

UNIVERSITÀ
DEGLI STUDI
DI PADOVA

Sustainability of Earth and Cislunar Orbit

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Presentation for the admission to the 2nd year

14/10/2025

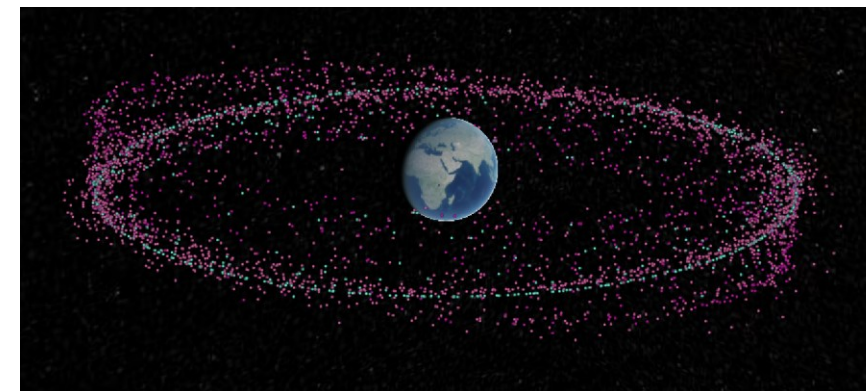
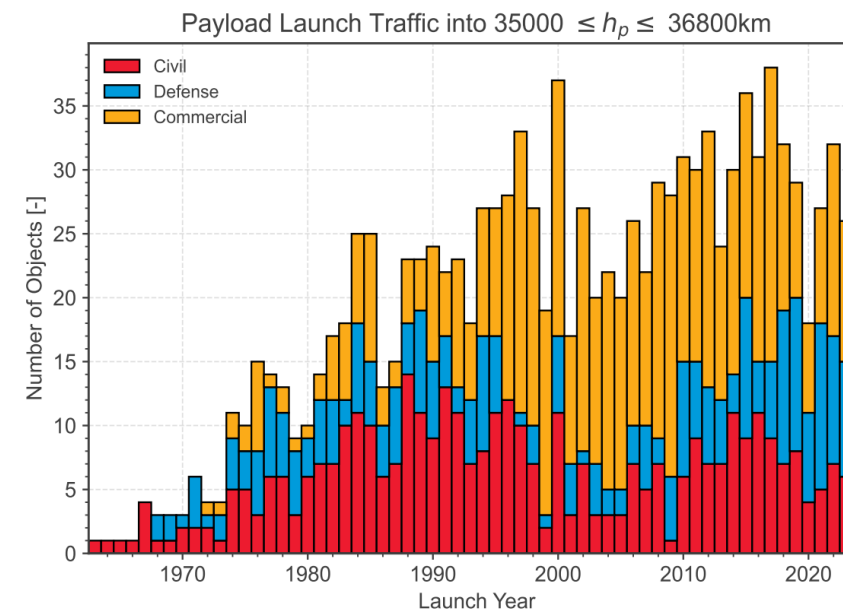
The number of objects in orbit is constantly growing due to:

- the increase of the **launch rate**;
- the deployment of **constellations** of satellites;
- multiplications of space debris caused by **fragmentation events**.

GEO has become an increasingly congested and vulnerable orbital region → INTELSAT 33 E explosion.

Urgent needs:

- better monitoring;
- stronger mitigation guidelines;
- Improve the fidelity of fragmentation simulations.



More than 400 lunar missions planned over the next 20 year around the **lunar environment**.

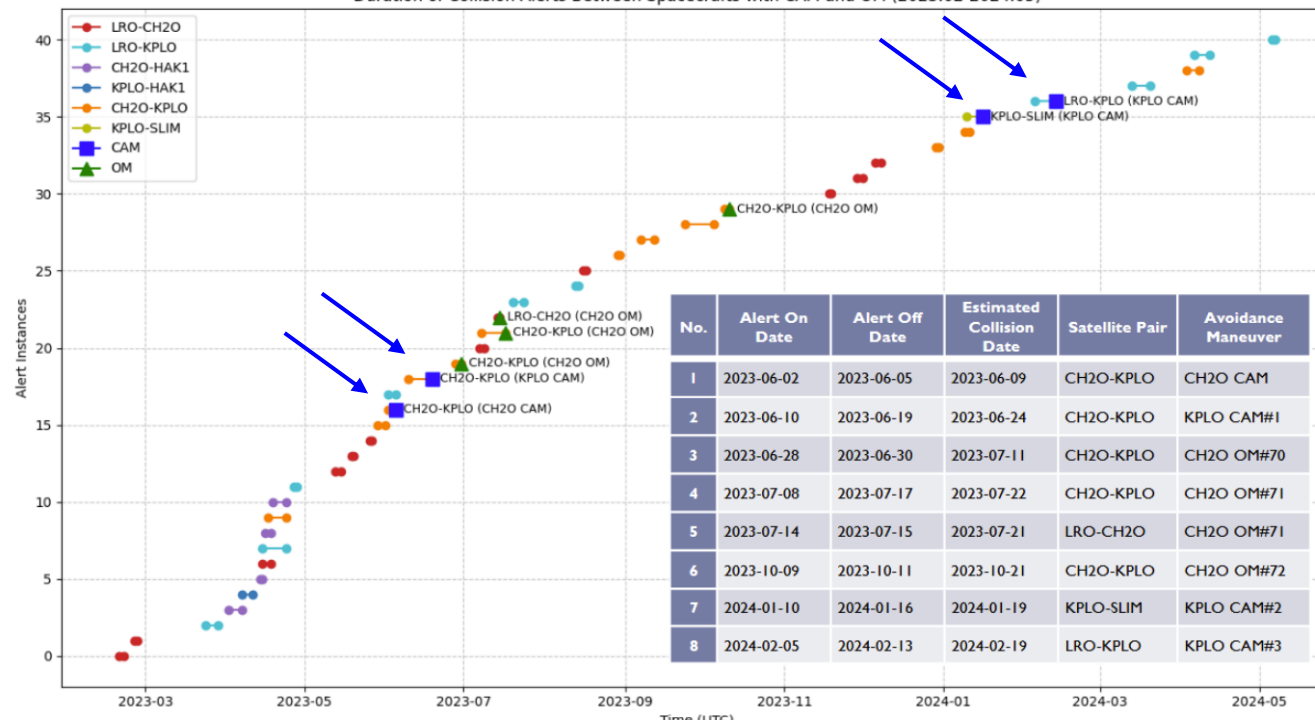
Challenges to be faced:

- Growing **debris risk**: at the current state, only the KPLO performed 4 CAM in less than a year;
- Limitations of **RF** and **EO ground based** methods.



Cislunar Space Domain Awareness (CSDA)

Duration of Collision Alerts Between Spacecrafts with CAM and OM (2023.02-2024.05)

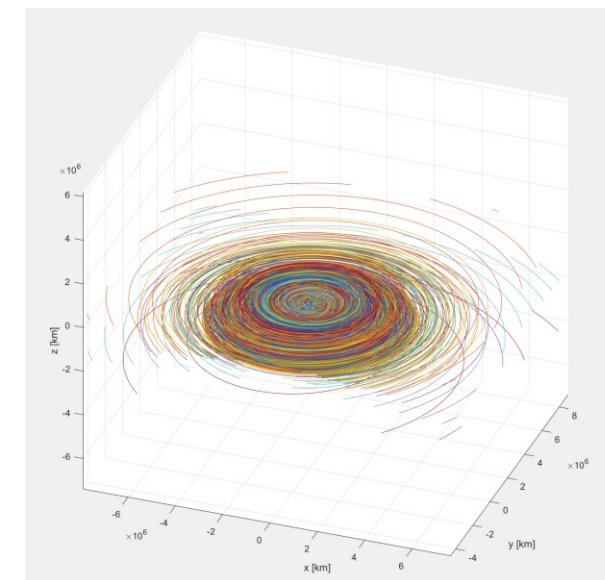
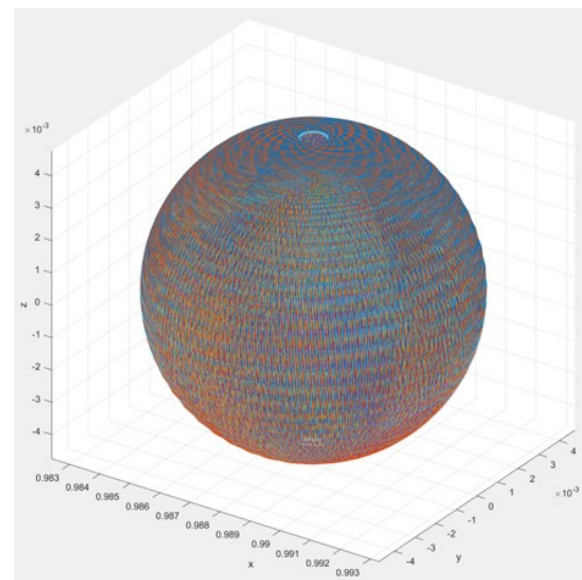
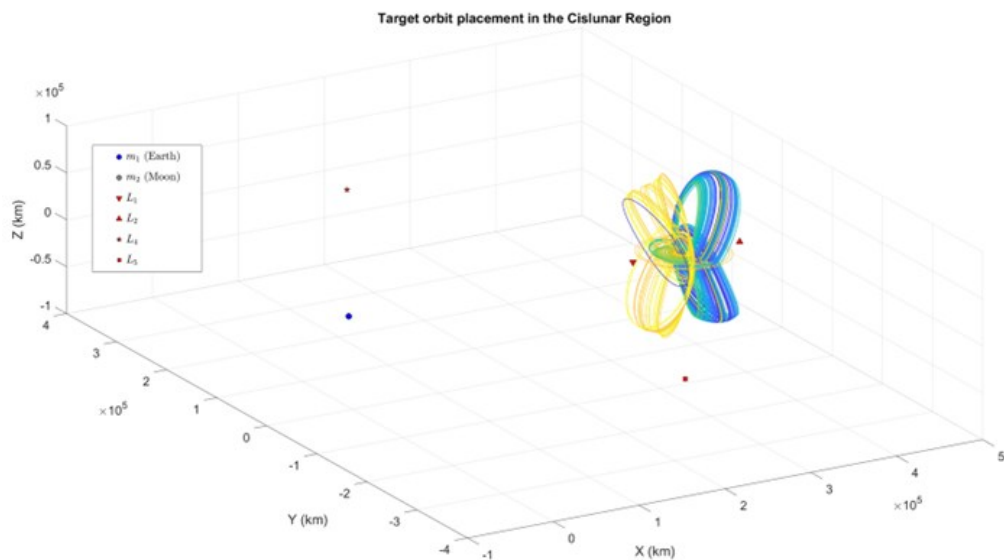


