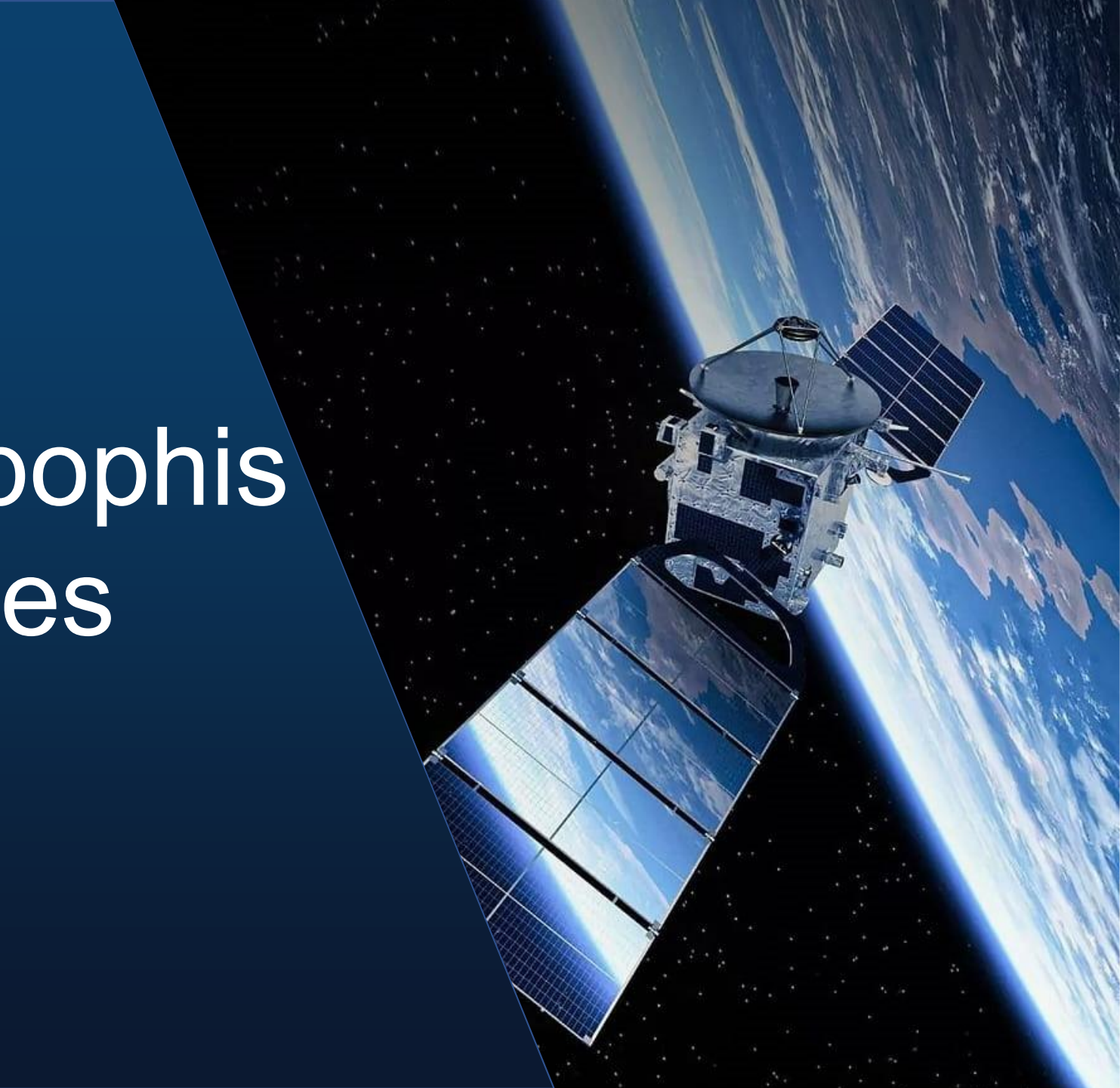
The effect of Apophis on GEO satellites

Dr Marta Ceccaroni
m.ceccaroni@cranfield.ac.uk

Miriam Martinez

Nicolo' Stronati

06/04/2025



Apophis

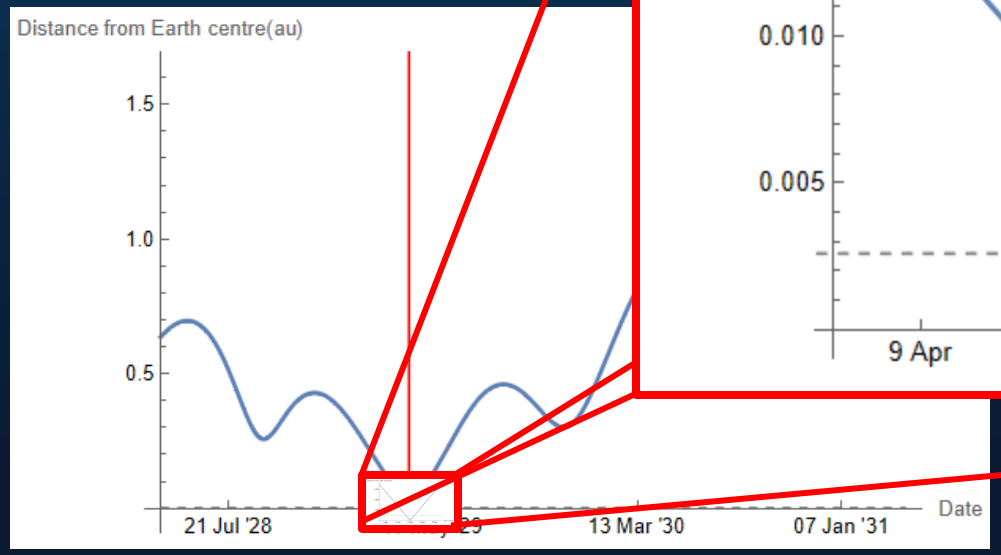
Diameter *375 m*

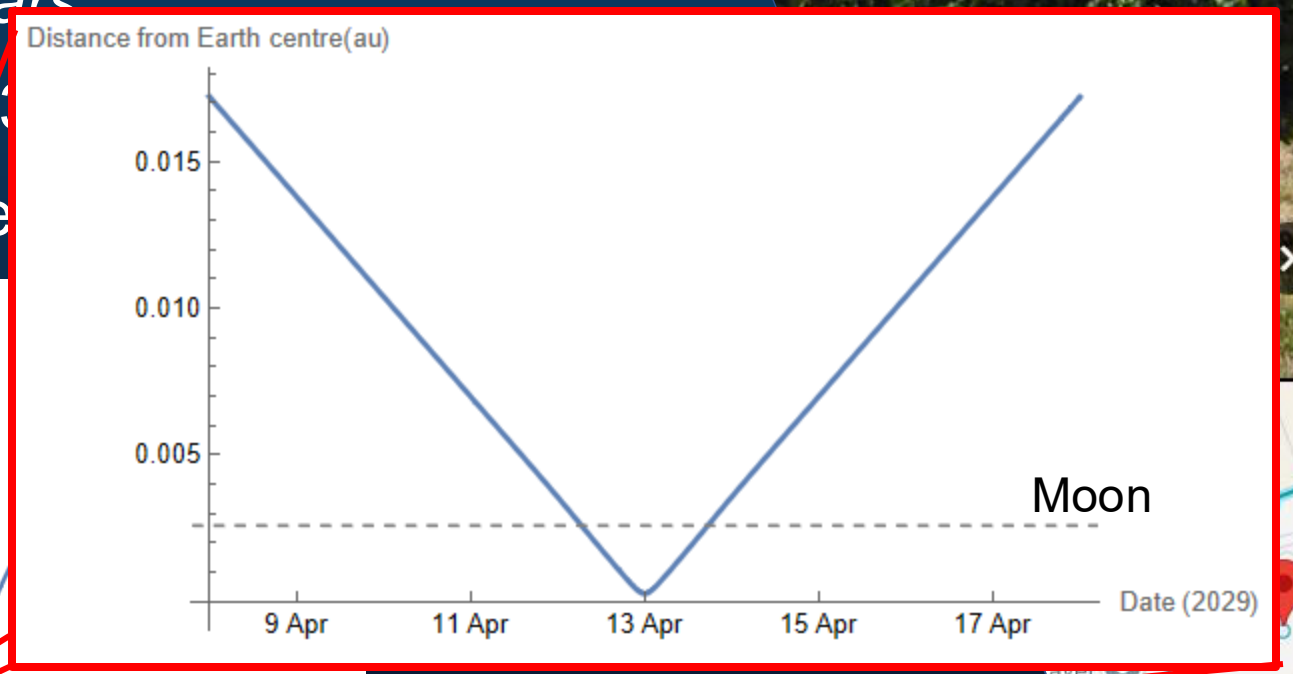
