High-precision Analyser for Lunar Orbits (HALO)

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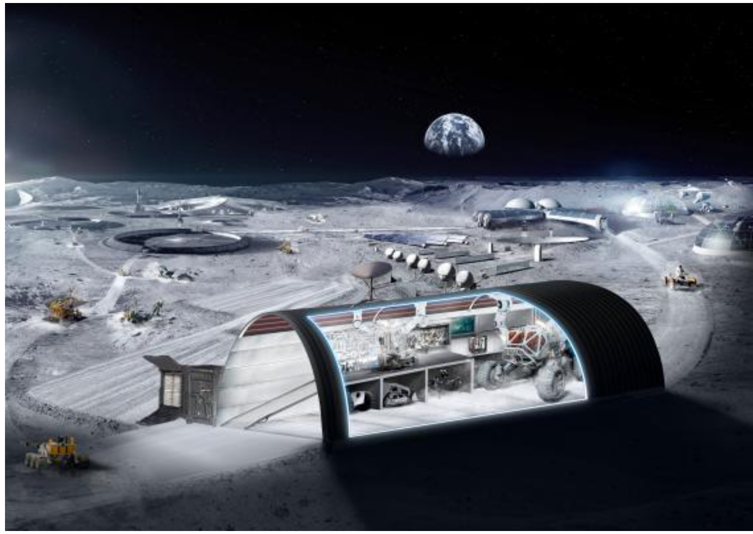
Moon to Mars Initiative

Artemis human exploration program
& Australia's contribution to Artemis



Trailblazer Program
Australian-made rover, **Roo-ver**

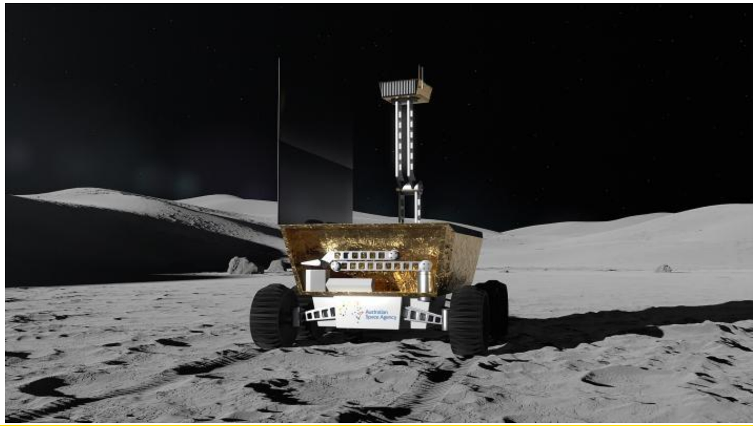


Image credit: [Australian Space Agency]

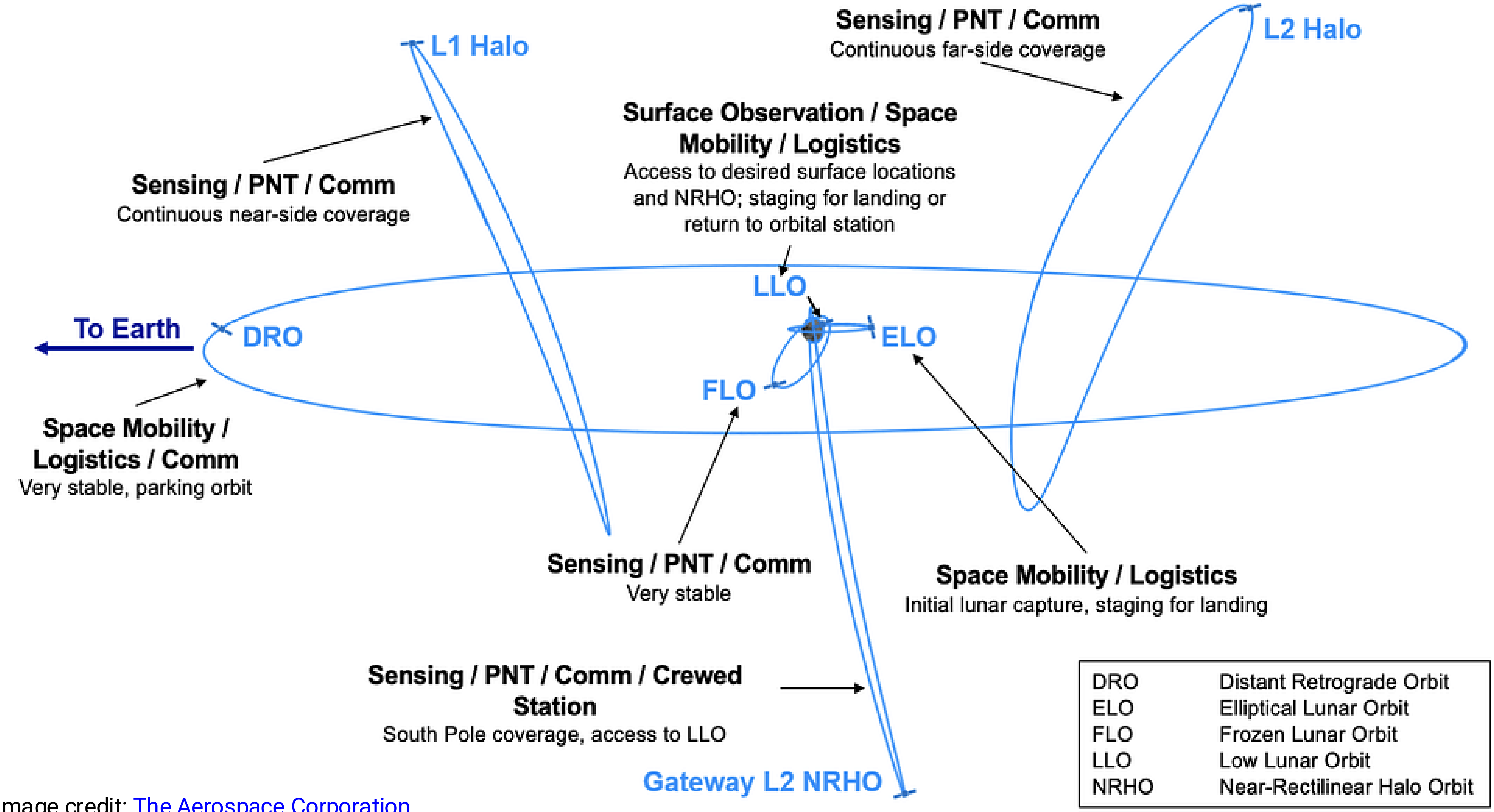
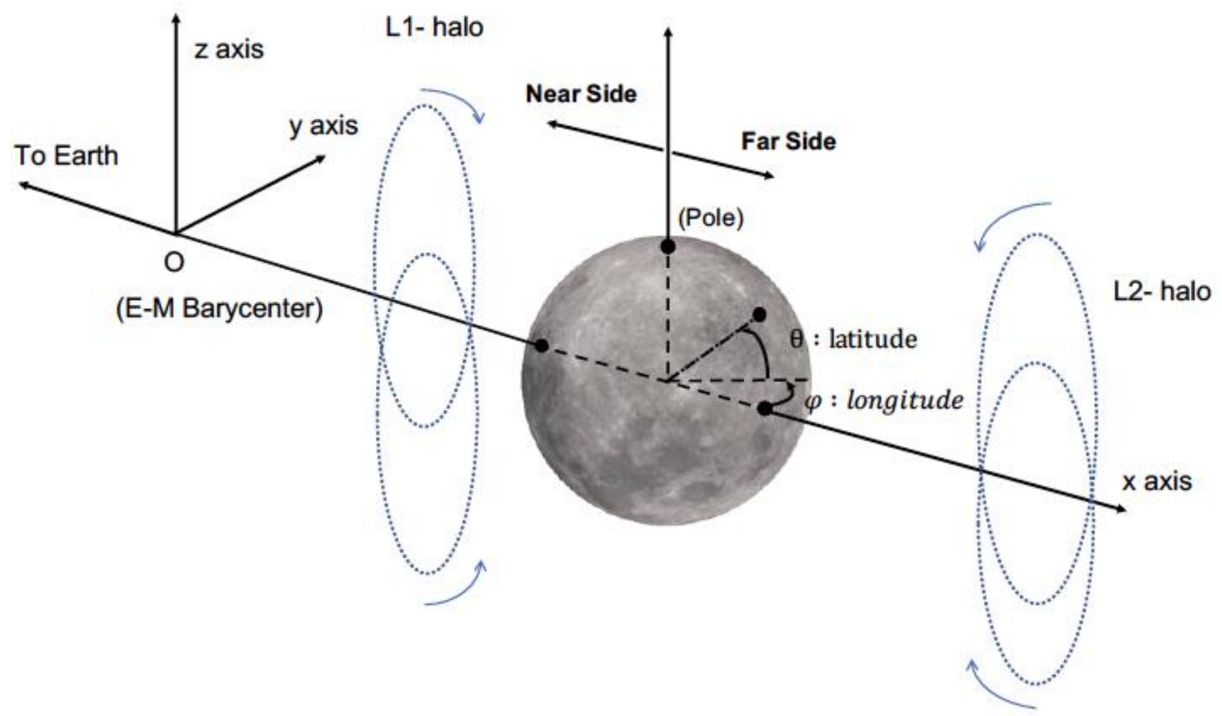