This project work could be divided in the following **main topics**:

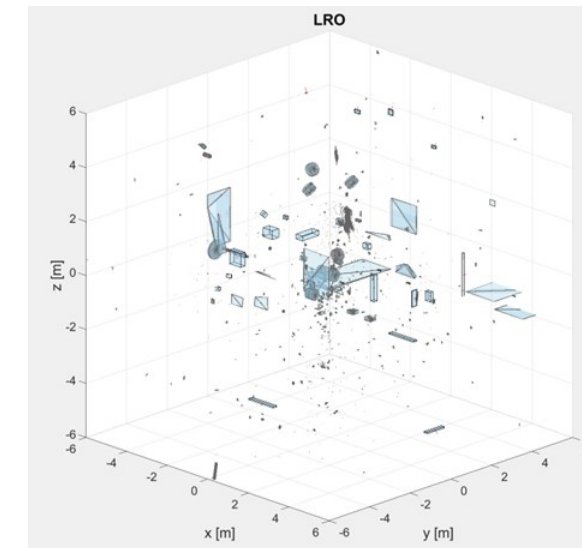
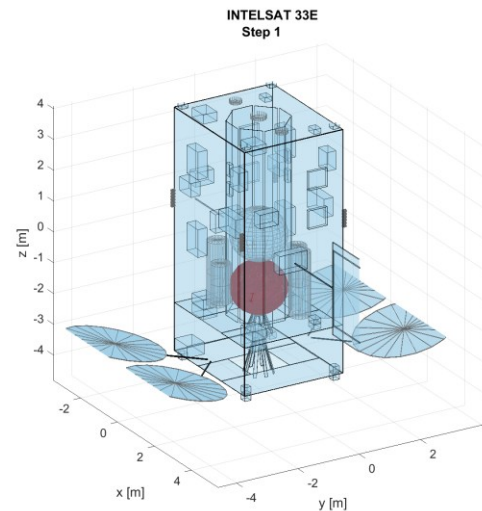
- **Extend SSA concepts** → Adapt and expand Space Situational Awareness to the cislunar domain in alignment with the **Inter-Agency Space Debris Coordination Committee (IADC)**.



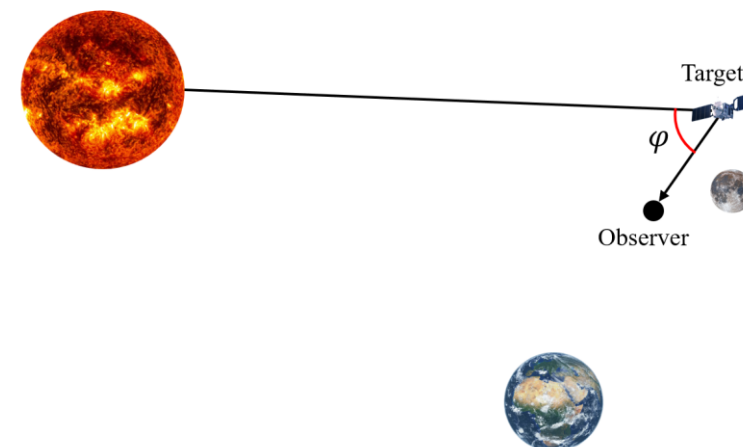
- **Simulate Dynamics** → Model future mission scenarios and build reference orbital populations.



- **Model Fragmentation** → Develop and analyse debris breakup cases in GEO and lunar orbits.



- **Develop Surveillance Infrastructure** → Design space-based and complementary ground-based tracking strategies.



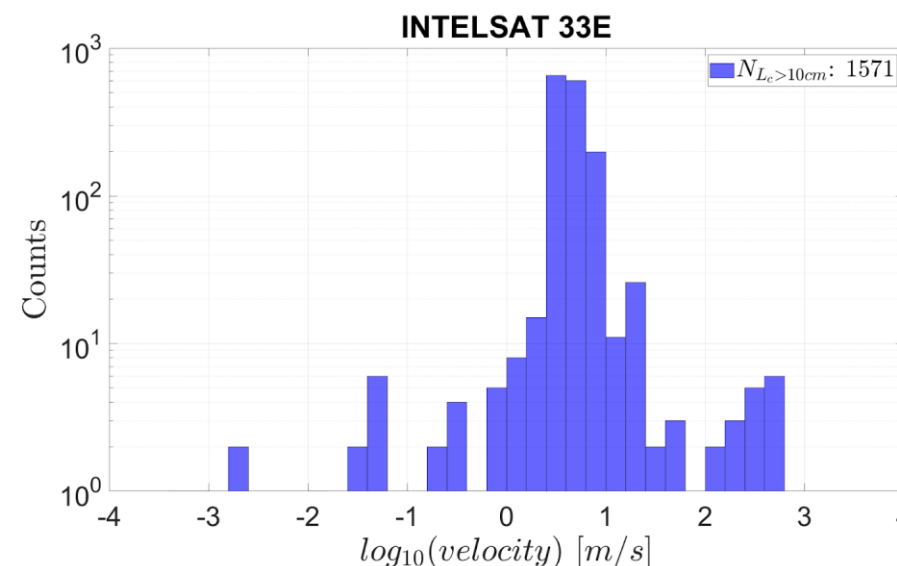
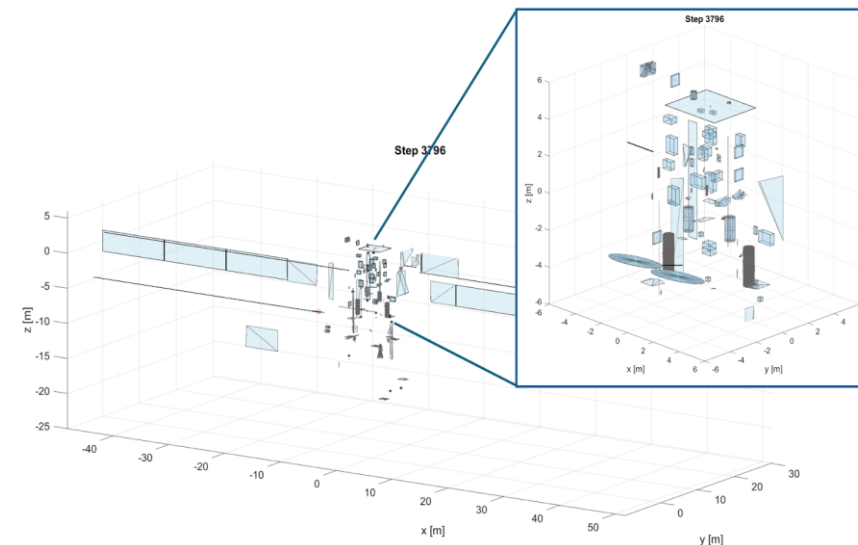
Fragmentation: tank explosion on Oct 19, 2024 → debris estimate ~ 700.