Weight: *1/4 mount Everest*

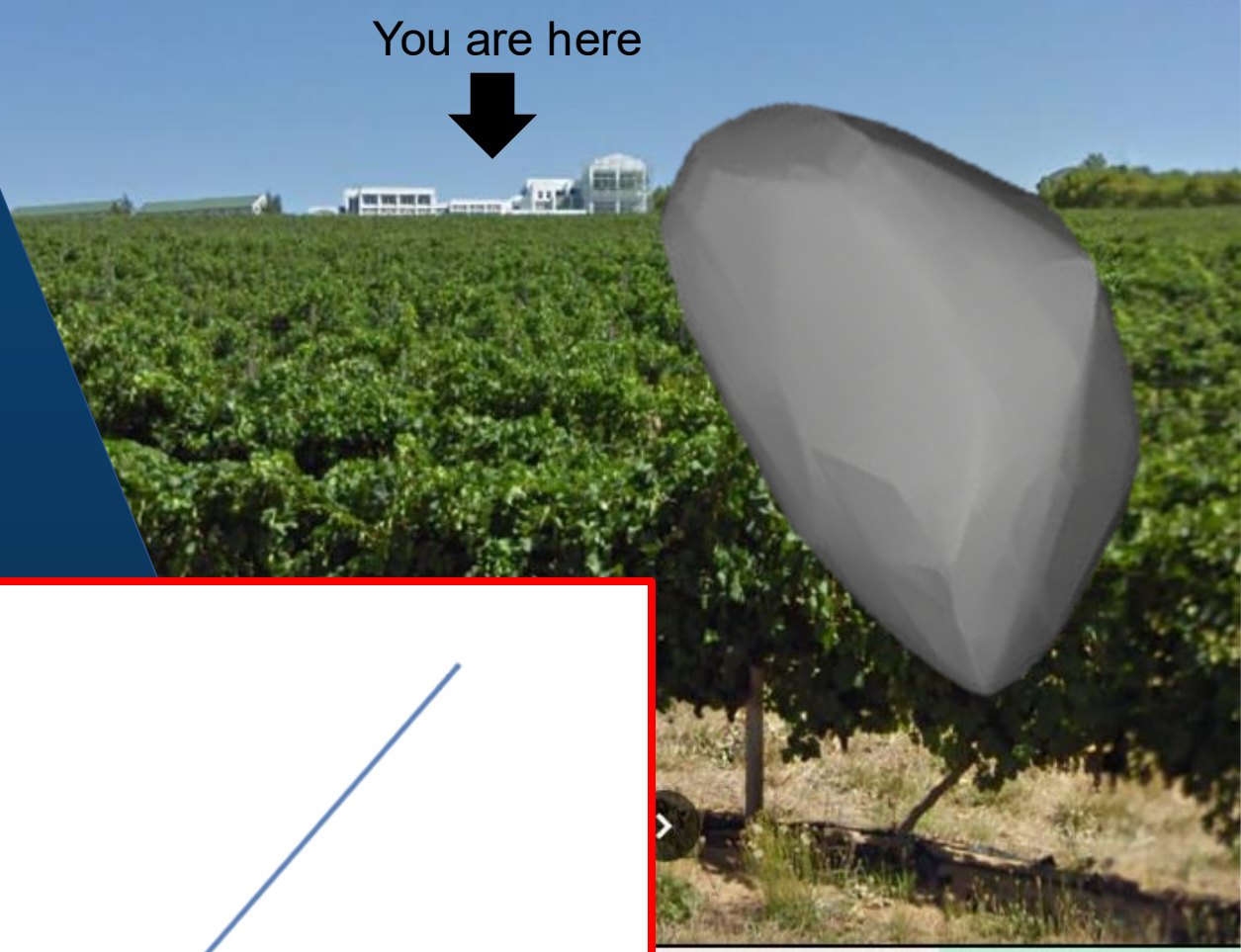
In risk list for > *15 years*

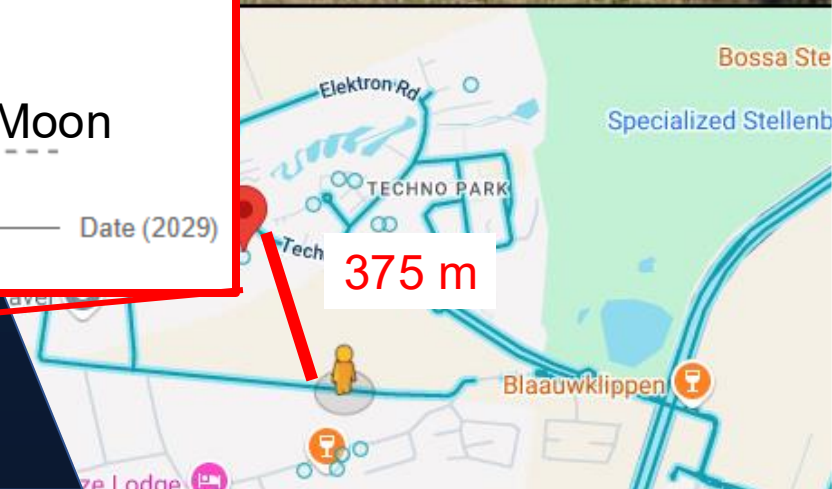
Passing by on April 1

Min possible distance



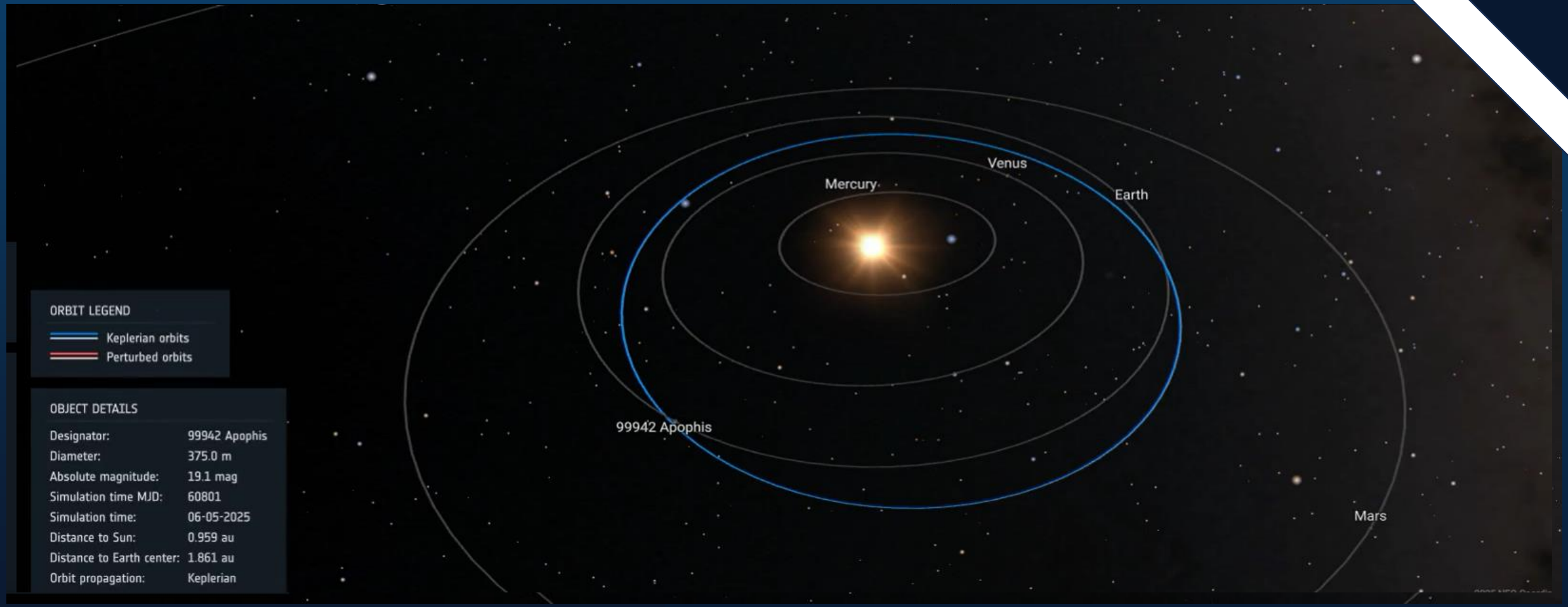






Where is it today?

