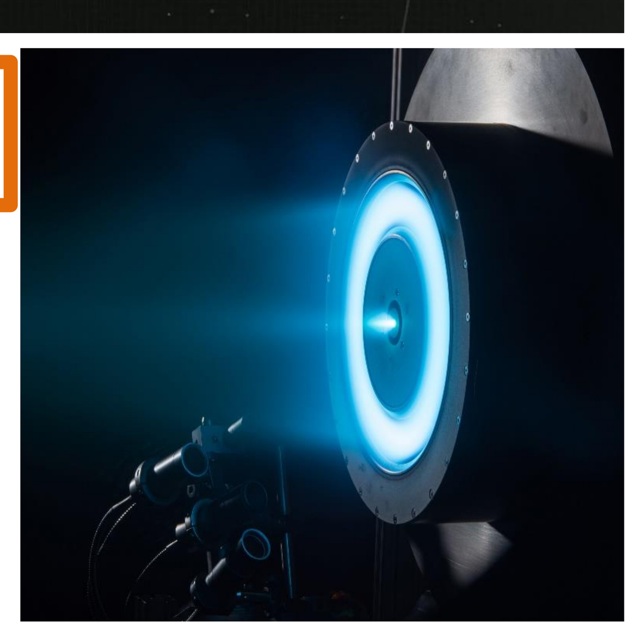
1. Guidance, Navigation, and Control – Low Thrust Constrained Trajectory Optimization





2. Atomic Clock: Better navigation & Science

3. Electric Propulsion: Efficient Maneuvers



4. System Design

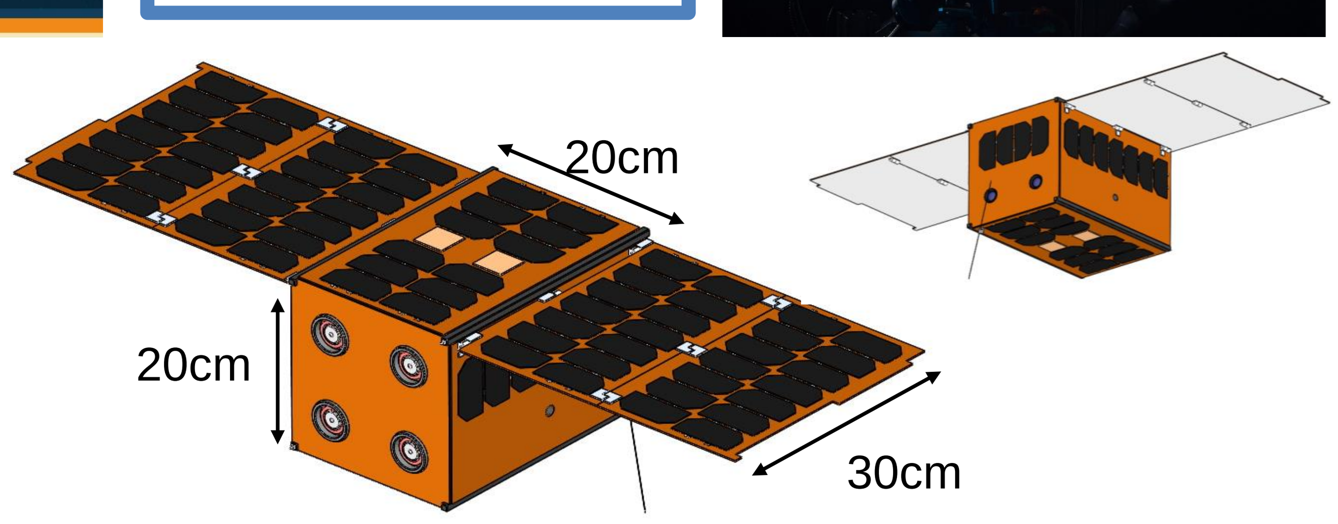
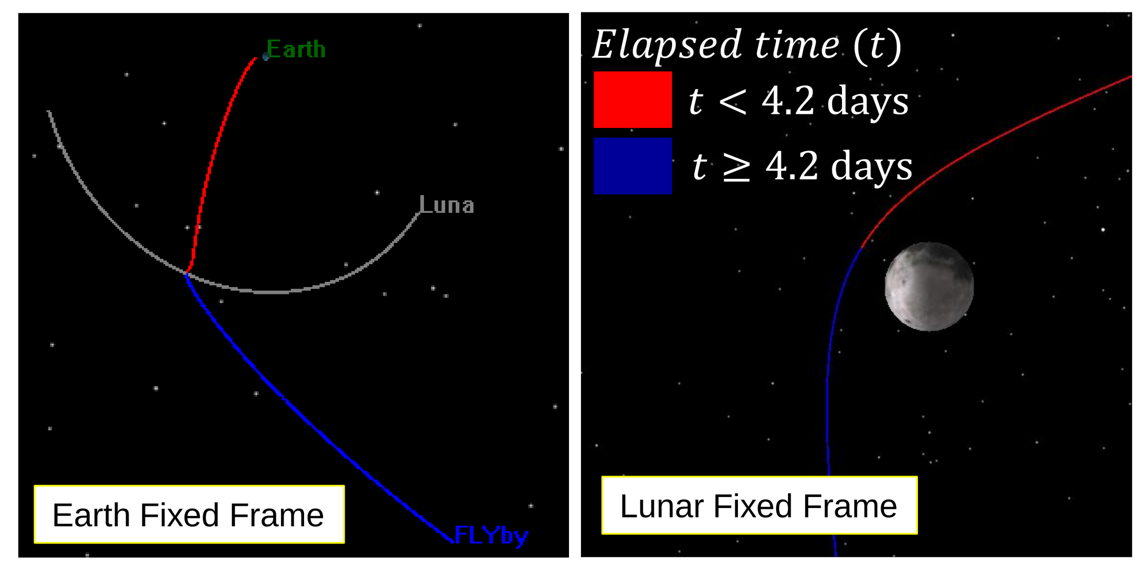