Geometrical model:

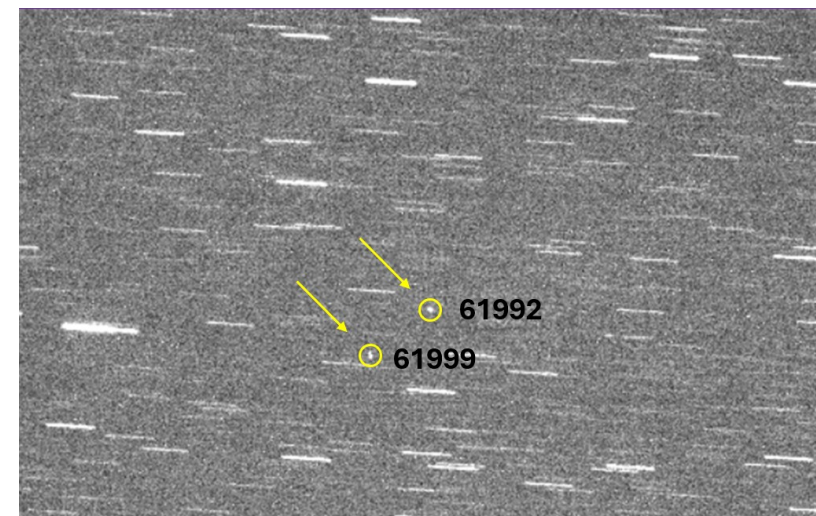
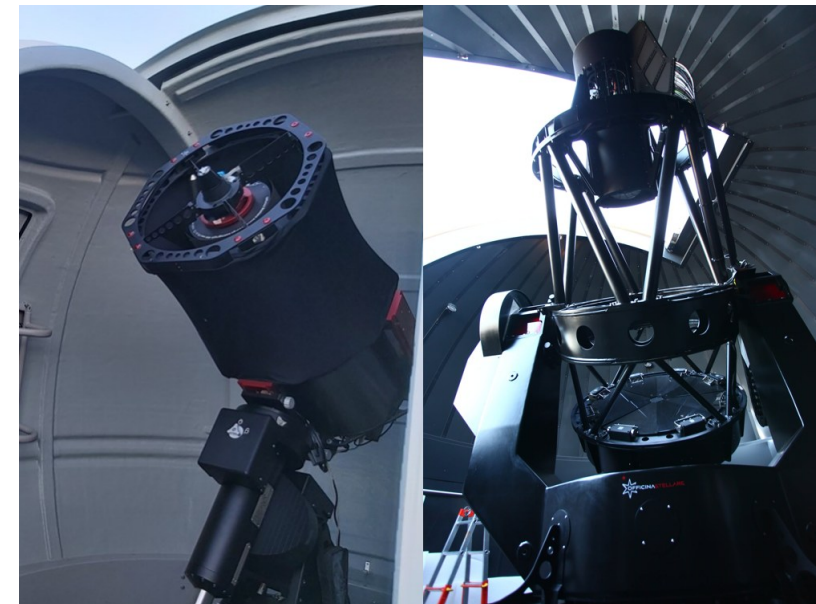
- **Mass:** 6600 kg;
- **Size:** 7.9 × 3.8 × 3.2 m (non-deployed) + ~40 m solar arrays.

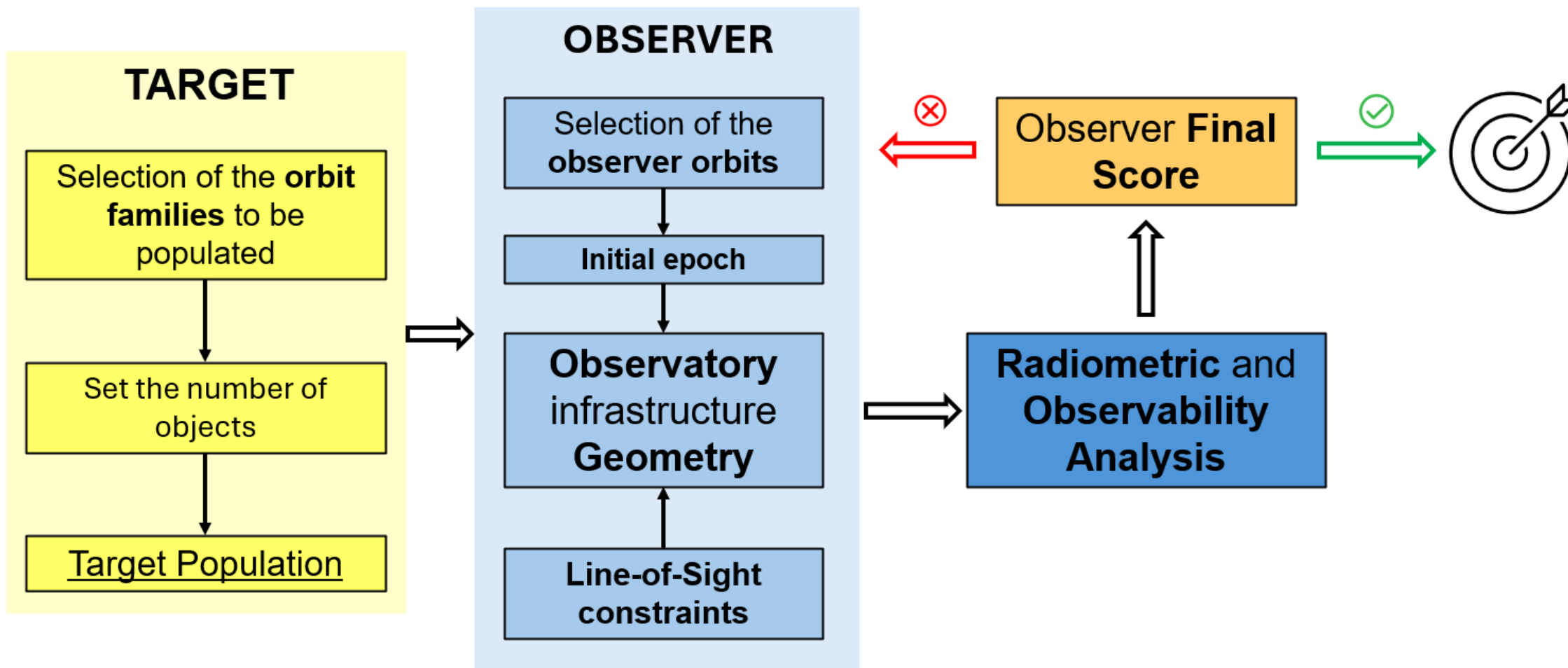
Outcomes:

- ~6000 fragments total → 1566 with $L_c > 10$ cm;
- **Area to mass ratio** (A/m) → different peaks for metallic and sandwich panels;
- **Velocity** → most of debris remains under 10 m/s.



- Fragmentation simulations compared with ground-based observations from the **GAL Hassin Astronomical Center** (Isnello, Sicily).
- Over **60 hours** of observations (2024–2025) targeting 11 IS-33E fragments using GRT and WMT telescopes.
- Preliminary results show **good agreement** between simulated and observed fragments, supporting model validation.