~ 2 au from Earth



NEOCC Orbit Visualisation Tool

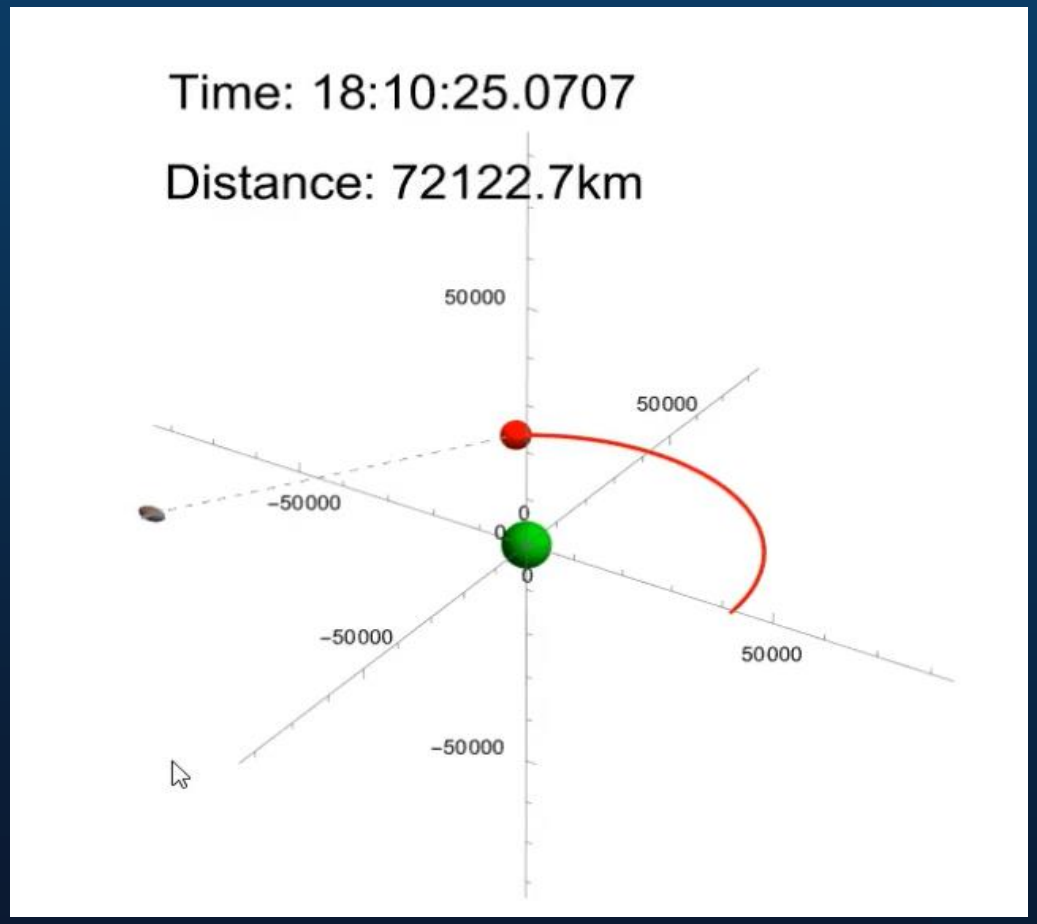
What about our satellites?

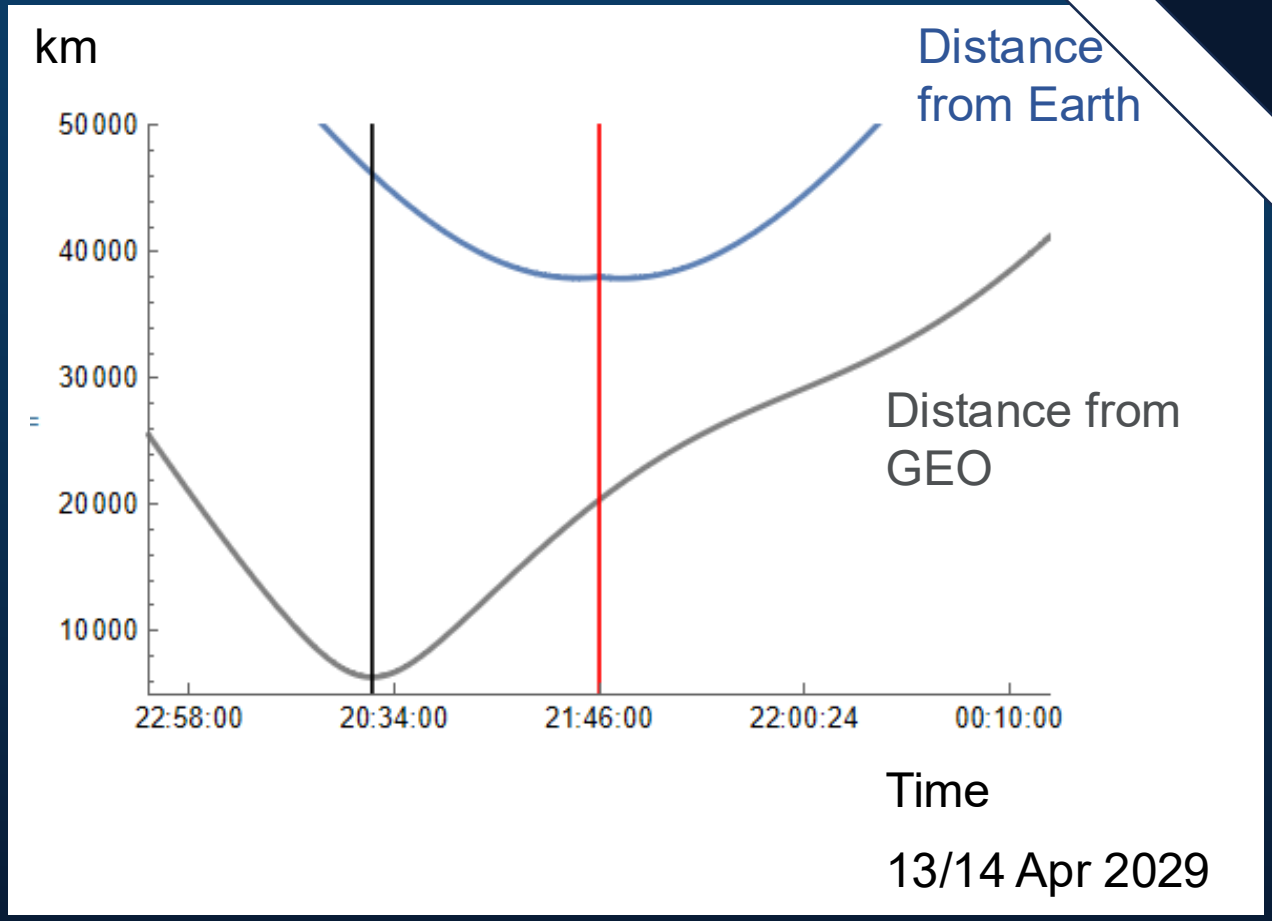
- 10 400 active satellites (December 2024)
- 580 to 800 active satellites in Geostationary Earth Orbit (GEO) (April 2025)

These account for most of the revenue from commercial space services.

What about our satellites?

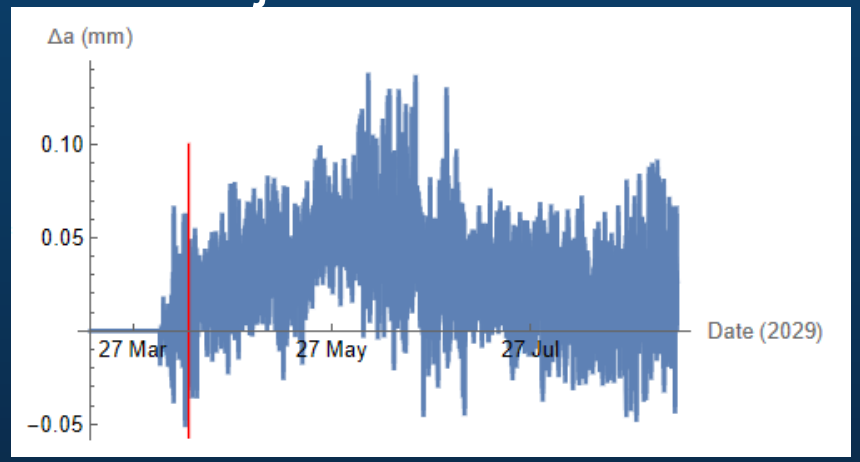
GEO: MOID 6327.264 km (20:27:07 UTC)