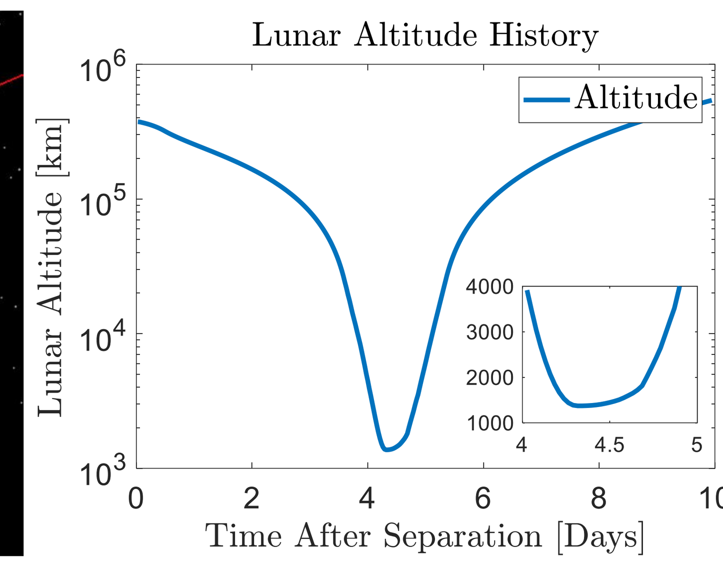
Fig. 2: Cad design of HORYU-VI CubeSat

1. Guidance, Navigation, and Control – Low Thrust Constrained Trajectory Optimization

This work presents low-thrust trajectory optimization strategy to obtain near circular lunar orbit for cubesats injected in lunar flyby trajectory. The cubesat is assumed to be equipped with unilaterel 4 hall-effect thrusters and released from SLS-2 rocket under Artemis-2 which is the next generation crewed Lunar mission.