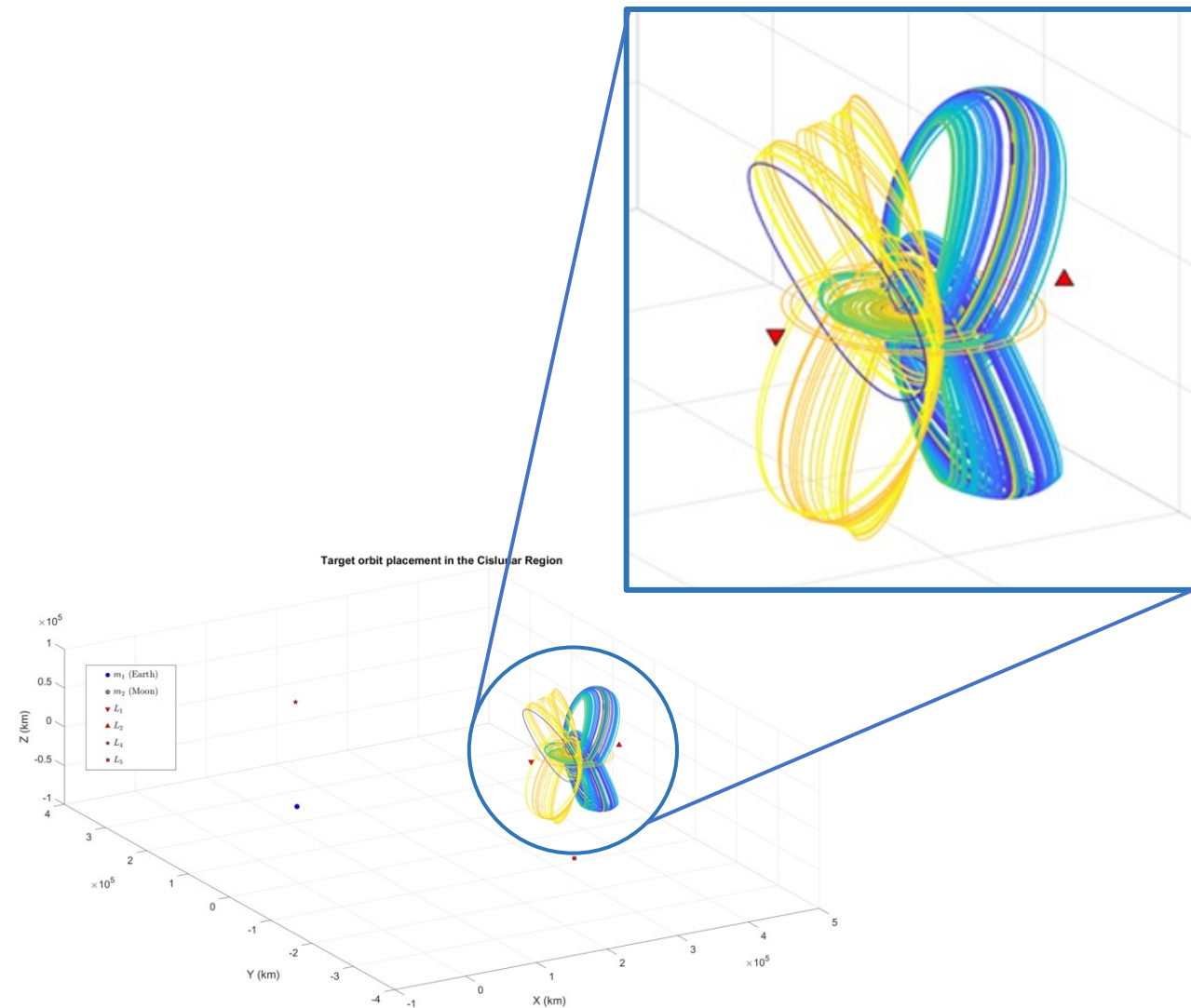




Random Synthetic population

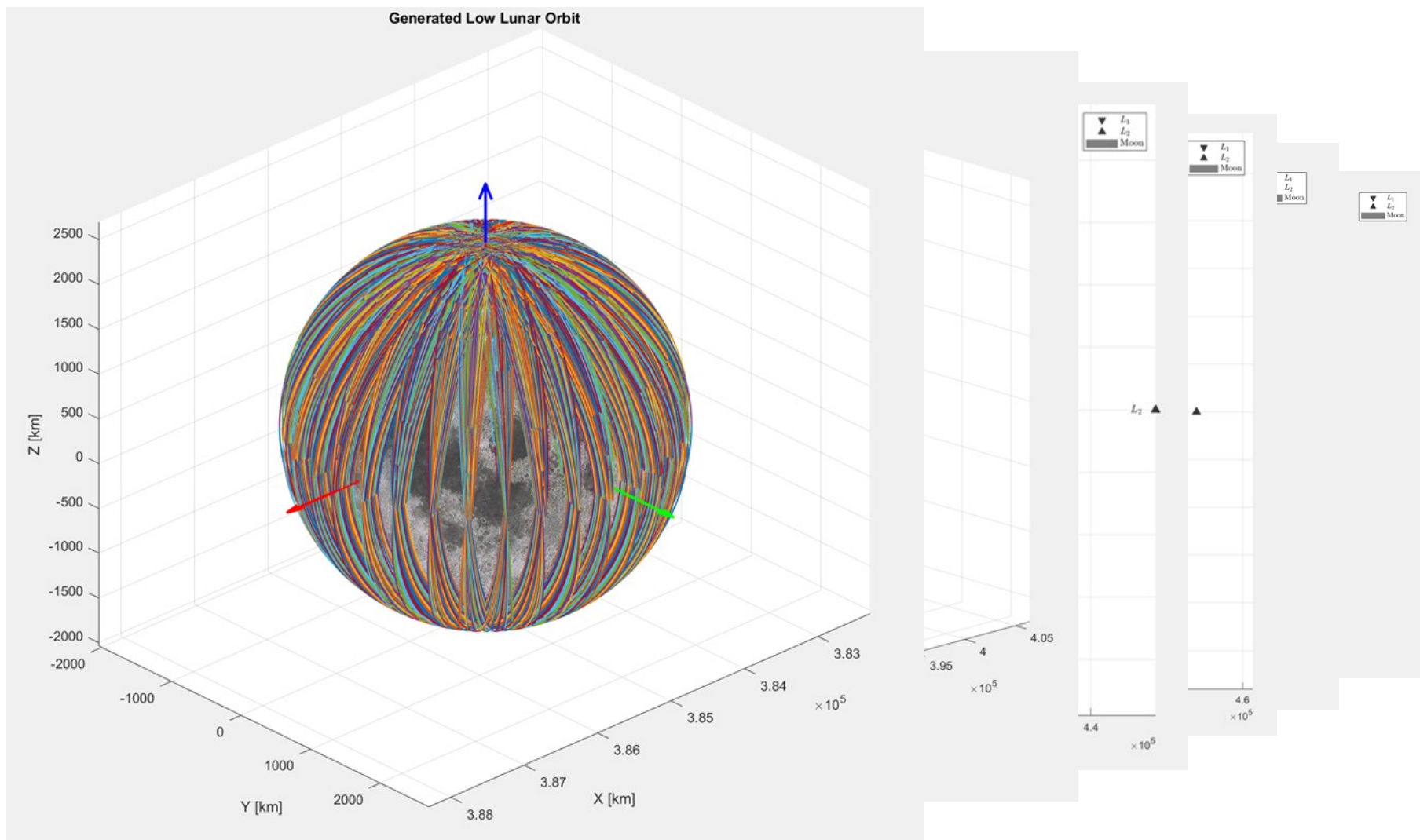
Objects randomly distributed across the orbital regimes expected to become most populated in the coming years:

- Low Lunar Orbits (**LLO**)
- Elliptical Frozen Lunar Orbit (**ELFO**)
- Distant Prograde and Retrograde Orbit (**DPO** and **DRO**)
- **HALO**