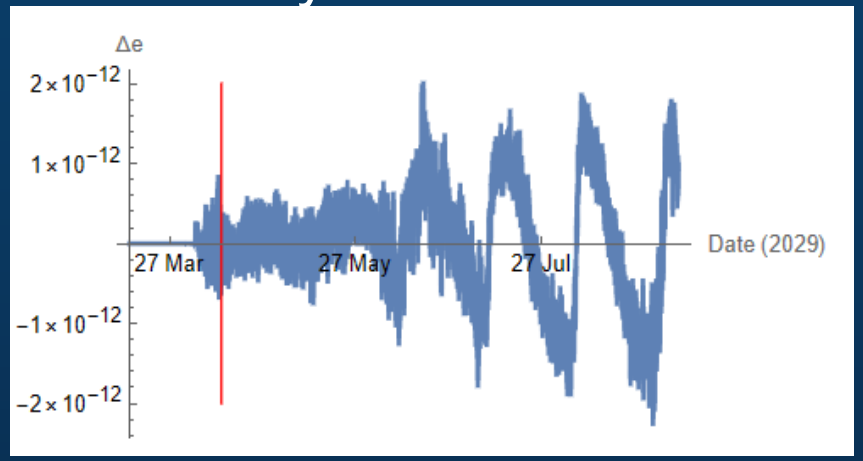


Apophis effect on GEO (Keplerian elements)

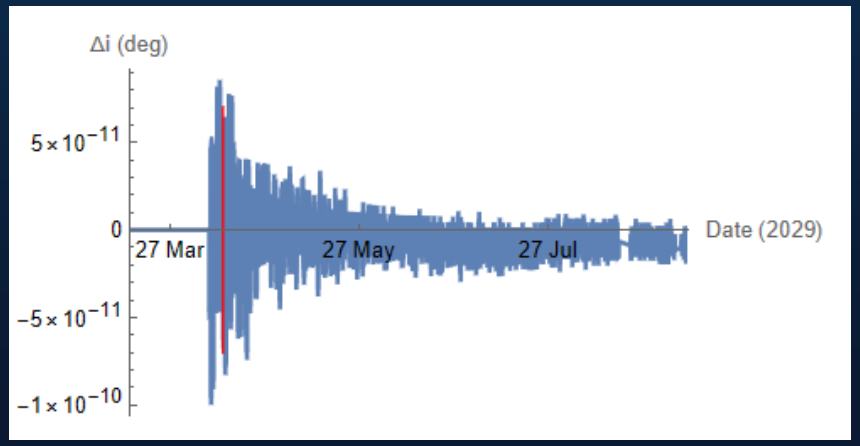
Semimajor axis



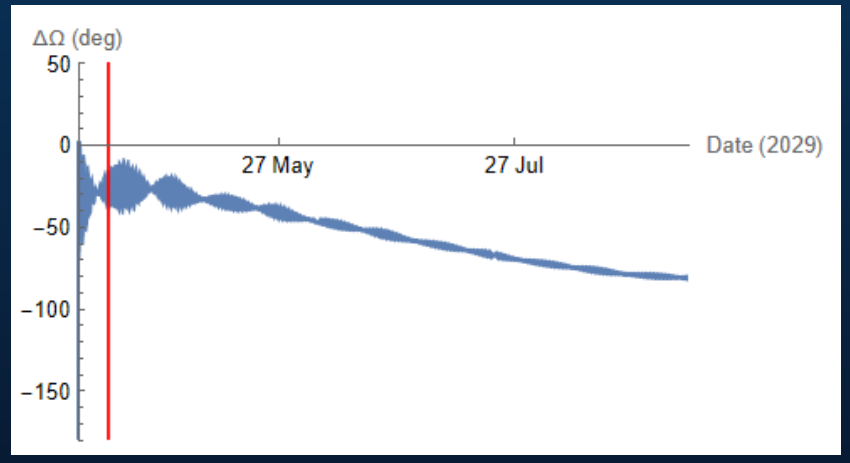
Eccentricity



Inclination

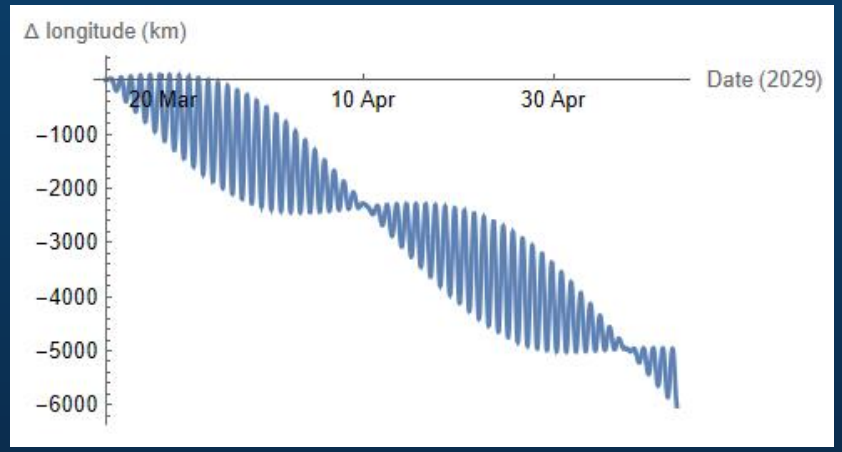


RAAN

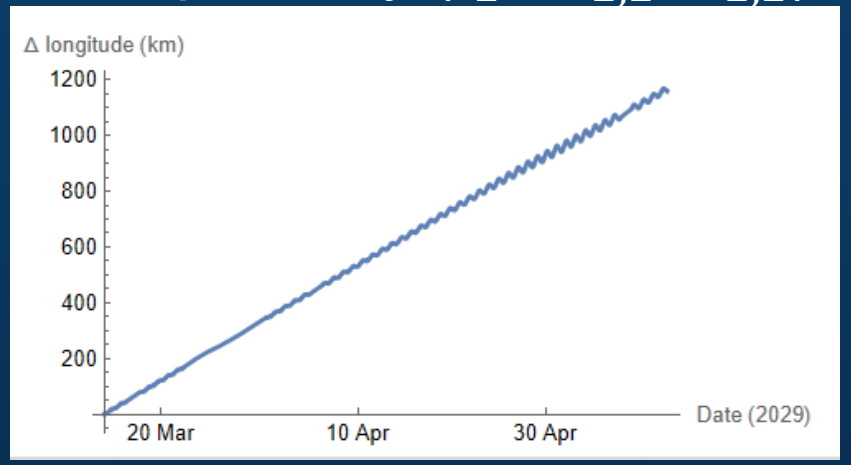


East-West drift (km)

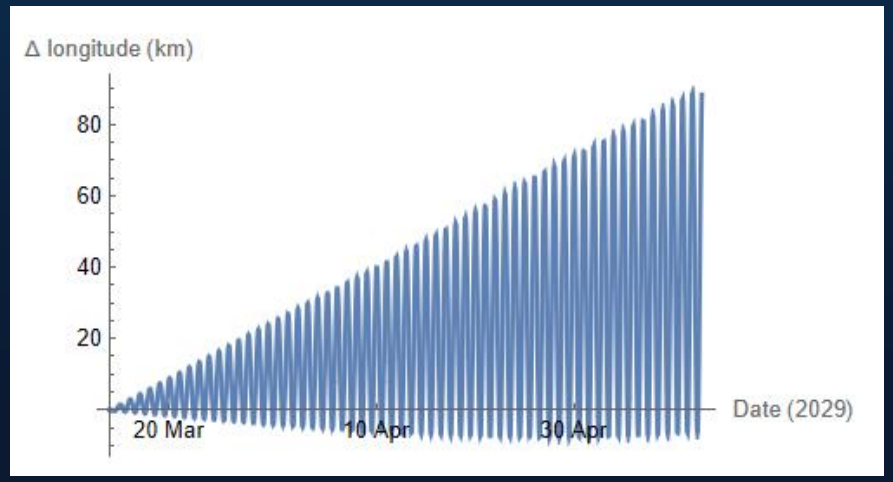
Moon



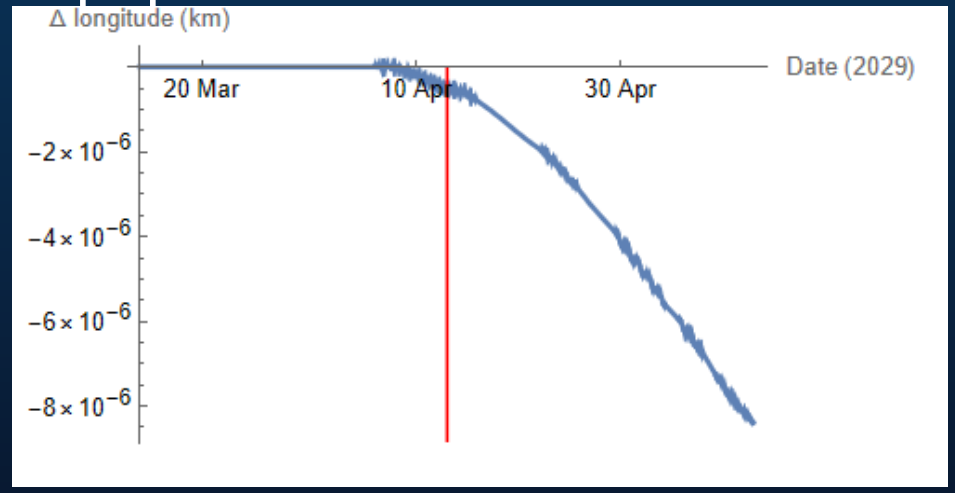
Non-sphericity (J_2 , $C_{2,2}$, $S_{2,2}$)