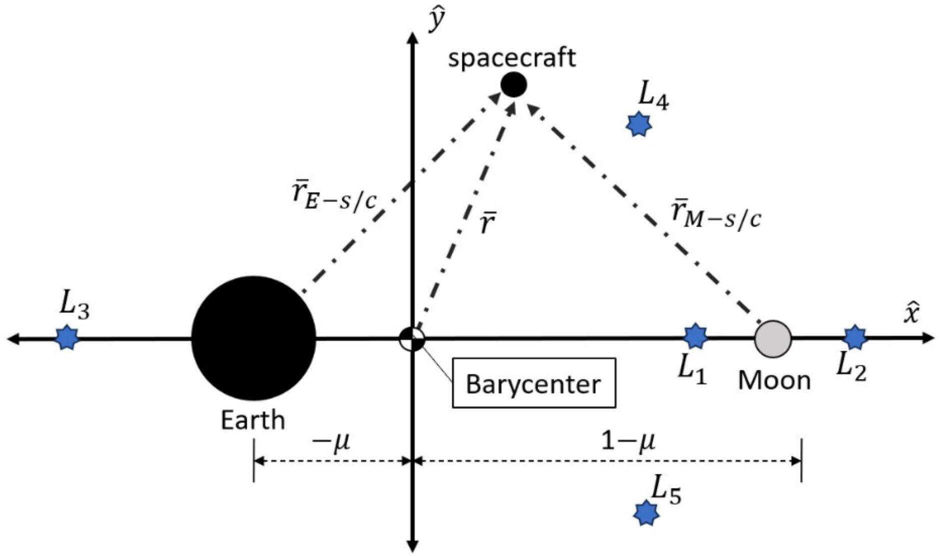
Image credit: The Aerospace Corporation

Coordinate Systems



Earth-Moon rotating frame
(image credit: Keidai Ilyama 2019)

- **Earth-Moon rotating frame**



CR3BP model in the Earth-Moon rotating frame
(image credit: Marta Lopez Castro)

- **Moon centred rotating frame**
- **Moon centred inertial frame**

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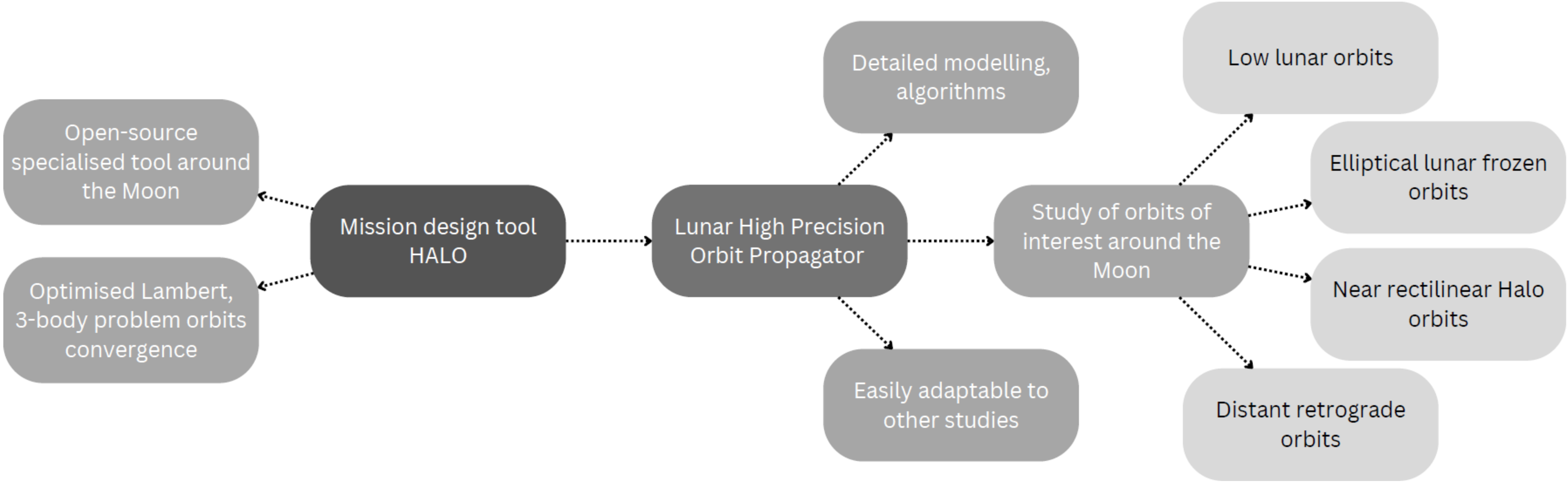
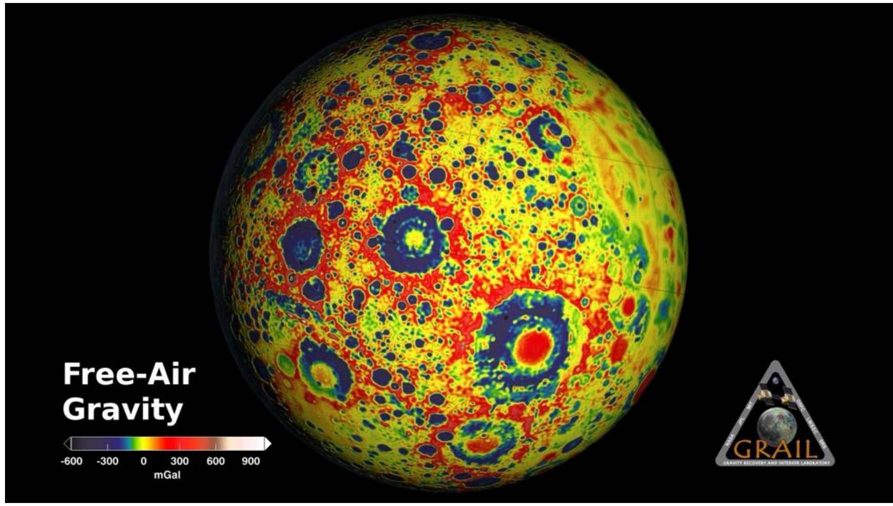


HALO functionalities

Force Models

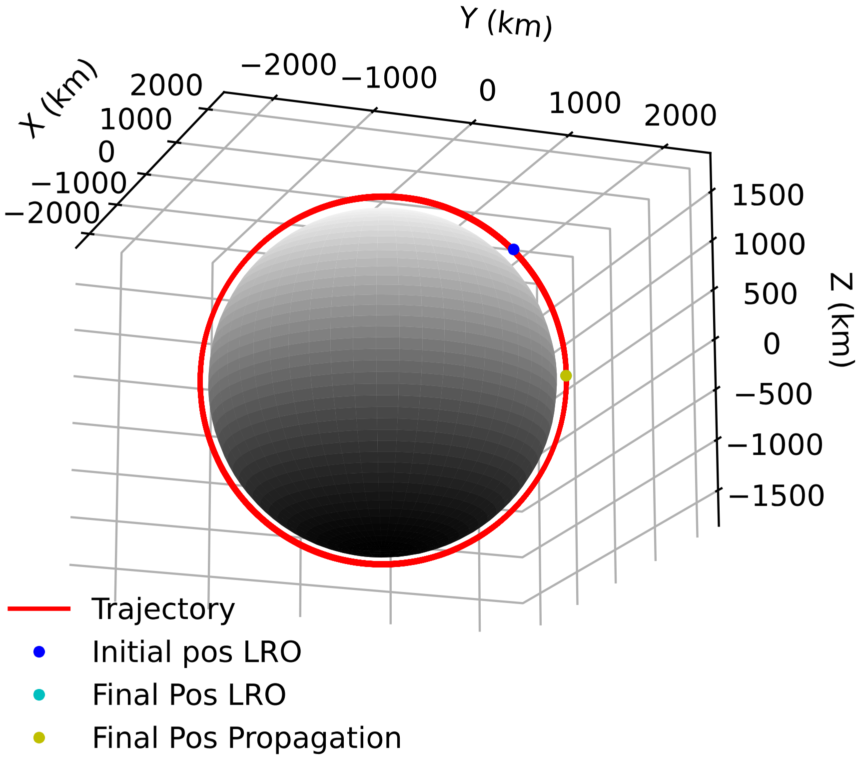
- **Field forces**
  - **Lunar gravitational field:** 350 × 350 harmonics model from the GRAIL mission
  - **Point mass attraction:** Sun and Jupiter, JPL DE430
  - **Earth gravitational attraction:** 100 × 100 harmonics model, EGM2008
  - **General relativistic correction**
- **Surface forces**
  - **Solar radiation pressure:** spherical satellite geometry
  - **Earth albedo**