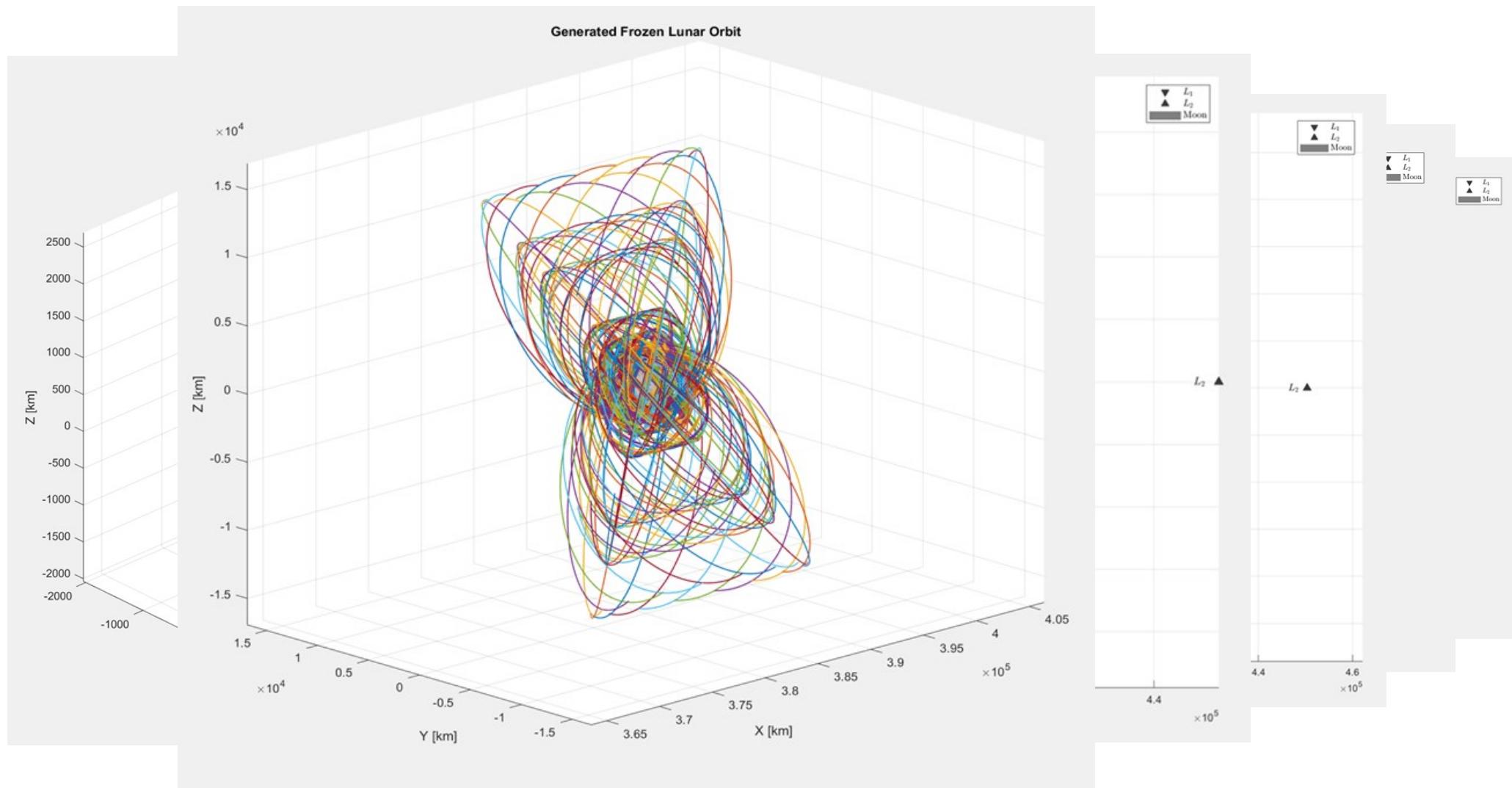


Target Definition: LLO



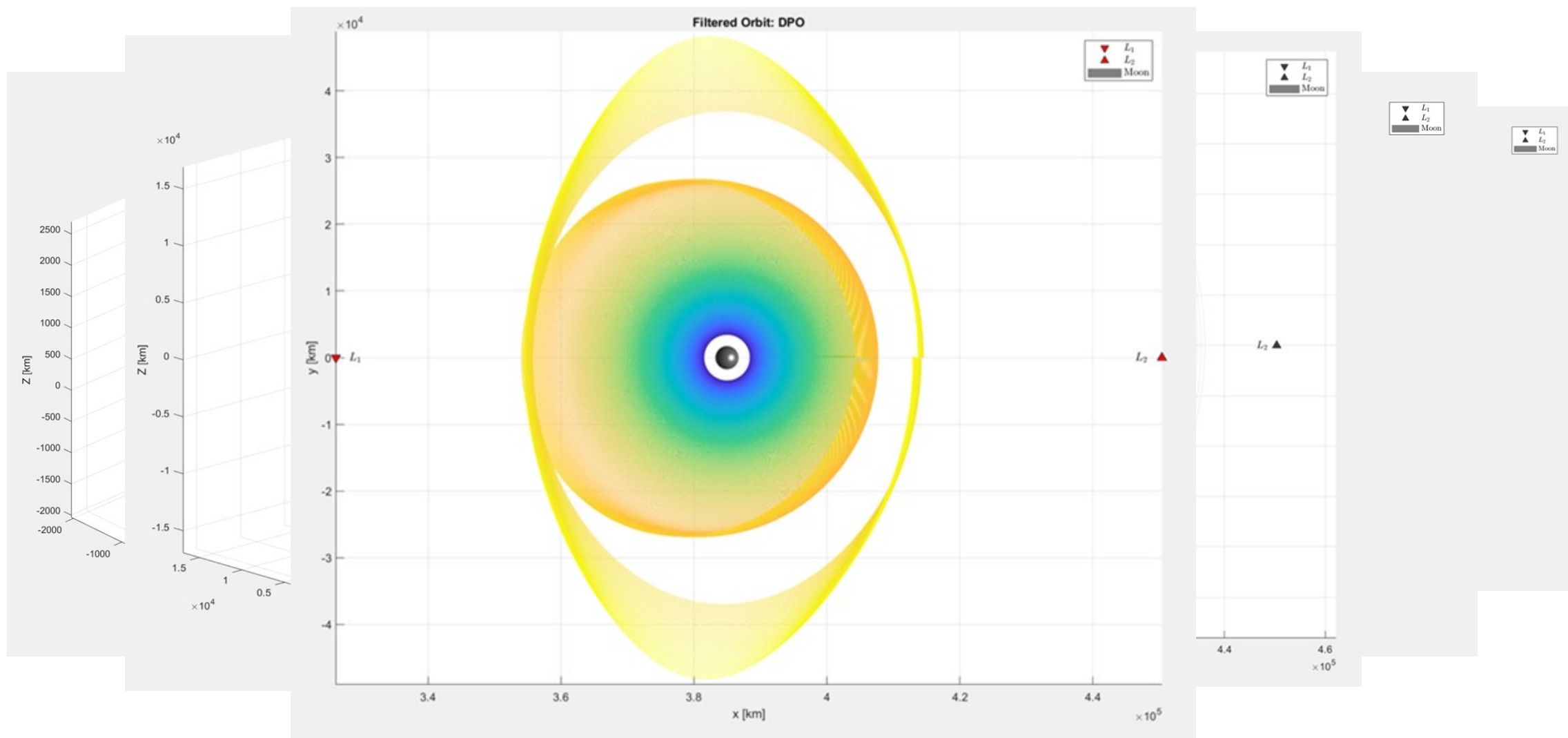


Target Definition: ELFO



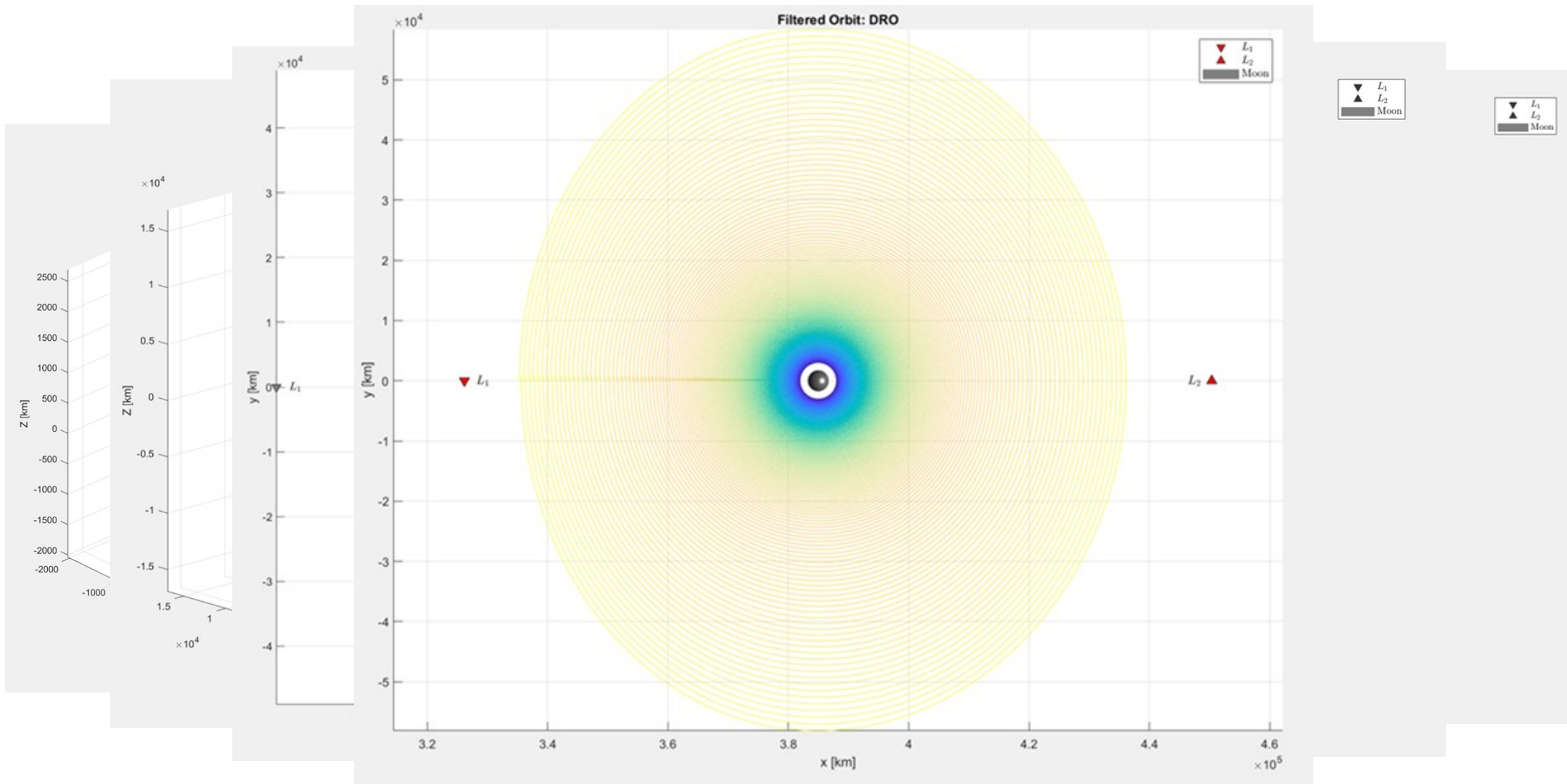