SRP

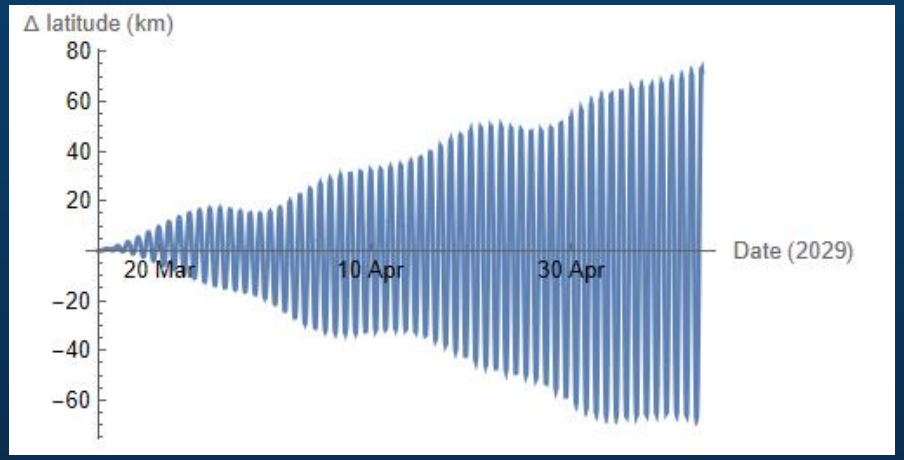


Apophis

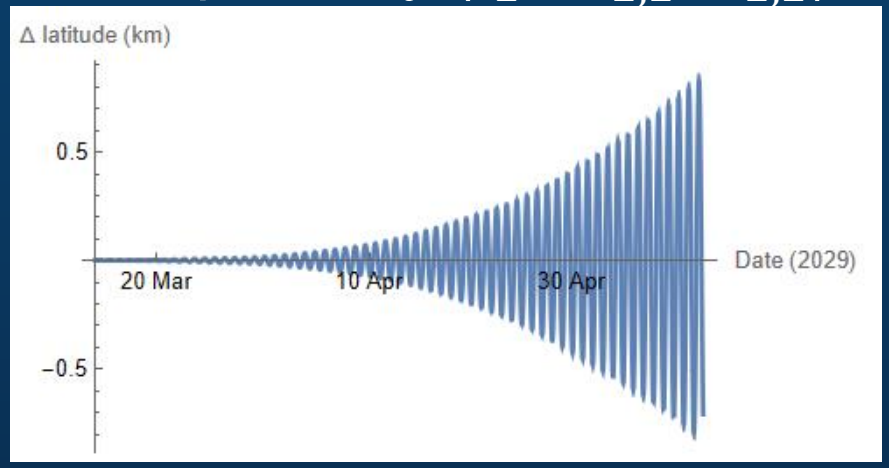


North-South drift

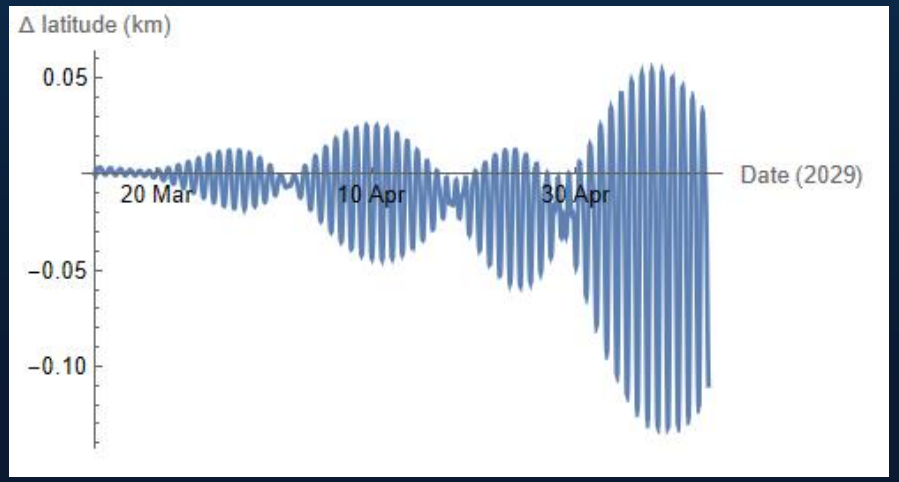
Moon



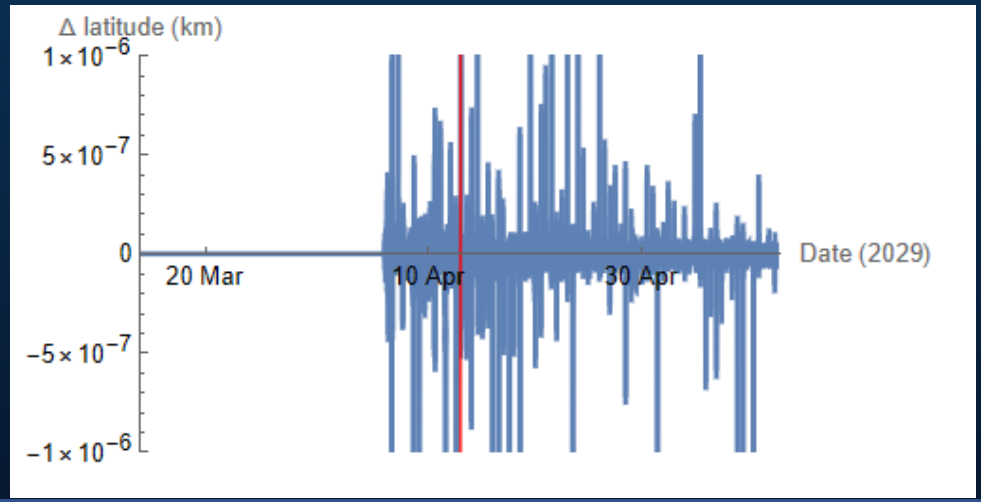
Non-sphericity (J_2 , $C_{2,2}$, $S_{2,2}$)