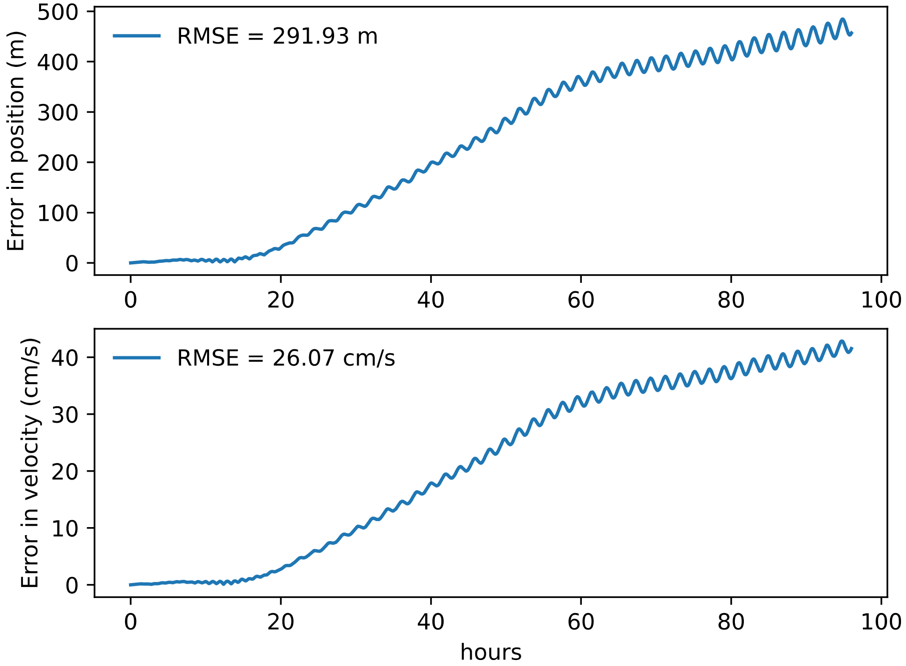
Lunar gravity model by the GRAIL mission

Assessments in Low Lunar Orbit

Lunar Reconnaissance Orbiter (LRO): perilune 60 km and apolune 130 km
Scenario : February 1, 2020, over a four-day window, ~48 orbit rev
Reference orbit: [Horizons System (nasa.gov)]()