Target Definition: DPO



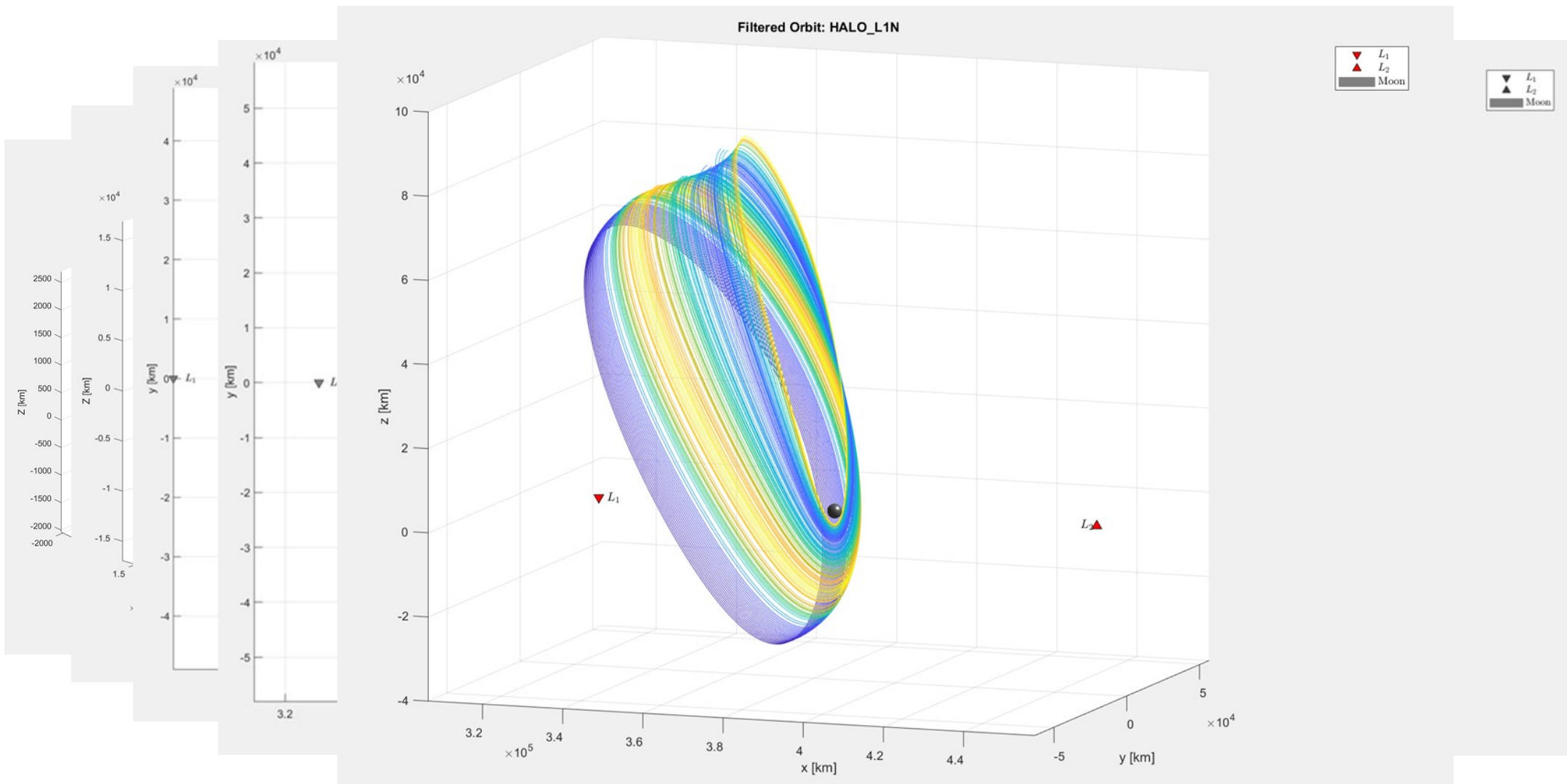


Target Definition: DRO



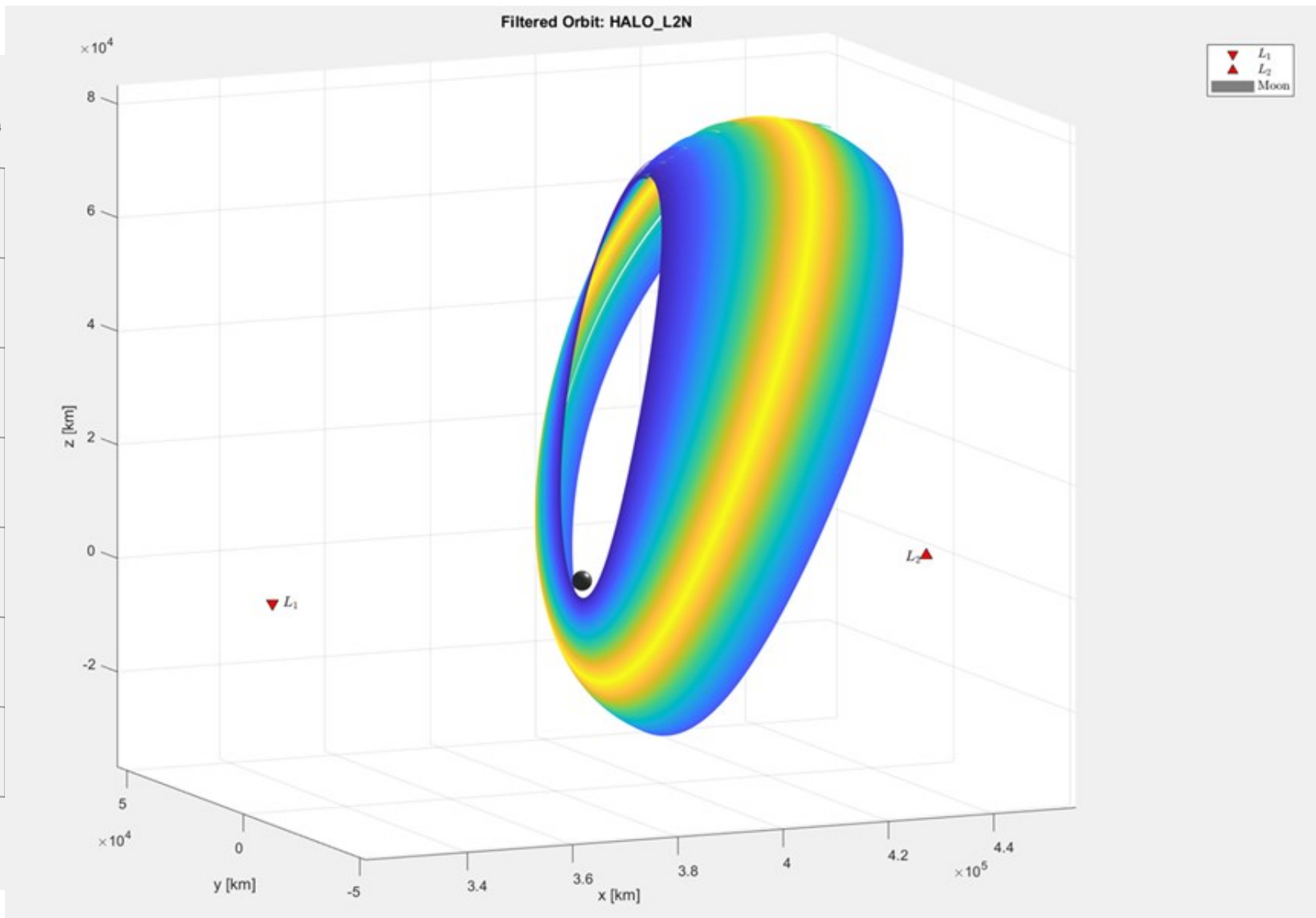
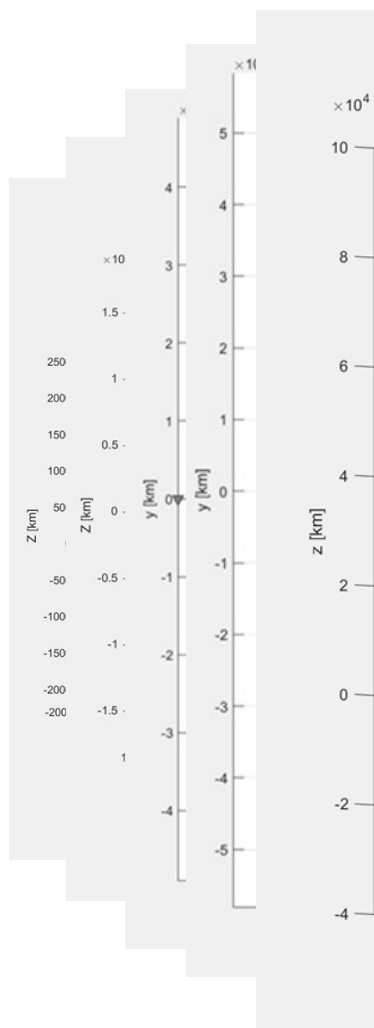