SRP

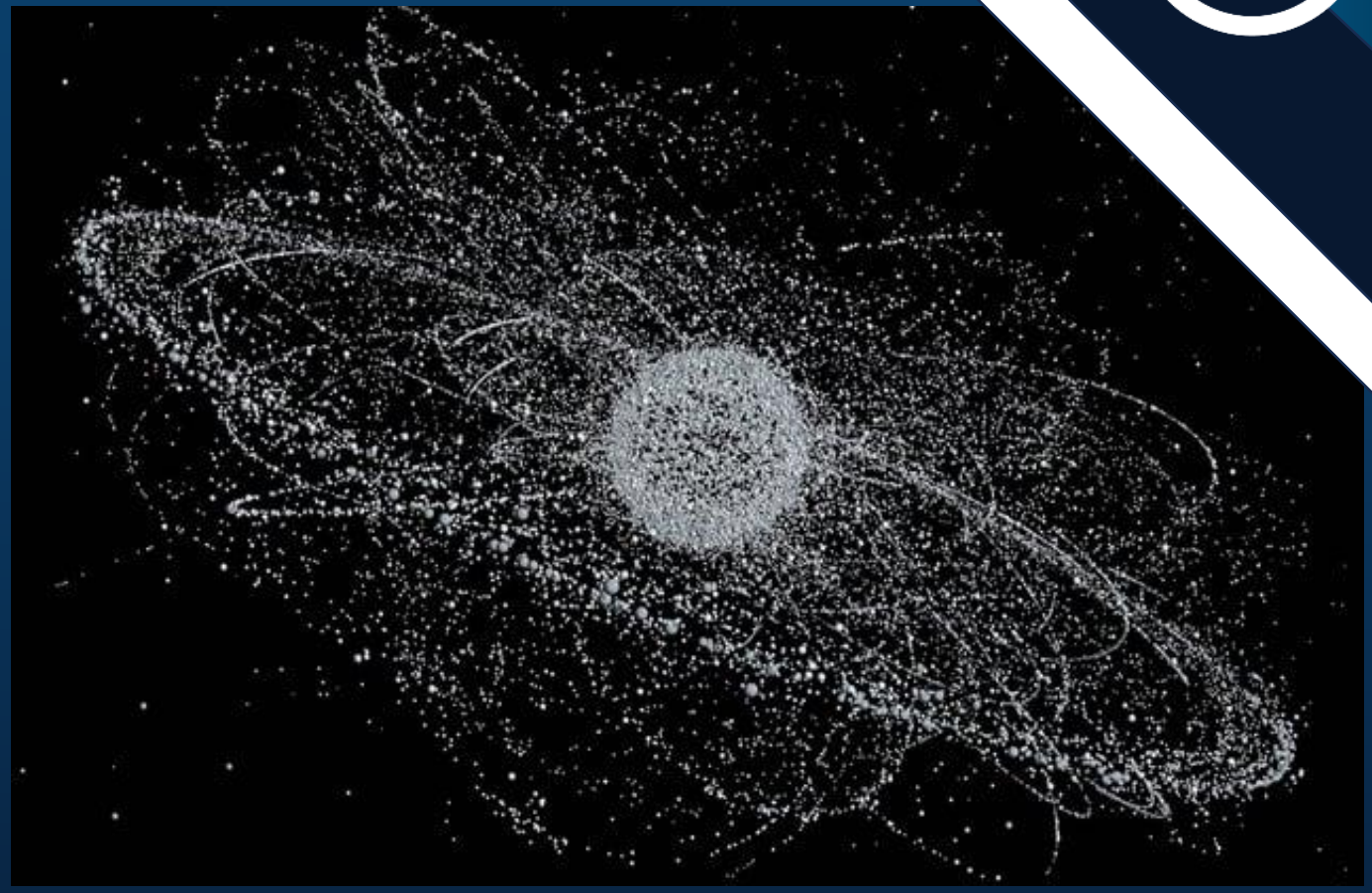


Apophis



GEO debris

- Tracked objects 1 m and above:
  >1000
- Most classified as “Large”
- Estimated untracked objects
  10 cm and above: thousands



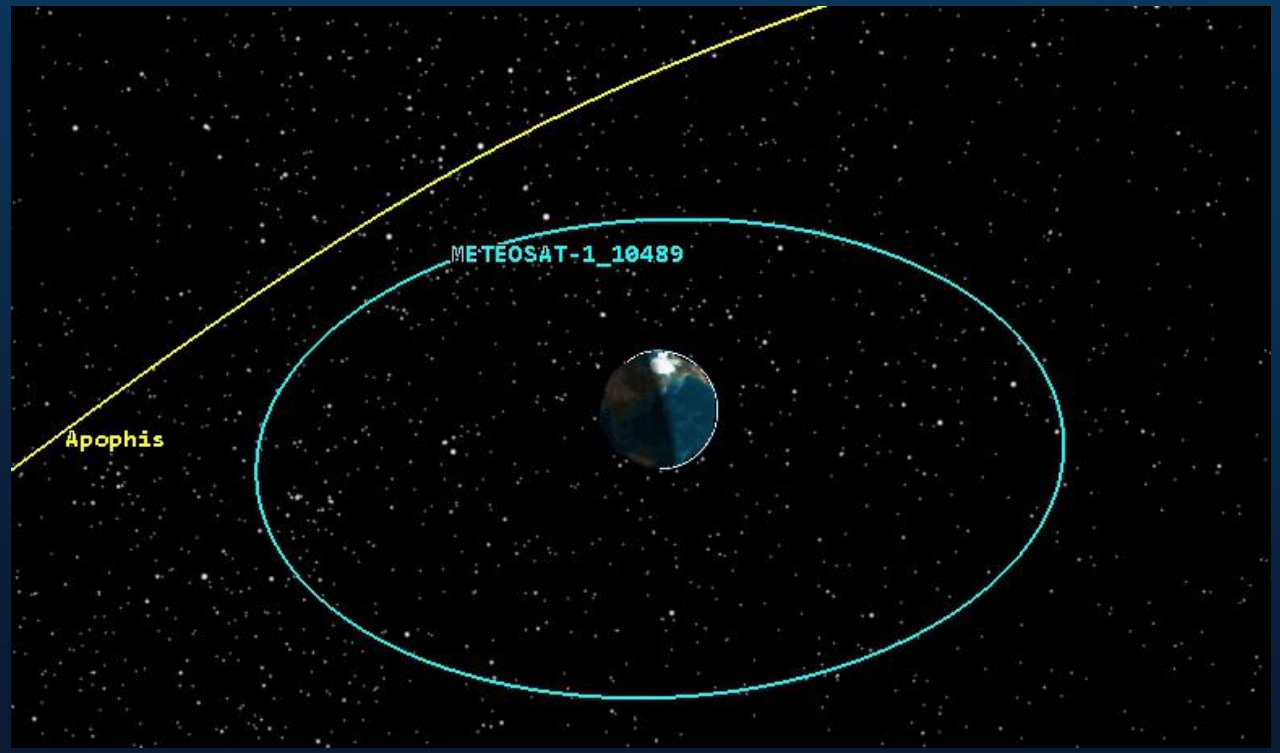
Every known debris orbiting Earth… 12 yrs ago

METEOSAT 1 (1977-1984)

Diameter 2.16 m

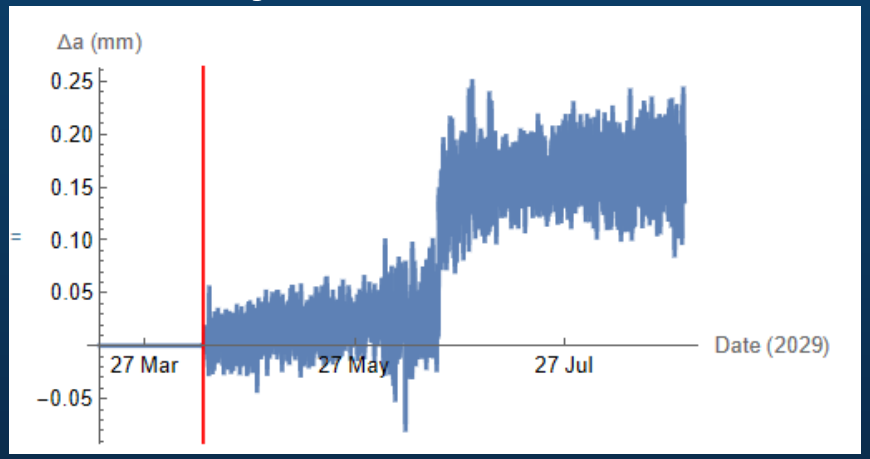
Height 3.195 m

Mass 282 km

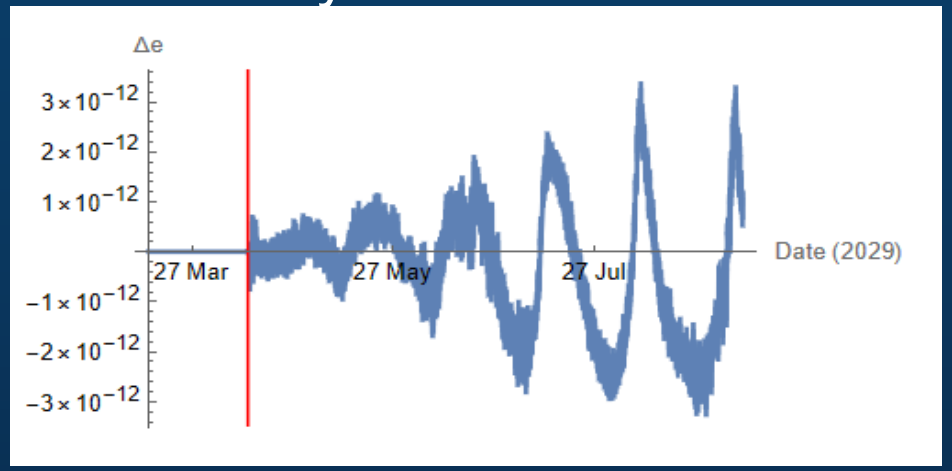


METEOSAT 1 Keplerian elements (uncontrolled orbit)