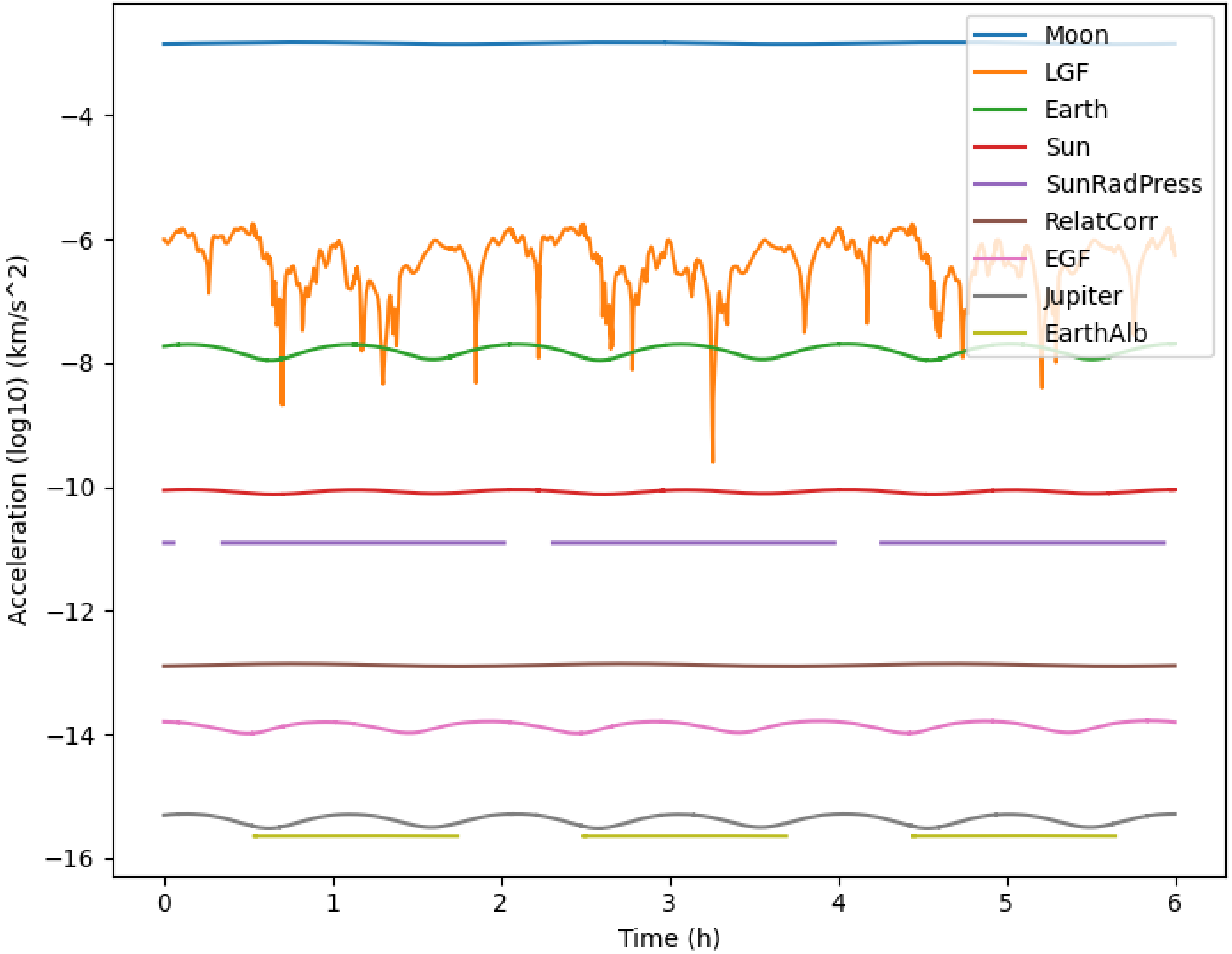


LRO Trajectory in the Moon centered inertial frame



Propagation errors compared to the LRO reference orbit

Assessments in Low Lunar Orbit

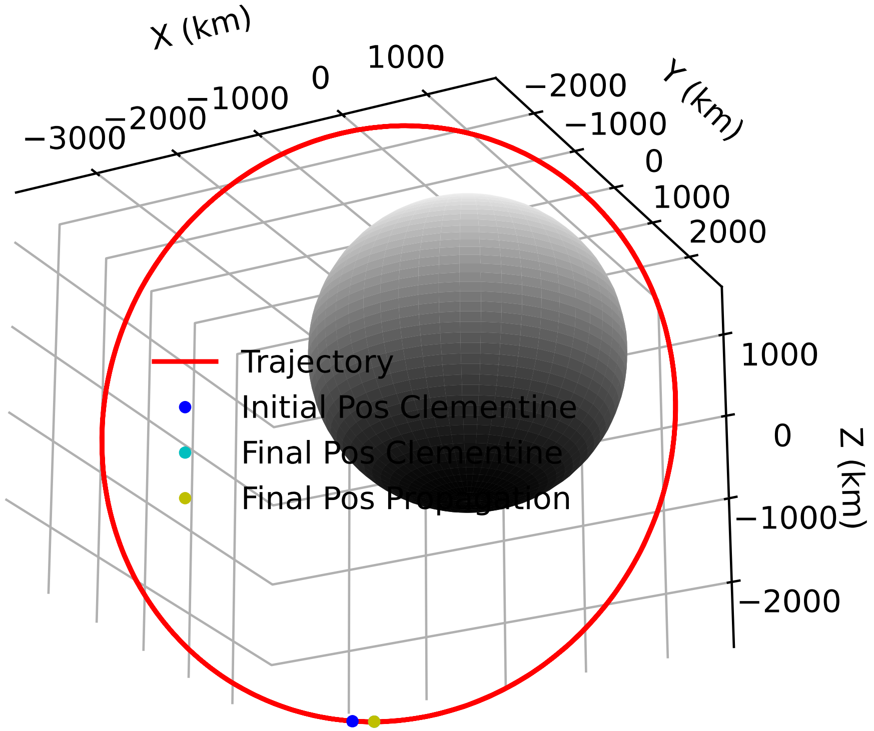


Magnitudes of perturbations for LRO in LLO

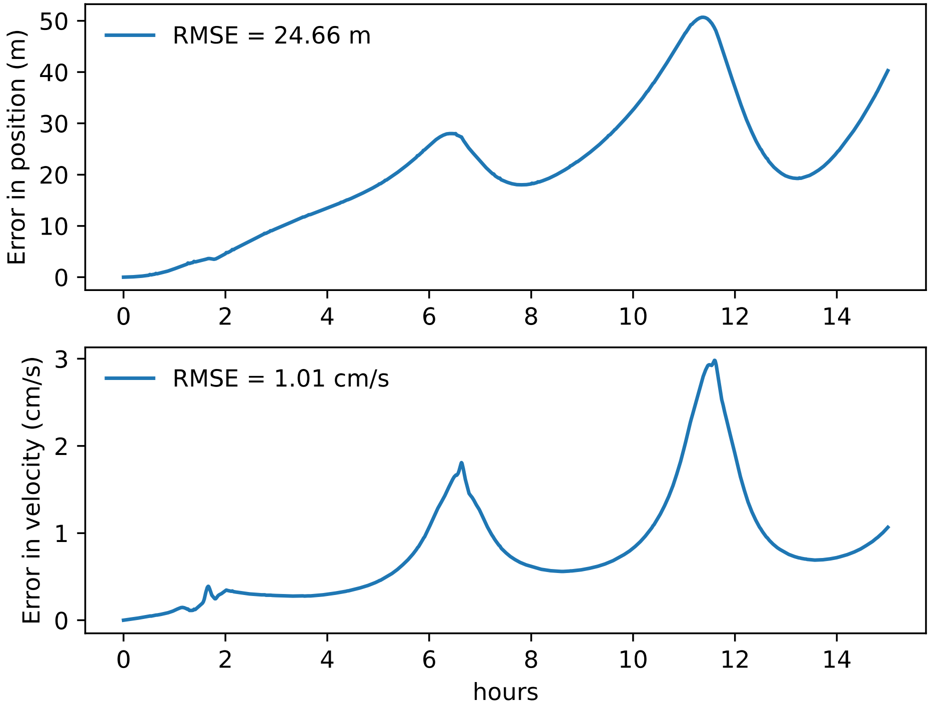
Assessments in Elliptical Lunar Polar Orbit

Clementine: perilune 415 km, and apolune 2939 km
Scenario: 15-hour time span on April 15, 1994 (three orbit rev)


Clementine spacecraft
(Image Credit: NASA)