Target Definition: HALO L1



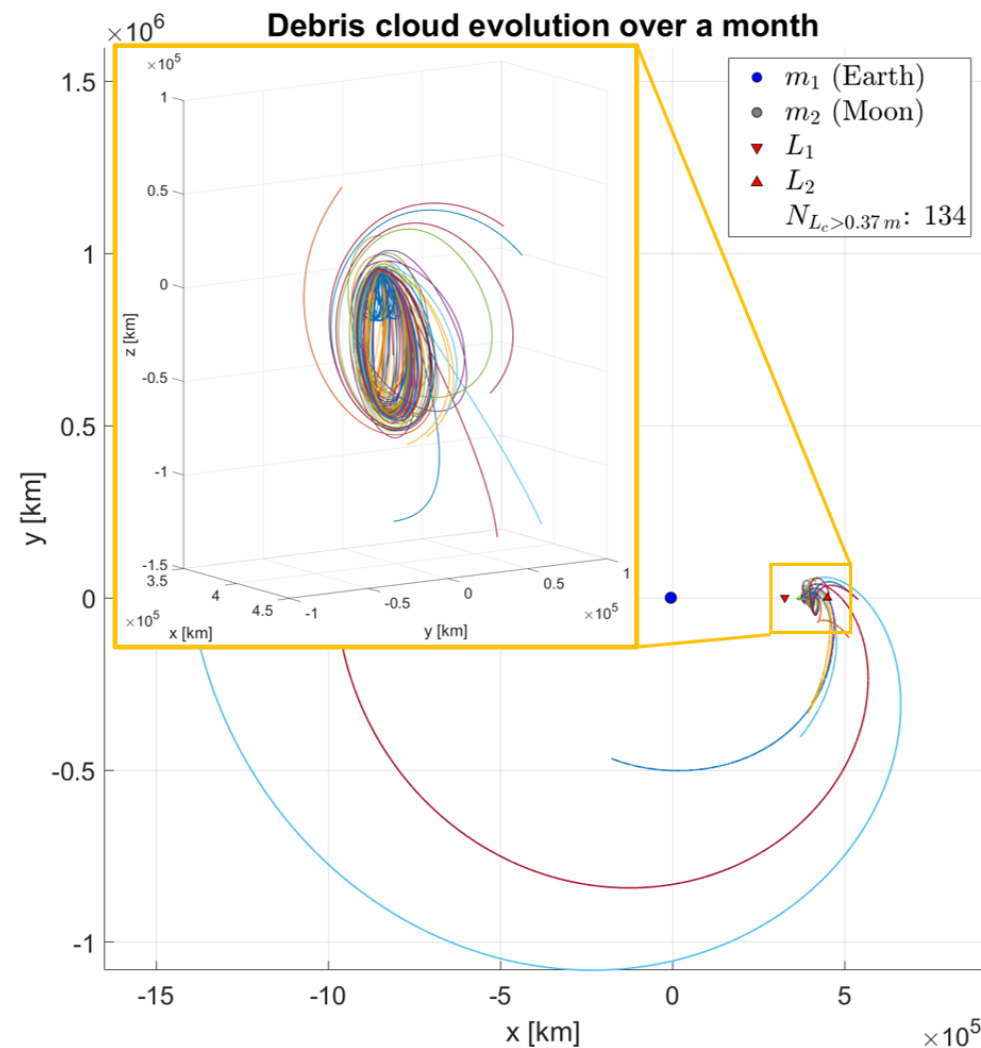
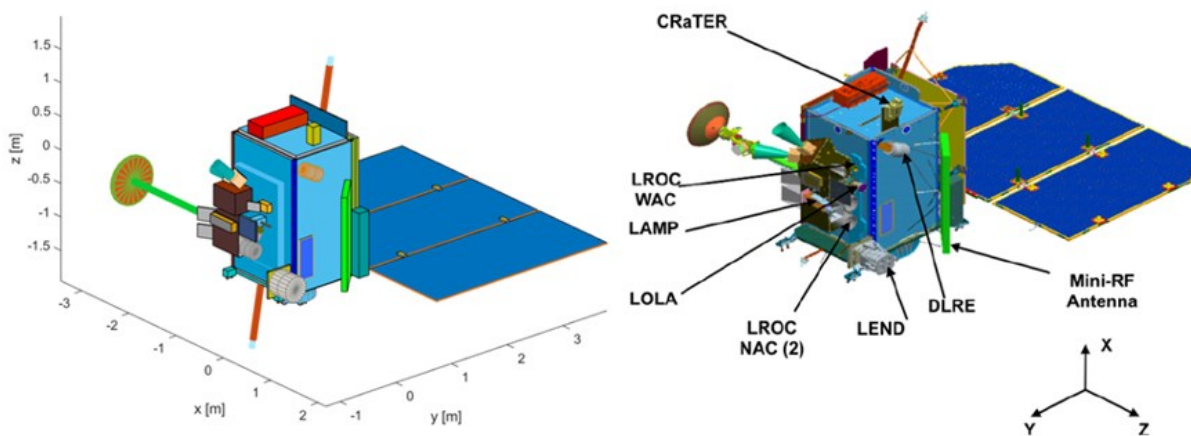


Target Definition: HALO L2



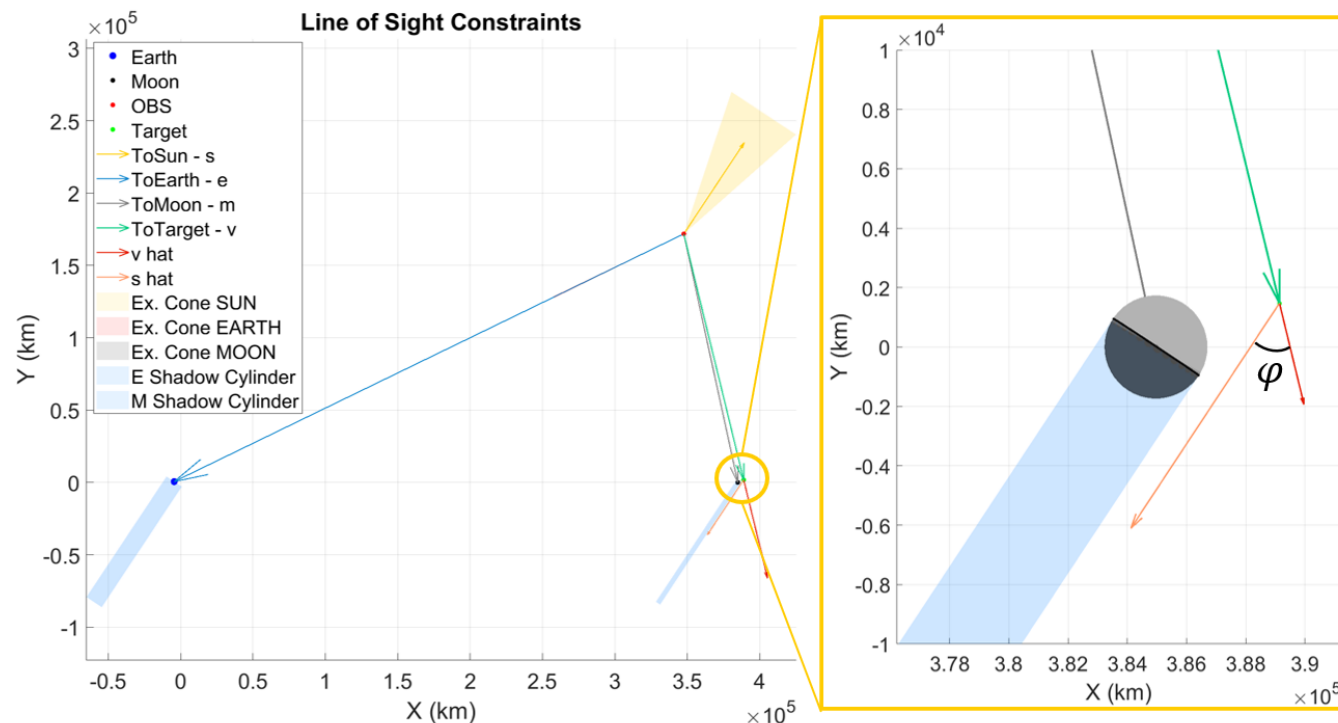
Debris Cloud

- **Object:** Lunar Reconnaissance Orbiter (LRO)
- **Tool:** CSTS
- **Event:** Explosion at perilune of NRHO (9:2 resonance, L2 Halo South)
- **Fragments simulated:** 134 ($L_c > 0.37$ m)



Three **fundamentals conditions** must be satisfied for an observer to detect an objects:

1. The object must lie within the observer's **line of sight**;
2. The object must be **illuminated**;
3. The object must exhibit an **apparent magnitude** above the observer's detection threshold.