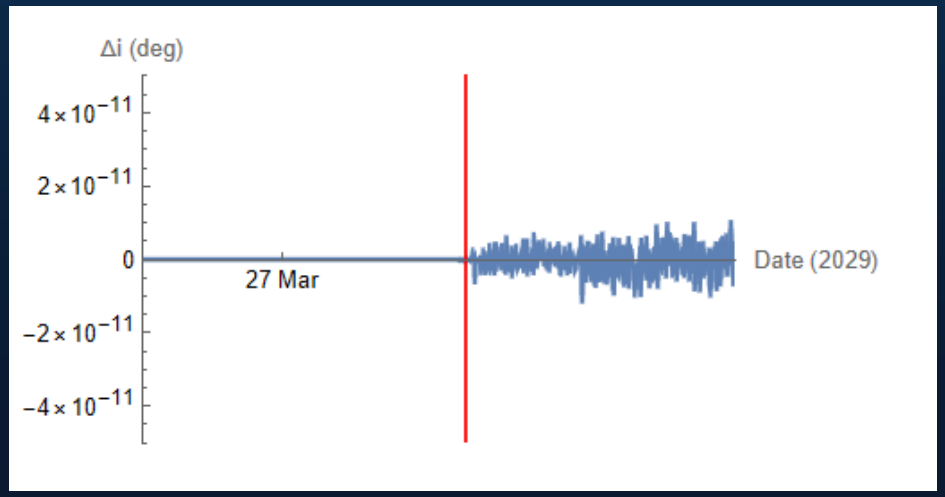
Semimajor axis



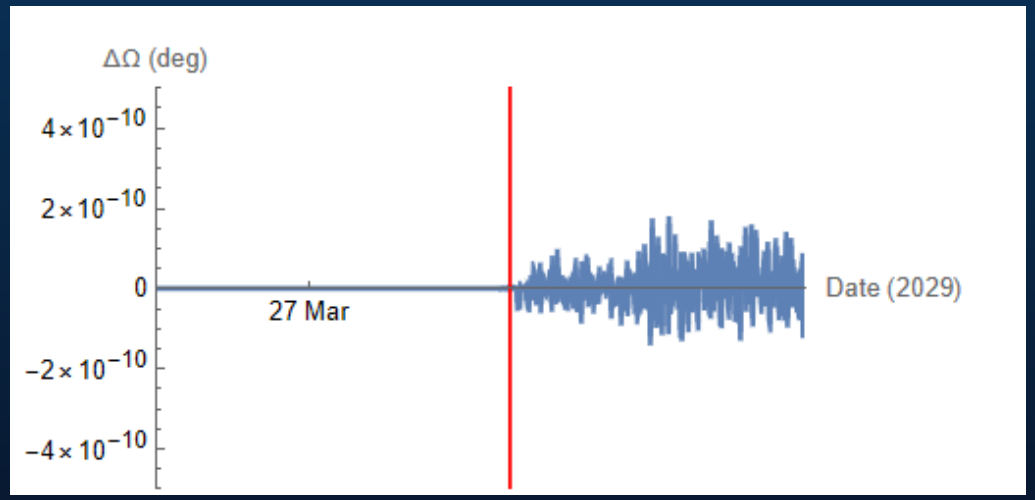
Eccentricity



Inclination

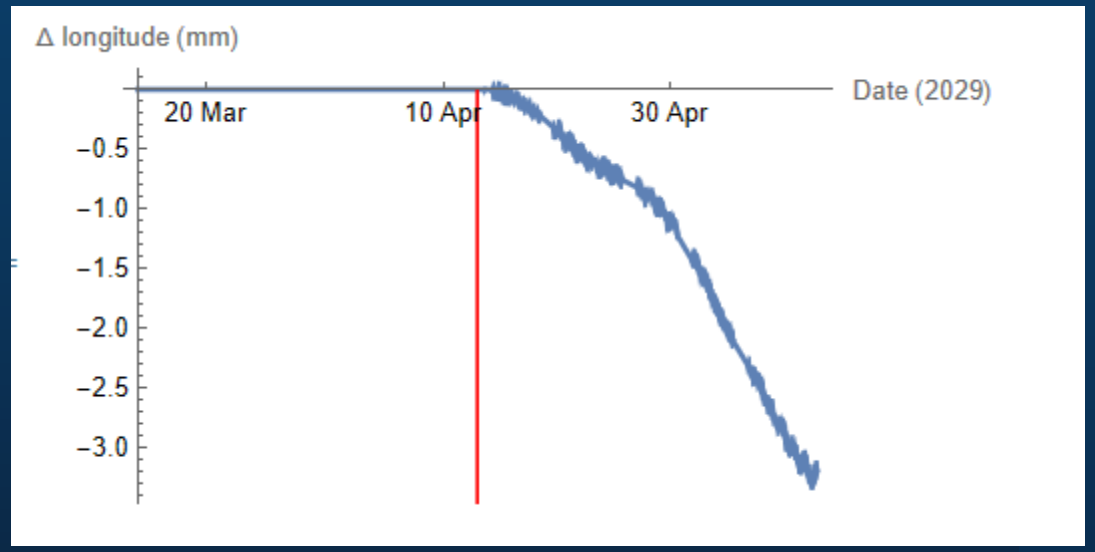


RAAN

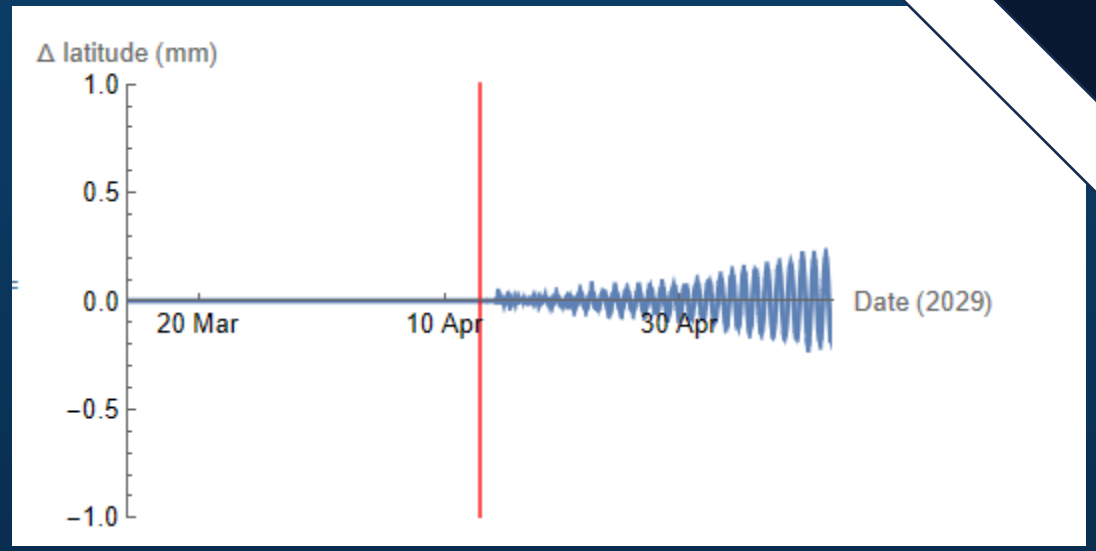


METEOSAT 1 Drift (uncontrolled orbit)

E-W



N-S



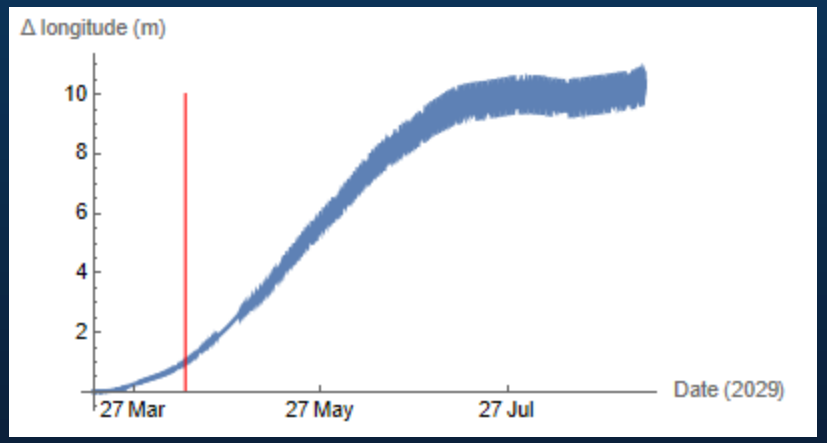
Close Approach geometry

- Geometry and relative velocity change the effects of close approaches
- Parallel close approach geometries amplify effects

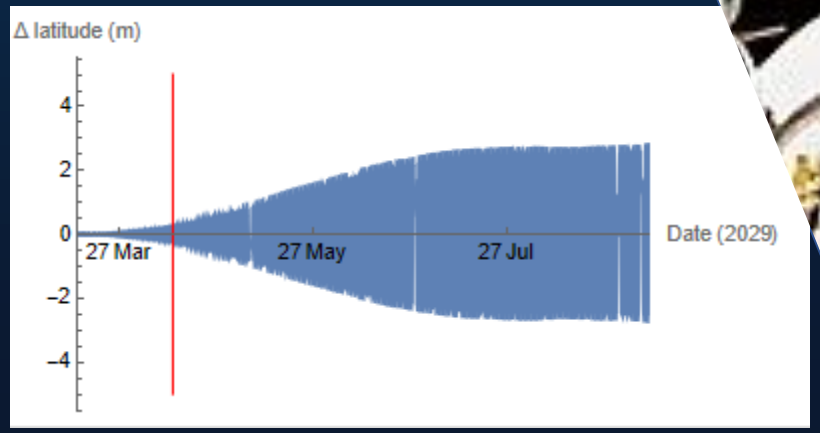
Intelsat 603 (1990- 2015)

- Mass 4.2 kg
- Height 5.2 m

E-W



N-S



Conclusions

- Effects << SRP, non-sphericity, Luni-solar perturbations
- Main disturbance on RAAN
- Irrelevant Δv for station keeping of active satellite
- To be taken into account for collision avoidance for peculiar Debris geometries

Thank you!