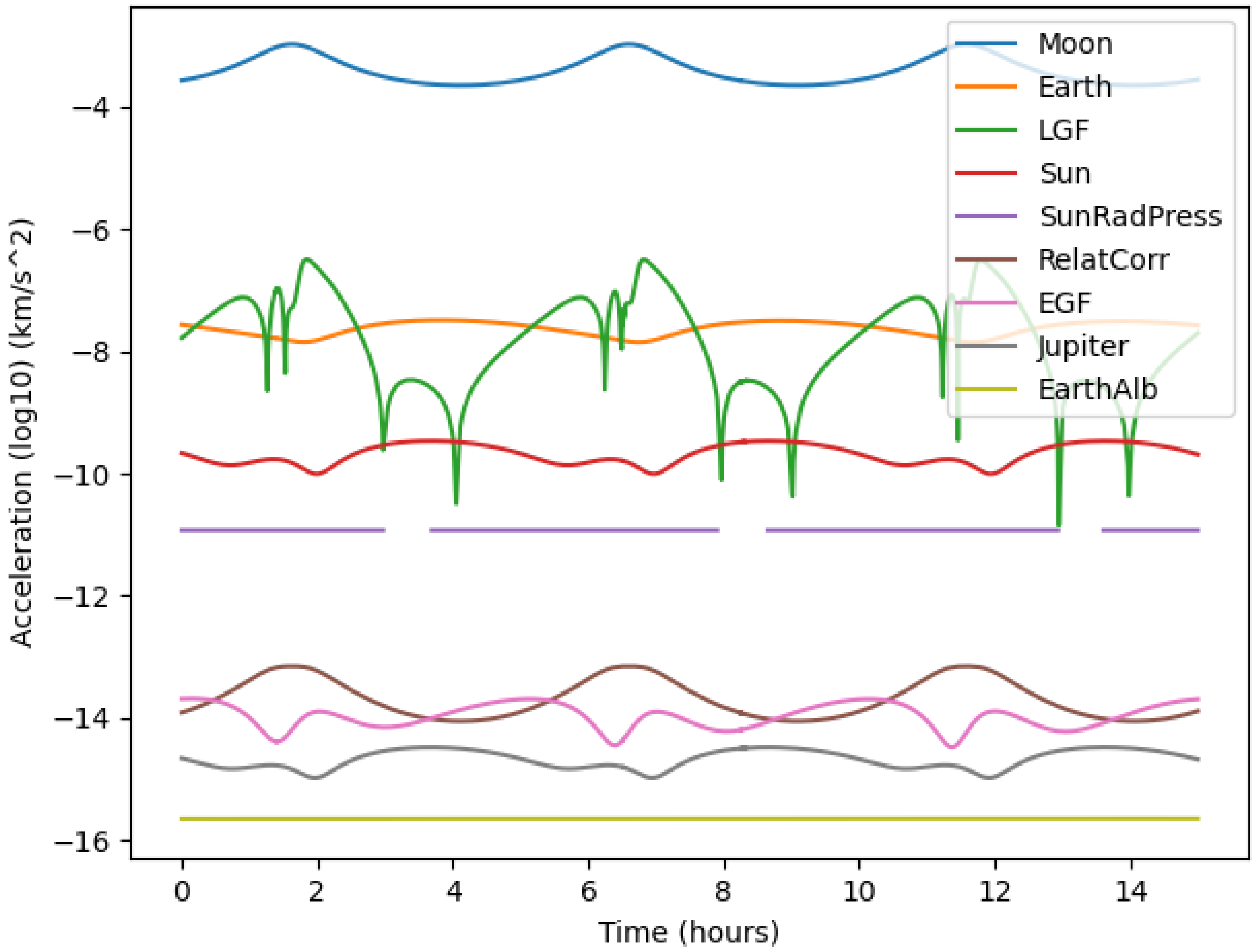


The Clementine spacecraft in the Moon centered inertial frame



Propagation errors compared to the Clementine reference orbit

Assessments in Elliptical Lunar Polar Orbit

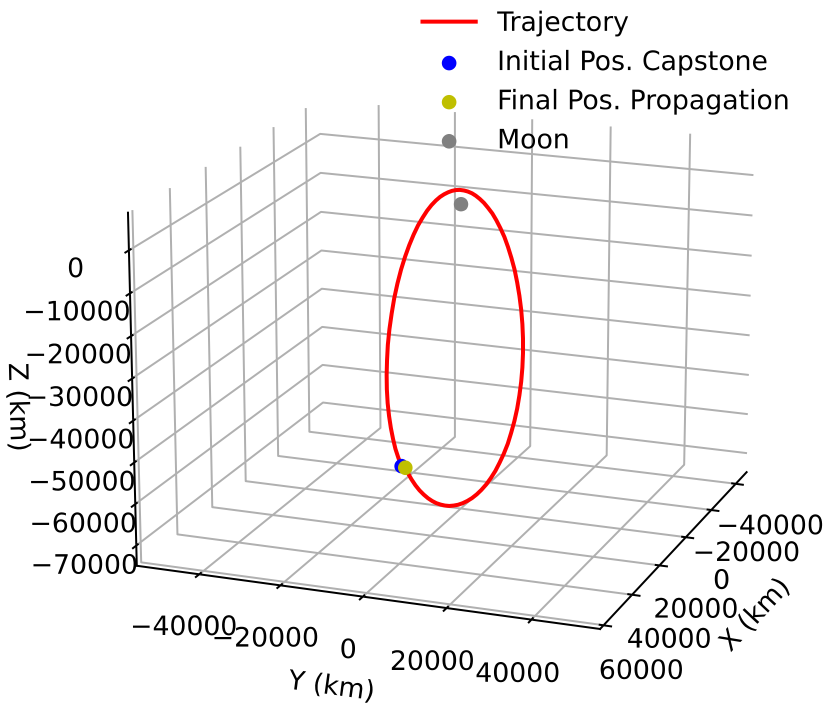


Magnitudes of perturbations for Clementine in the elliptical lunar orbit

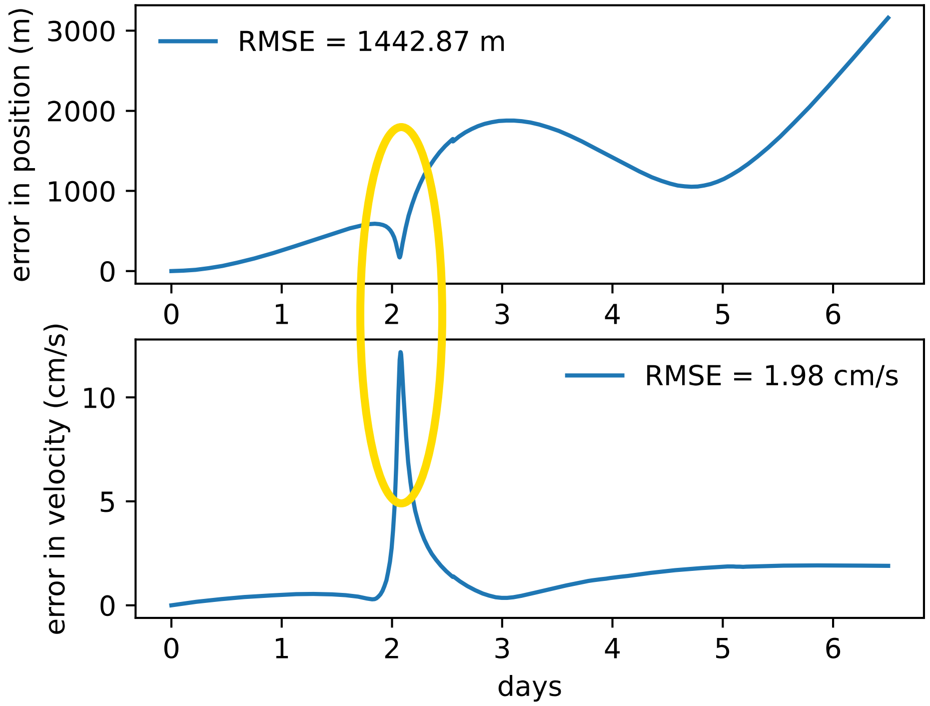
Assessments in Near Rectilinear Halo Orbit

CAPSTONE: 9:2 synodic resonance, perilune 1,610km and apolune 69,918 km
Scenario: time span of 6.5 days from 25 November 2022, ~ 1 orbital rev


CAPSTONE CubeSat
(Image Credit: Advanced Space)

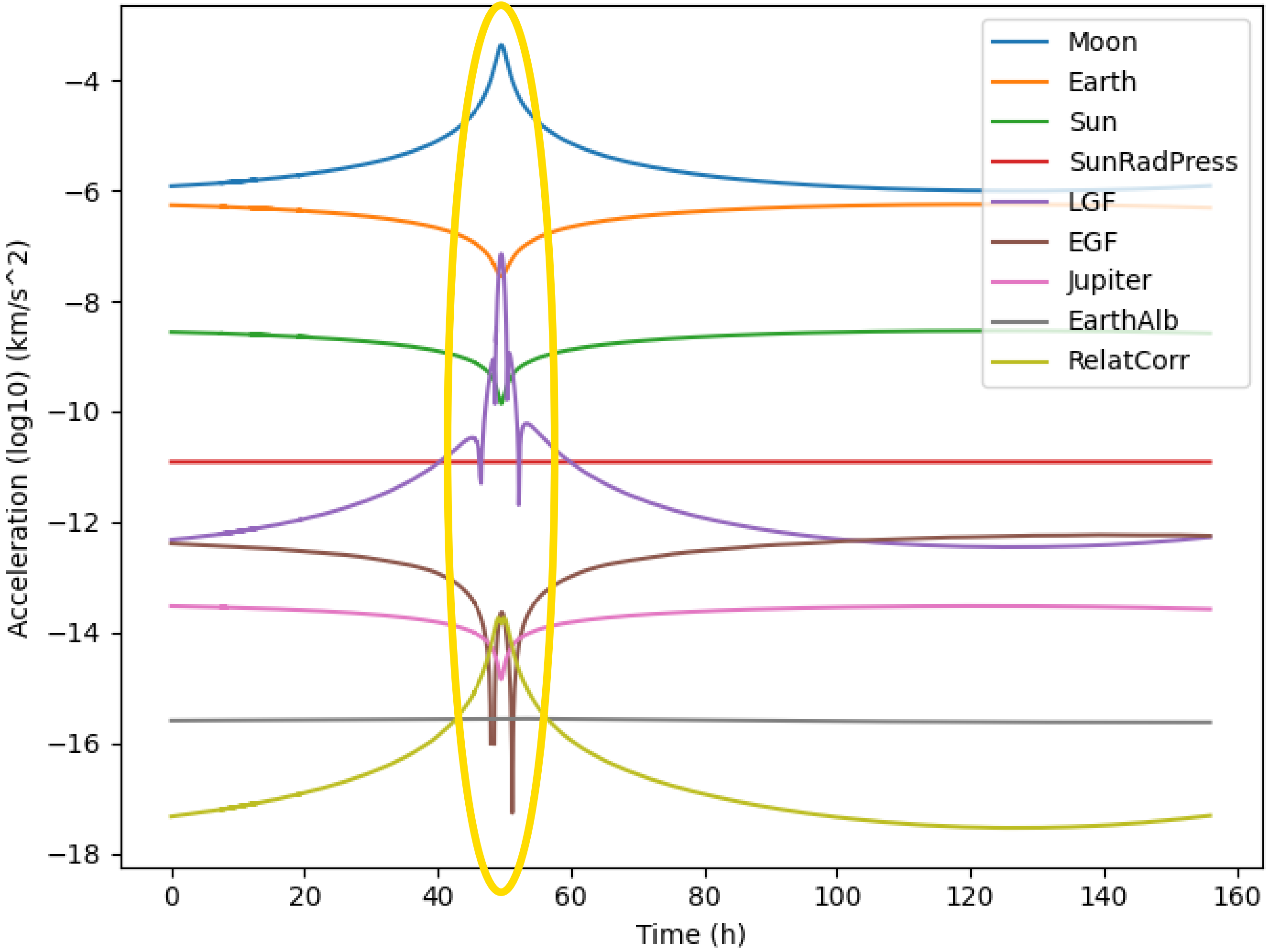


CAPSTONE trajectory in the Moon centred rotational frame



Propagation errors compared to the CAPSTONE reference orbit

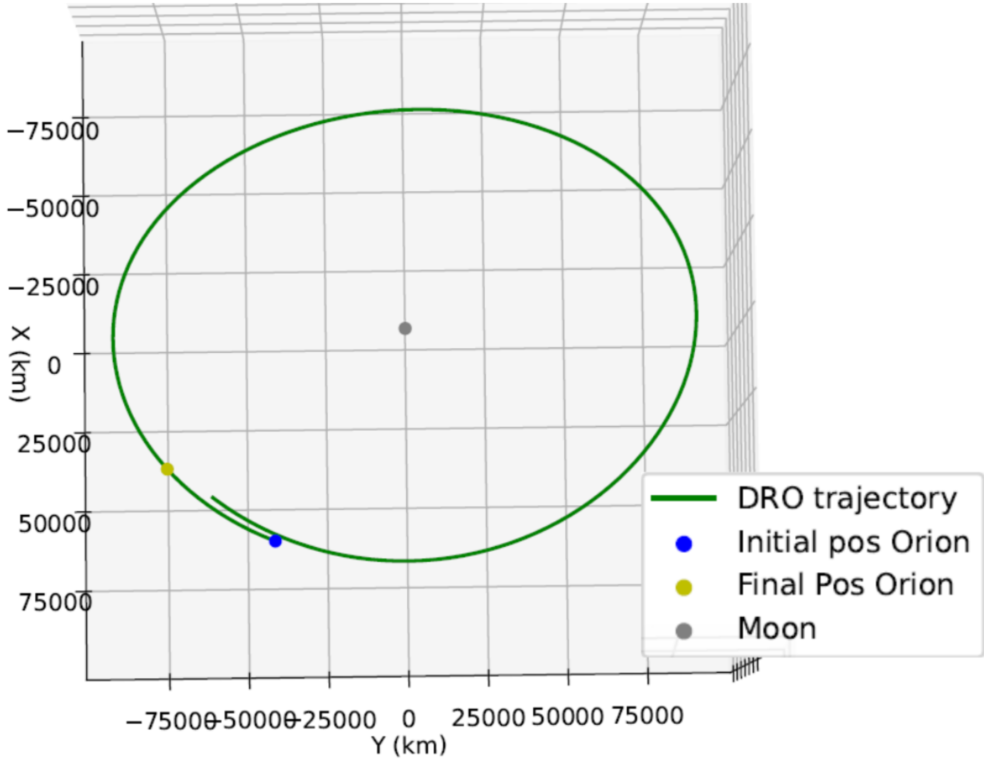
Assessments in Near Rectilinear Halo Orbit