**Observers on synodic resonant
DRO and DPO**

Observatory Assessment

Magnitude of Acceptance (MoA:
threshold magnitude for 90% of
detectable objects in line-of-sight)



preliminary observer performance



Signal to Noise Ration analysis



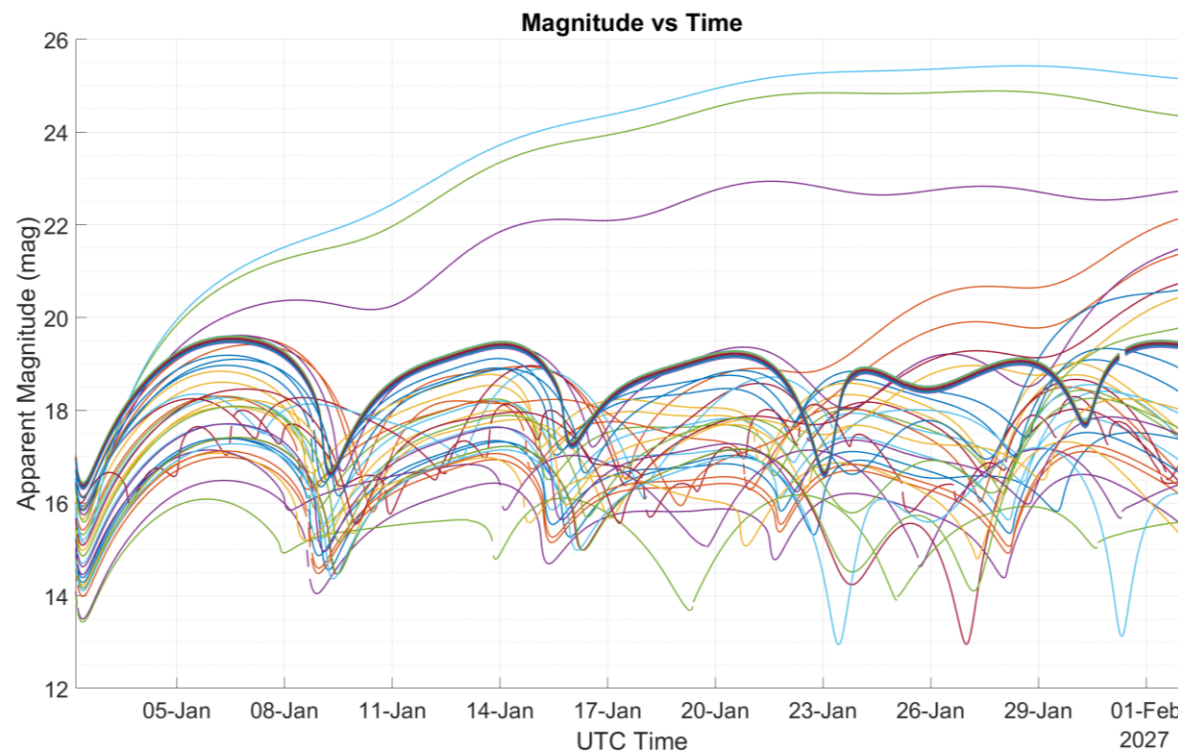
evaluation of actual detectability

Parameter	Value
D [m]	0.1
N	2
p [m]	4e-6
QE	0.85
λ_{avg} [nm]	625
τ_{opt}	0.756
$q_{p_{dark}}$ [e ⁻ /pix/s]	0.0001
σ_r [e ⁻]	1.2
t [s]	5
n	1
I_{sky} [$m_{varcsec}^{-2}$]	22.9

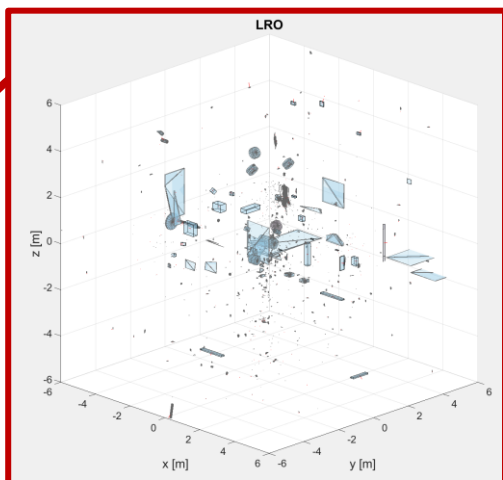
An observer on the **DRO 5:1** demonstrated encouraging results.

Detection capability:

- objects > 0.5 m might be observed with high visibility percentages;
- A limiting apparent magnitude around 20 could be considered a benchmark for future sensors.

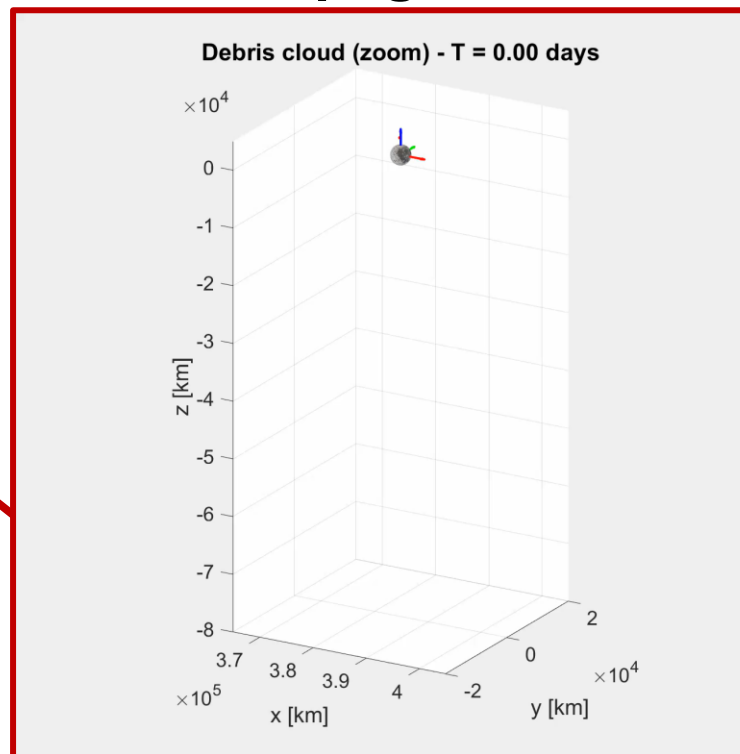


Fragmentation



**Data Post
Processing**

Propagation



**In the Future
Surveillance
Environmental
Assessment
...**



Journal Publications:

- Trabacchin, N., & Colombatti, G. (2025). Design of an Orbital Infrastructure to Guarantee Continuous Communication to the Lunar South Pole Region. *Aerospace*, 12(4), 289. <https://doi.org/10.3390/aerospace12040289>.
- Li, G., Wang, X., Yang, Y., Pastorello, A., Reguitti, A., Valerin, G., ... & Li, W. (2025). Optical and Near-infrared Observations of SN 2023ixf for over 600 days after the Explosion. arXiv preprint arXiv:2504.03856.

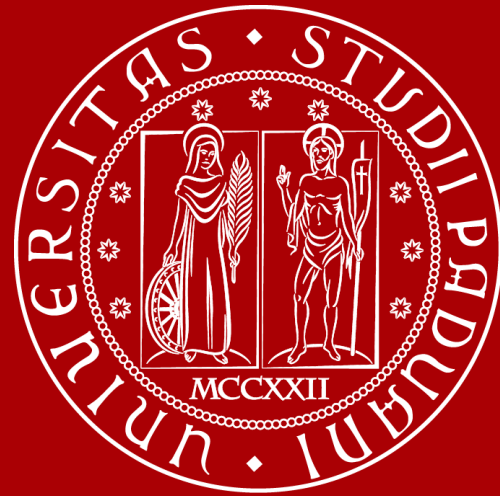
Conference Articles:

- Trevisanuto, G., Enzo, S., Trabacchin, N., Anese, G., Valmorbida, A., Bettanini, C., & Lorenzini, E. (2025). Possible applications of spinning tethered systems for Earth and Moon observation: an overview. In Proceedings of the 15th IAA Symposium on Small Satellites for Earth System Observation 2025 (SSEO15).
- Trabacchin, N., Armellin, R., Akniyazov, C., Olivieri, L. & Colombatti, G. (2025). Towards Effective Space Situational Awareness in Cislunar Space: Orbital Characterization and Electro-Optical sensor design. 76th International Astronautical Conference, Sydney.
- Trabacchin, N., Tasso, P., Giacomuzzo, C., Olivieri, L., Biagini, A. & Nastasi, A. (2025). Investigating the fragmentation of INTELSAT 33E in GEO orbit. 76th International Astronautical Conference, Sydney.

Classification of a Transient:

- Classification of TCP J17374270+4915116 into Central Bureau for Astronomical Telegrams.

Thanks for your attention!



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