i. Trajectory without actuation

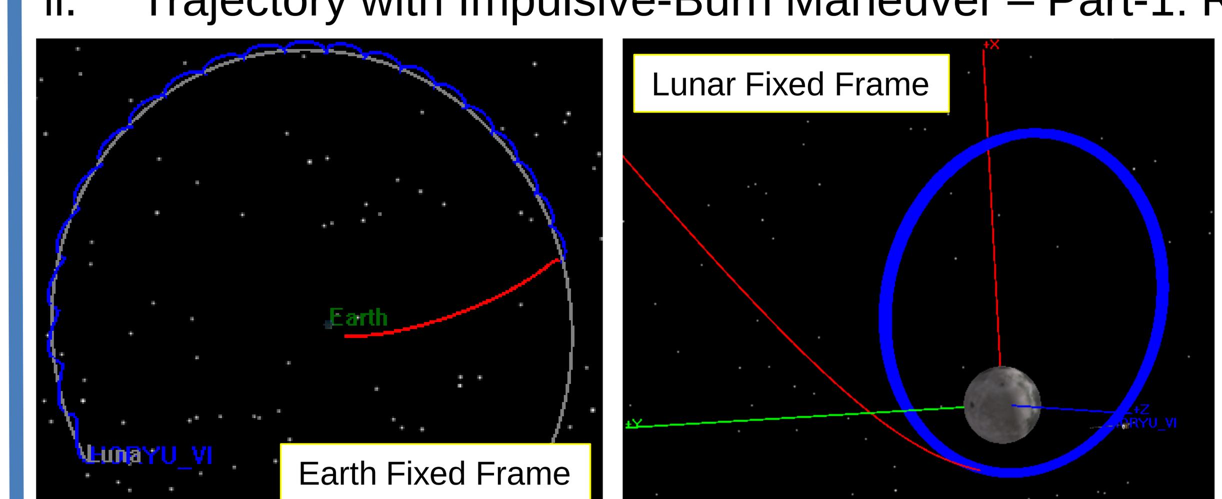




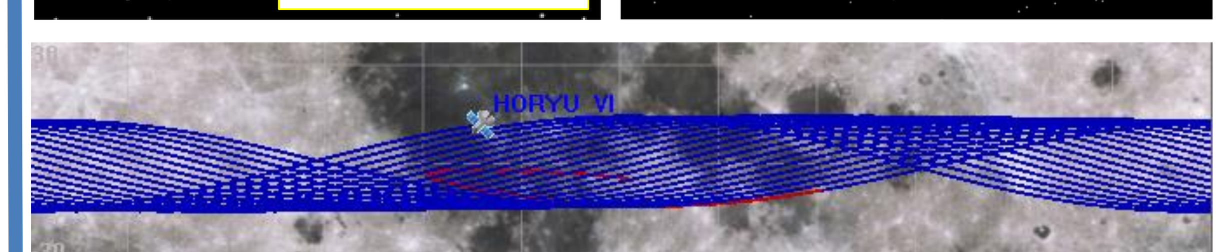
When the cubesat is released, it gains sufficient energy to escape Earth-Moon system and enters in heliocentric orbit after lunar flyby.

Transfer Type	Typical Duration	Benefits	Example
Direct, conventional	3-6 days	Well known, quick	Apollo, LRO, others
Direct, staging	2-10 weeks	Quick, many launch days	Clementine, CH-1
Direct to lunar L1	1-5 weeks	Staging at L1	None to date
Low-thrust	Many months	Low fuel, many launch days	SMART-1
Low-energy	2.5-4 months	Low fuel, many launch days	Hiten, GRAIL, ARTEMIS