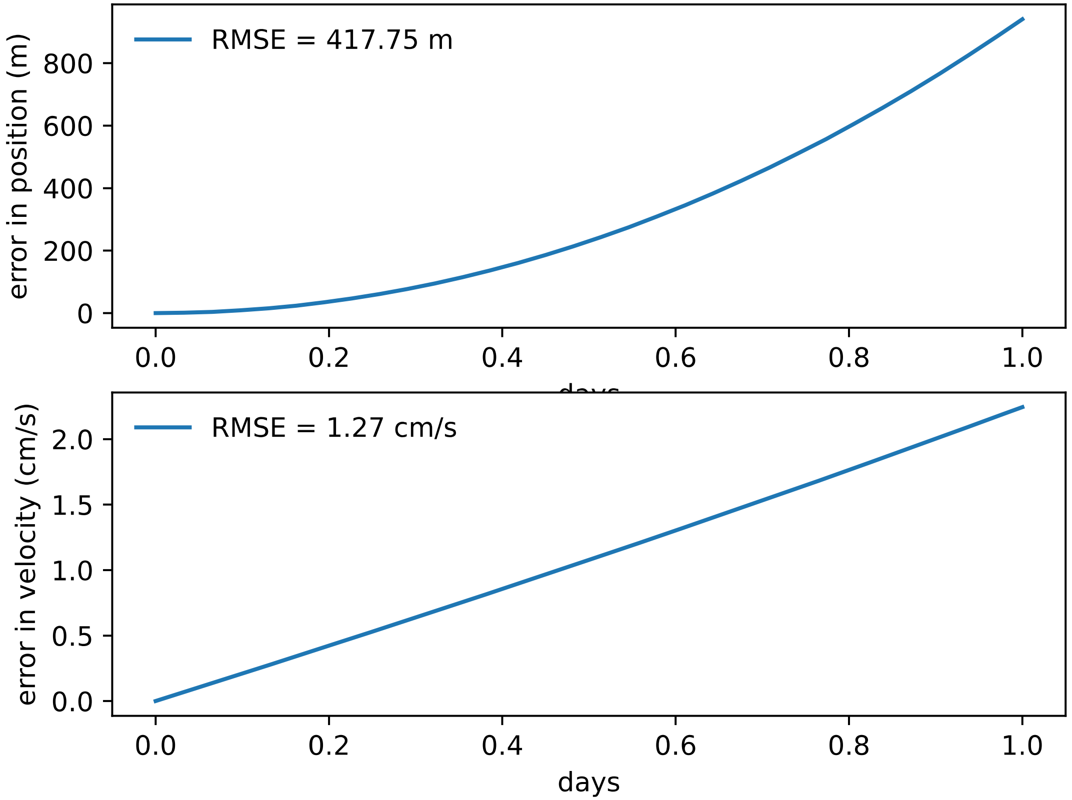
Magnitudes of perturbations for CAPSTONE in NRHO

Assessments in Distant Retrograde Orbit

Artemis I/Orion: 14-day period, perilune 70,100 km and apolune 94,800 km
Scenario: time span of 1 days from 29 November 2022

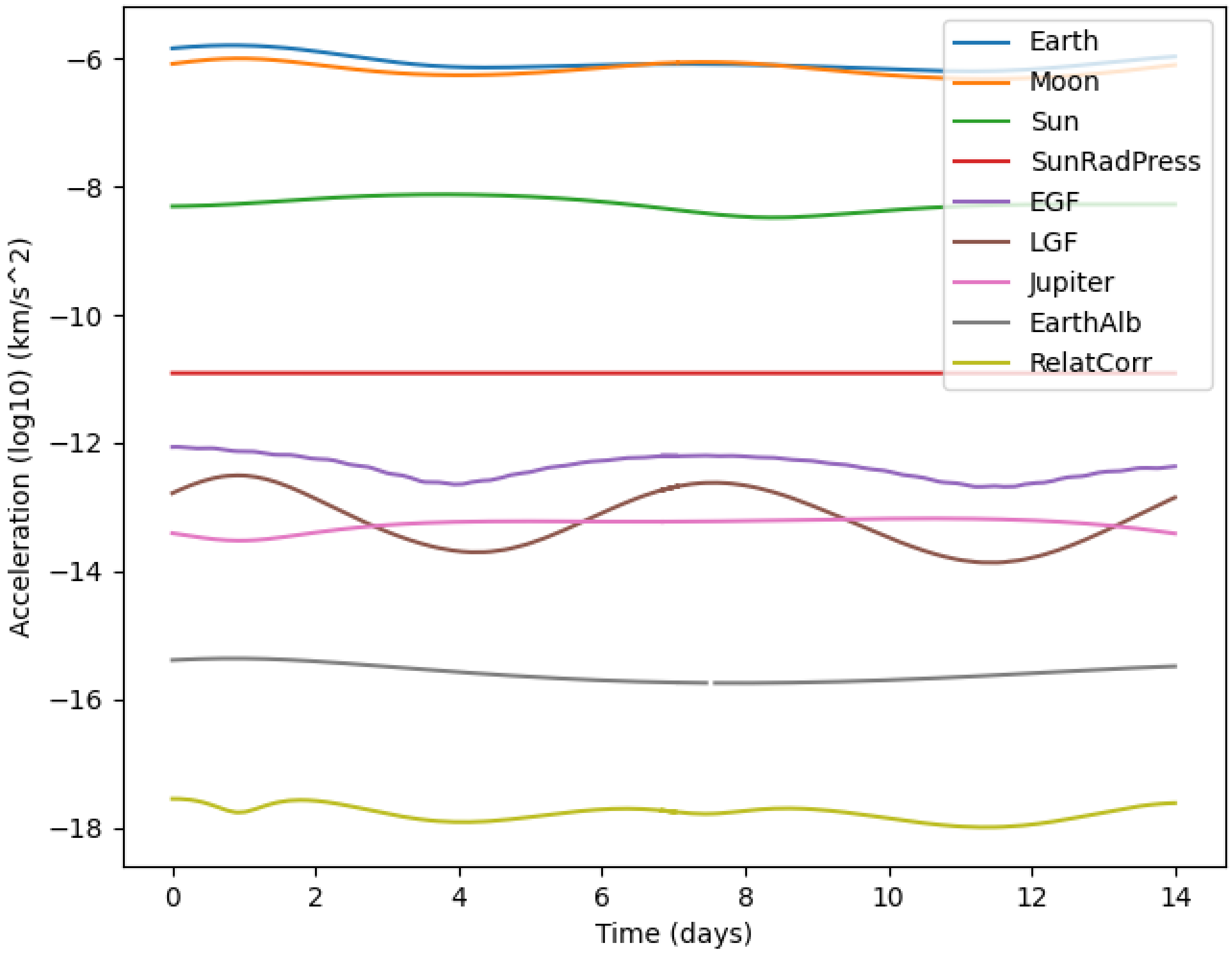


Orion trajectory in the Moon centred rotational frame



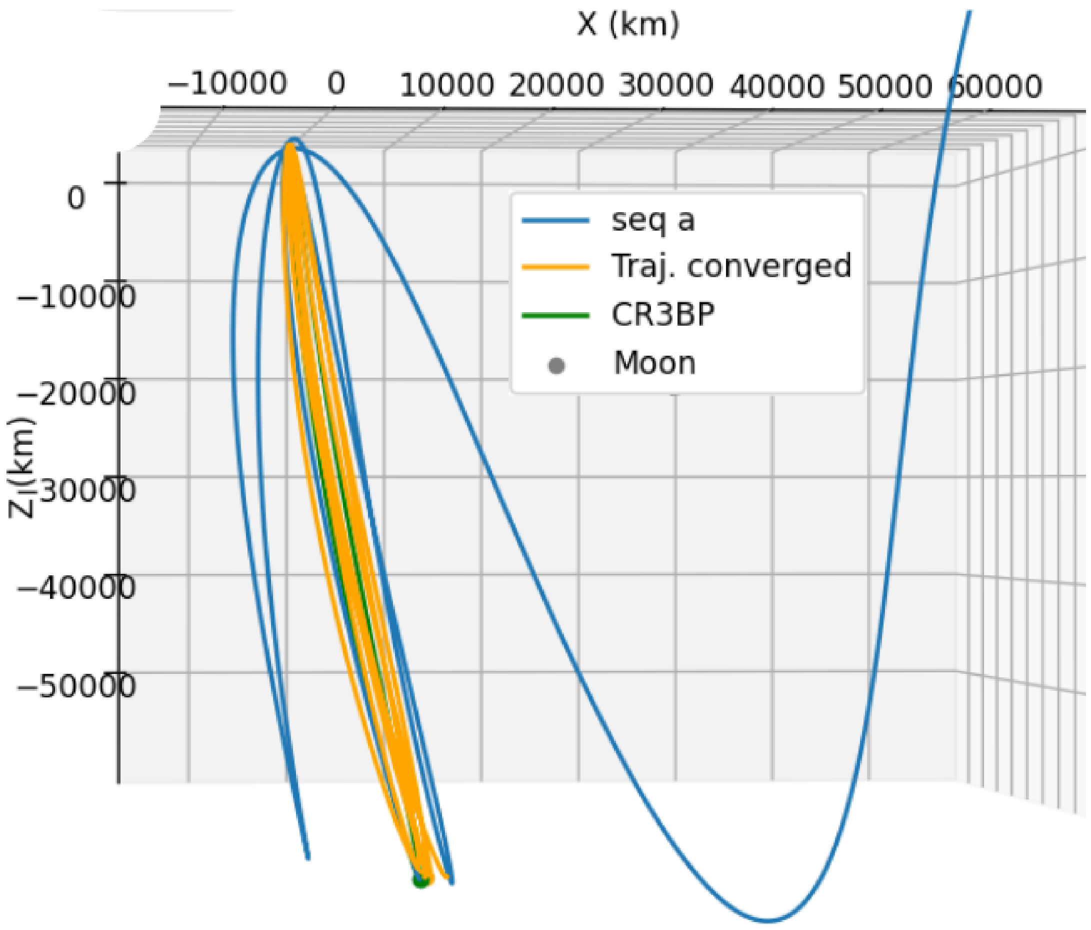
Propagation errors compared to the Orion reference orbit

Assessments in Distant Retrograde Orbit

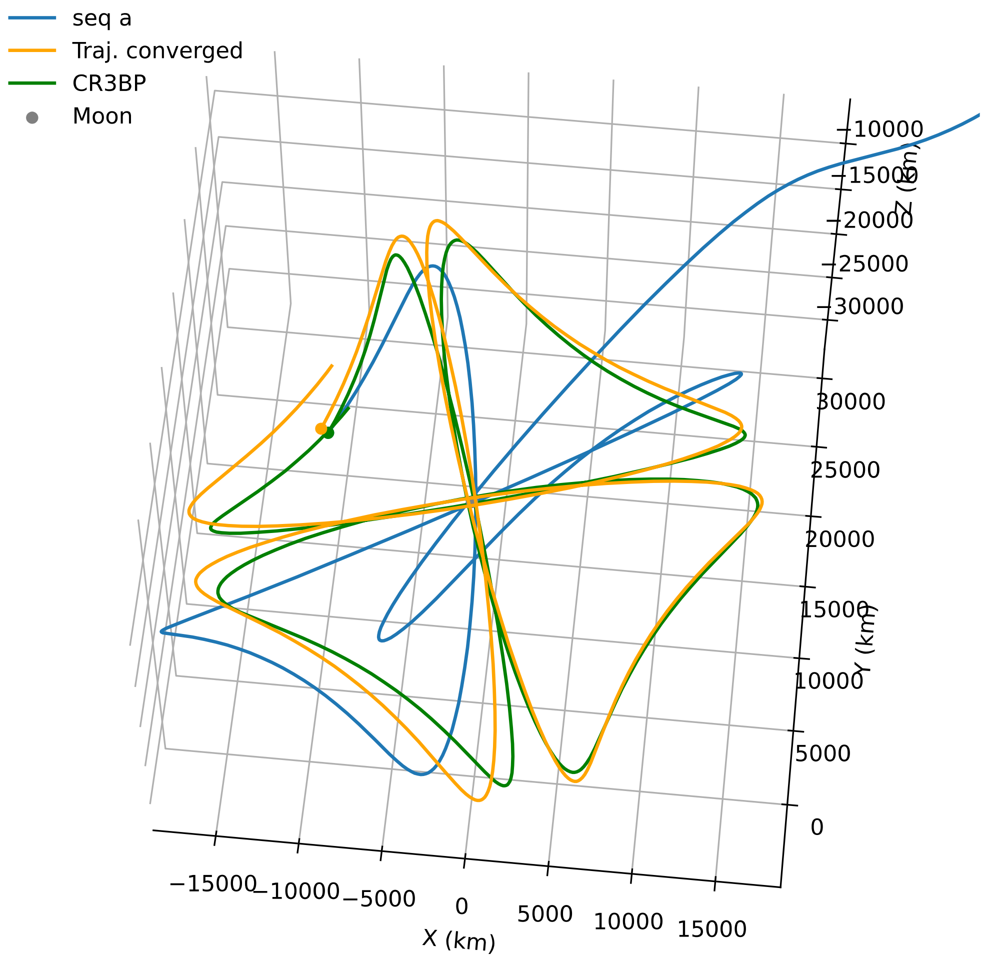


Magnitudes of perturbations for Orion in DRO

Preliminary Mission Design - Periodic NRHO Optimisation



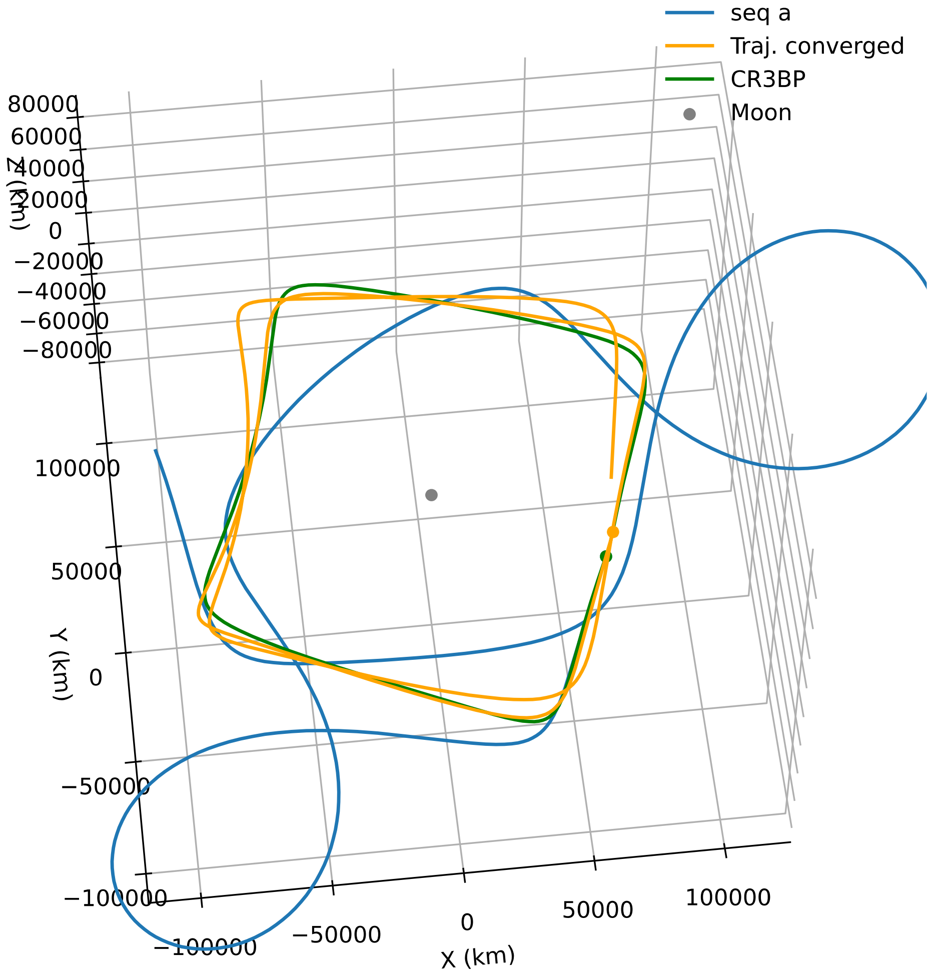
Optimised NRHO trajectory in the Moon centred rotational frame