ii. Trajectory with Impulsive-Burn Maneuver – Part-1: RMAG Correction

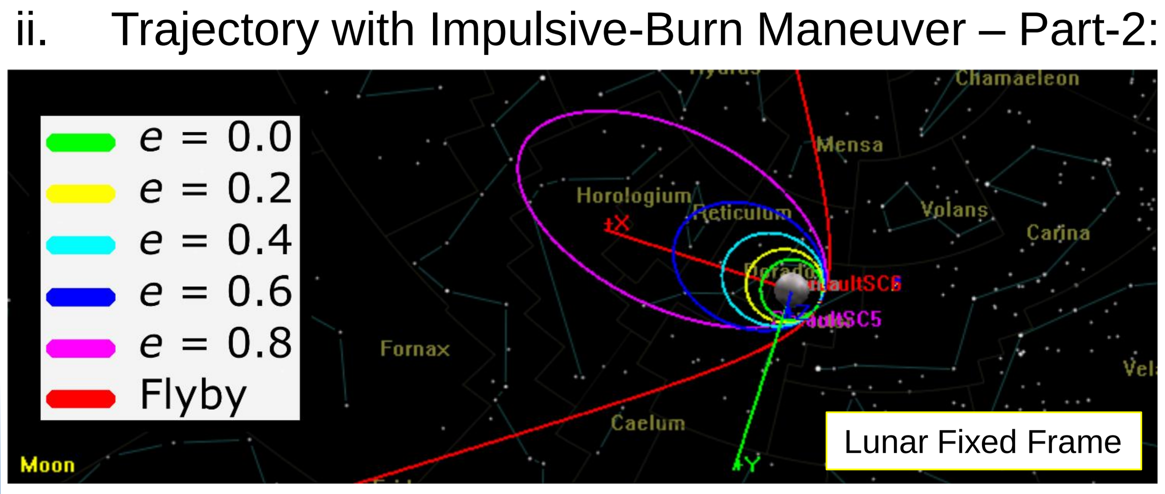


- Impulsive-burn trajectory is designed and optimized as a starting point to obtain the nominal finite-burn Earth-Moon transfer trajectory.
- Objective of the optimizer is RMAG = 12000 km.



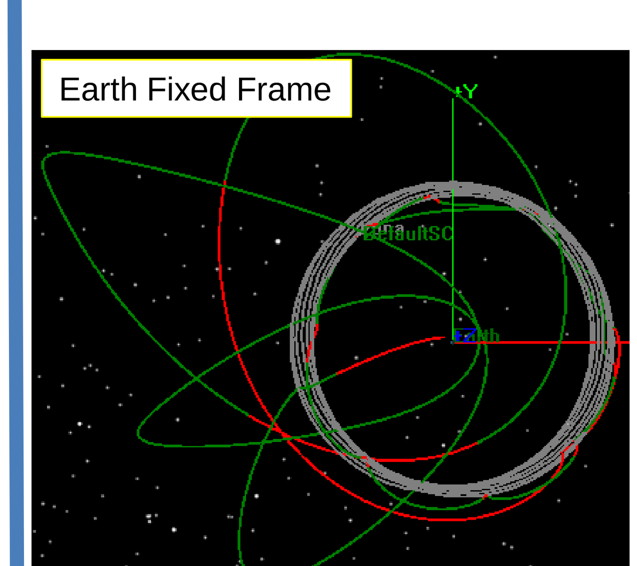
Axis	Delta-V [m/s]
X	369.554
Y	5.845
Z	75.171

ii. Trajectory with Impulsive-Burn Maneuver – Part-2: Eccentricity Correction

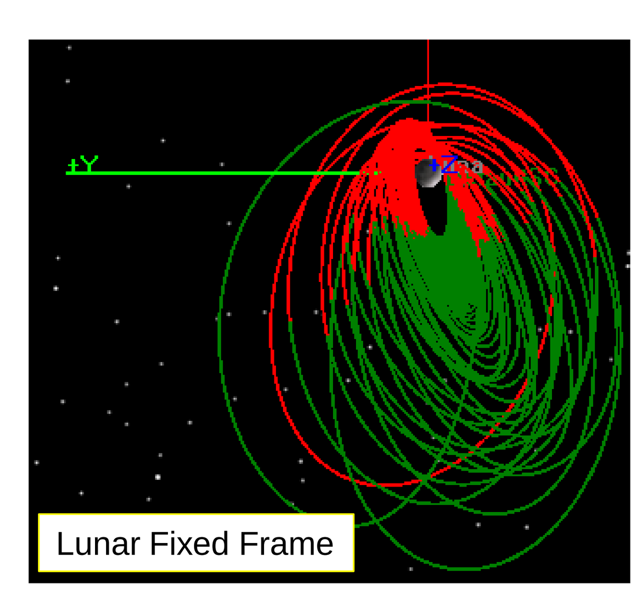


Eccentricity	Delta-V (m/s)
0	977.771
0.2	793.695
0.4	639.561
0.6	497.464
0.8	364.529

iii. Trajectory with Finite-Burn Maneuver: Low-thrust Optimization



Burn	Duration (Days)	Delta-V (m/s)
Pre-Flyby	2	17.28
Capture	6.62	57.24
	20.83	179.97
Orbit Correction	70	604.8
Total Burn Duration	99.45	859.29
Mission Duration	359	



iv. Ongoing Work

1) Uncertainty analysis
   1. Thrust, navigation, and pointing errors
   2. Actuator faults
   3. Mass decay
2) Comprehensive Delta-V budget
   1. Launch window analysis
   2. Lunar orbit station keeping
   3. Constraints on the Lunar arrival condition