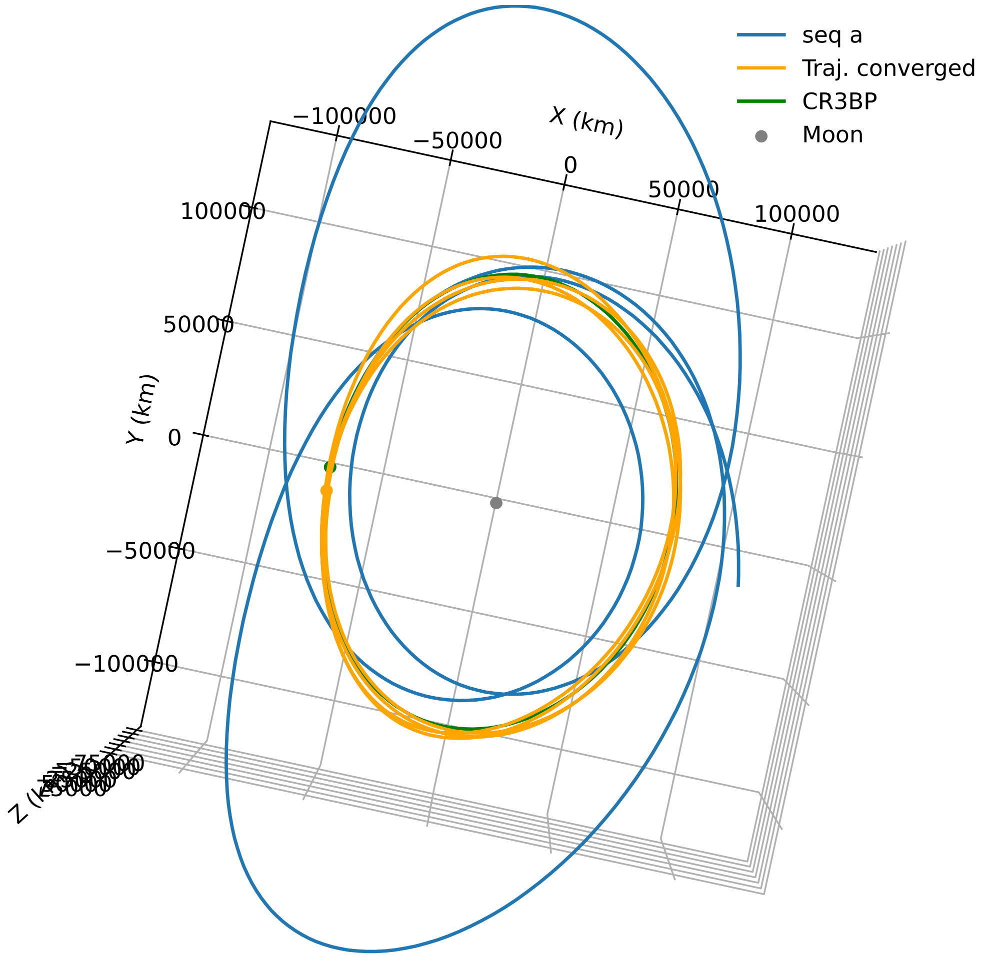
Optimised NRHO trajectory in the Moon centred inertial frame

Note: CR3BP initial state from JPL Three-Body Periodic Orbit Catalogue.

Preliminary Mission Design - Periodic DRO Optimisation



Optimised DRO trajectory in the Moon centred rotational frame



Optimised NRHO trajectory in the Moon centred inertial frame

Note: CR3BP initial state from JPL Three-Body Periodic Orbit Catalogue.

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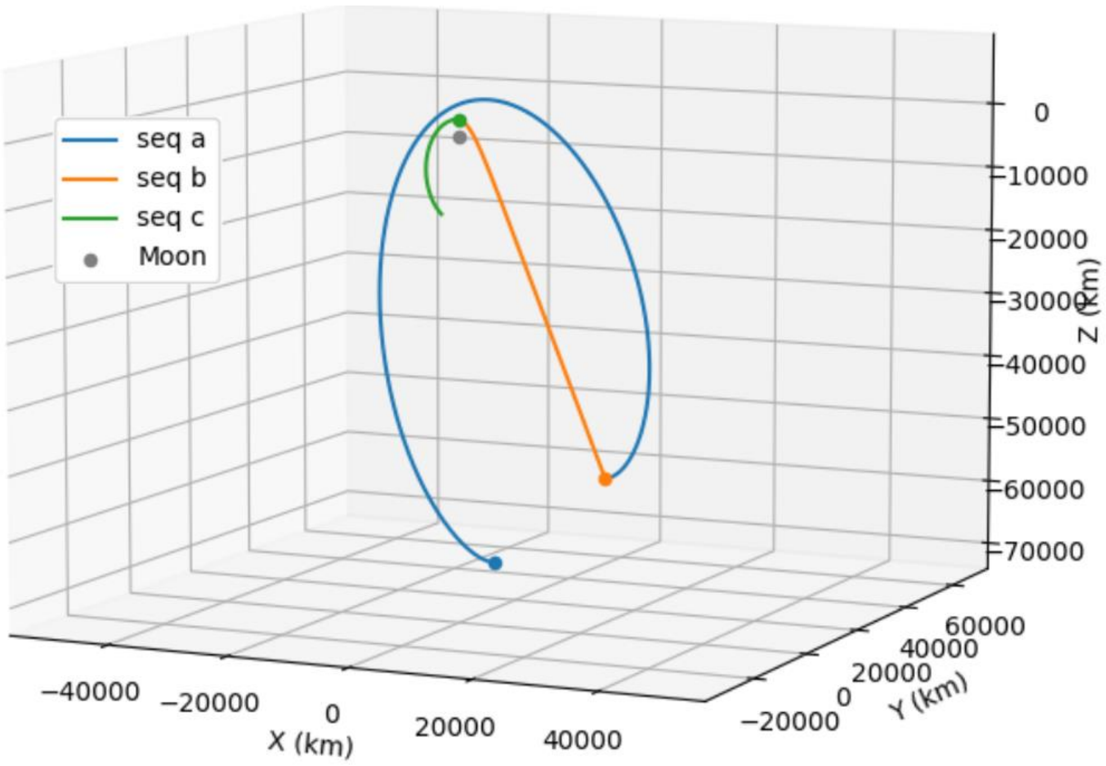
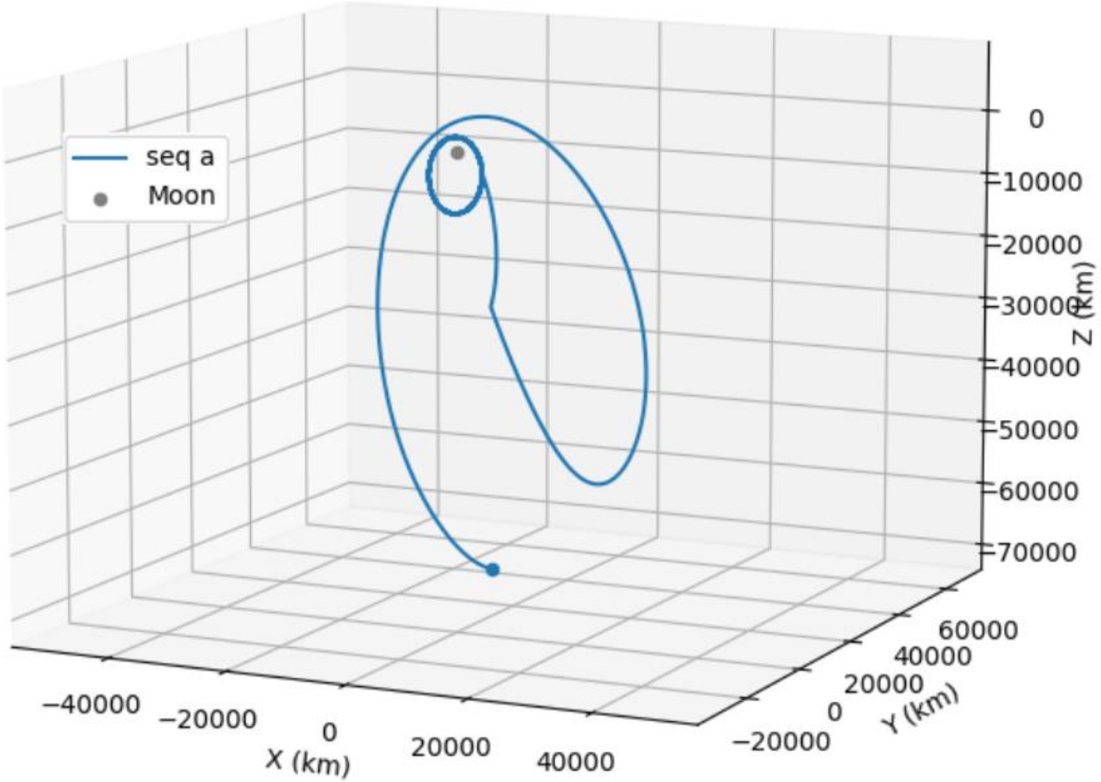
Preliminary Mission Design – Lambert Transfer Optimisation

Δv of 4.470 km/s and a position error of 251 km



Initial situation of a Lambert transfer between the Gateway NRHO and an ELFO

Δv of 0.816 km/s and a position error of 122 km



Converged situation of a Lambert transfer between the Gateway NRHO and an ELFO

Concluding Remarks

- **HALO**: Specialised tool for precise lunar orbit modelling and mission design with open-source flexibility.
- Enables detailed analysis of **LLO, ELFO, NRHO, and DRO**, offering insights into orbit dynamics and mission planning.
- Validated lunar orbit propagator ensures accurate and reliable orbit predictions for **cislunar missions**.

Preprint: HALO: A High-Precision Orbit Propagation Tool for Mission Design in the Cis-Lunar Domain

Github: https://github.com/Quent2G/High-precision-Analyser-of-Lunar-Orbits

Any questions?

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