Cranfield Aerospace

Special Issue

Advances in Asteroid Dynamics

Guest Editors

Dr. Marta Ceccaroni

Dr. Marco Fenucci

Deadline

31 October 2025

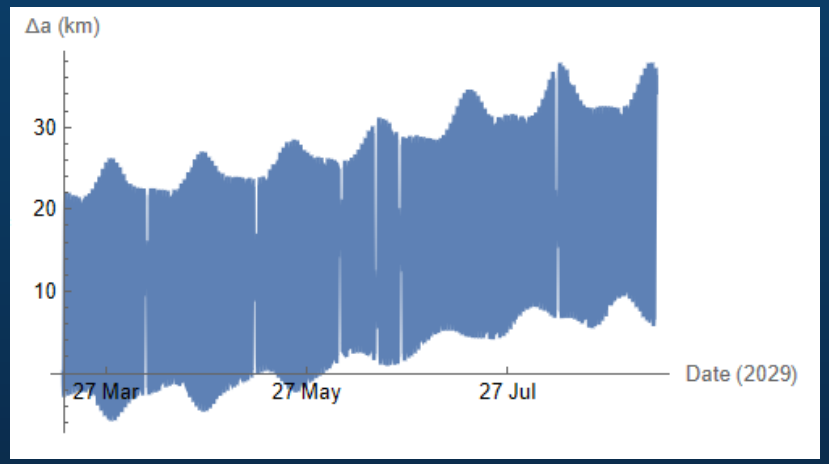
aerospace

IMPACT FACTOR 2.1

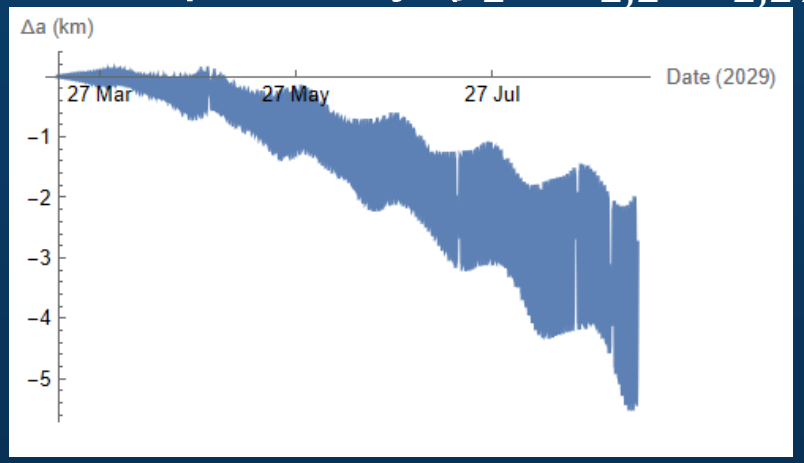
CITESCORE 3.4

Sun-Earth-S/C VS perturbation (Semimajor axis)

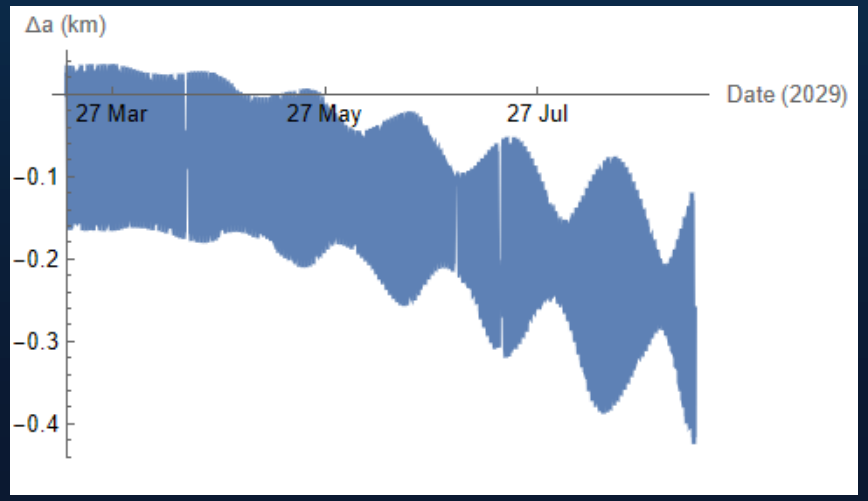
Moon



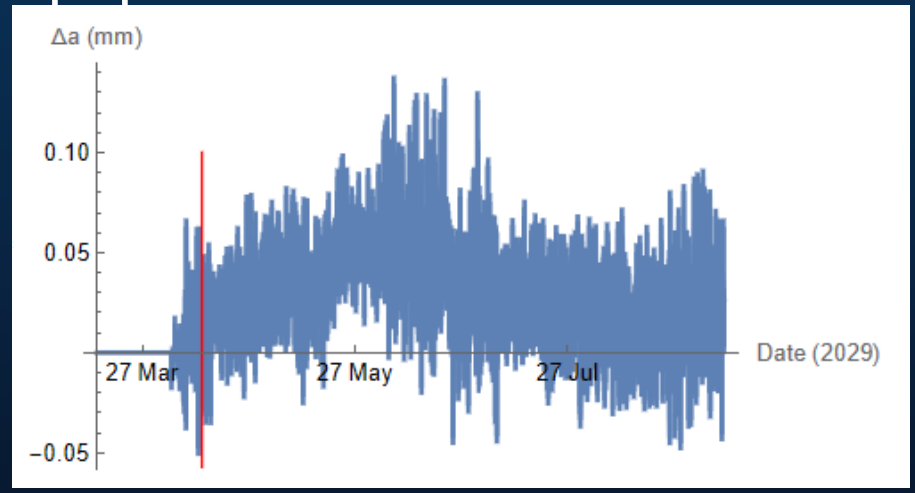
Non-sphericity (J_2 , $C_{2,2}$, $S_{2,2}$)



SRP

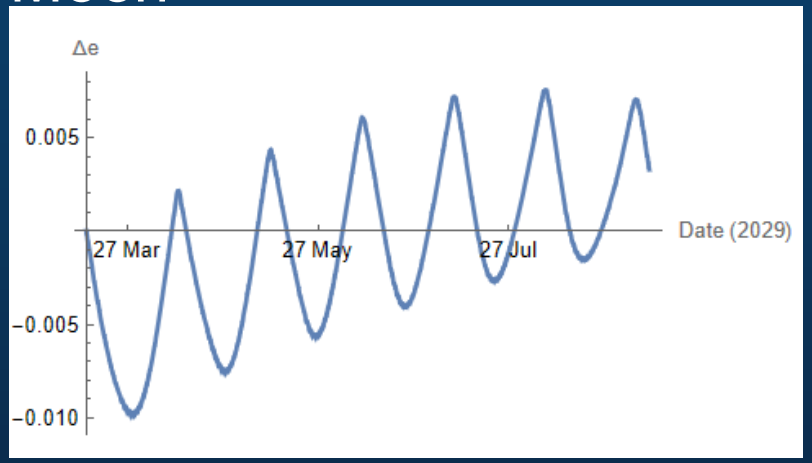


Apophis

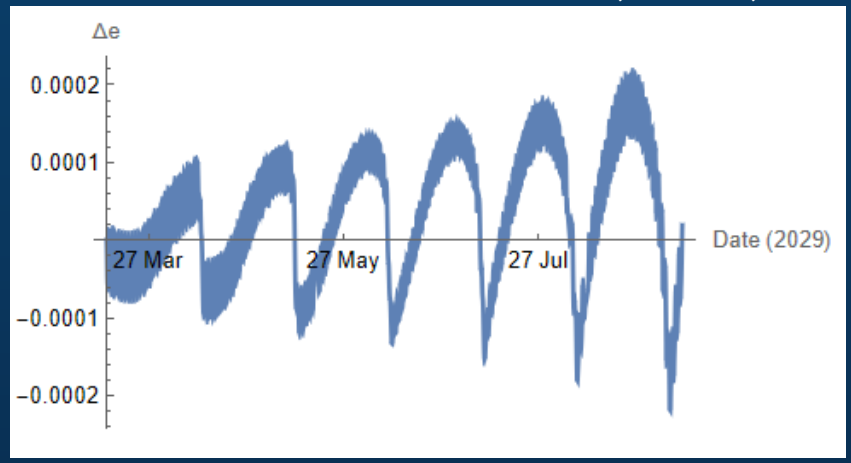


Sun-Earth-S/C VS perturbation (eccentricity)

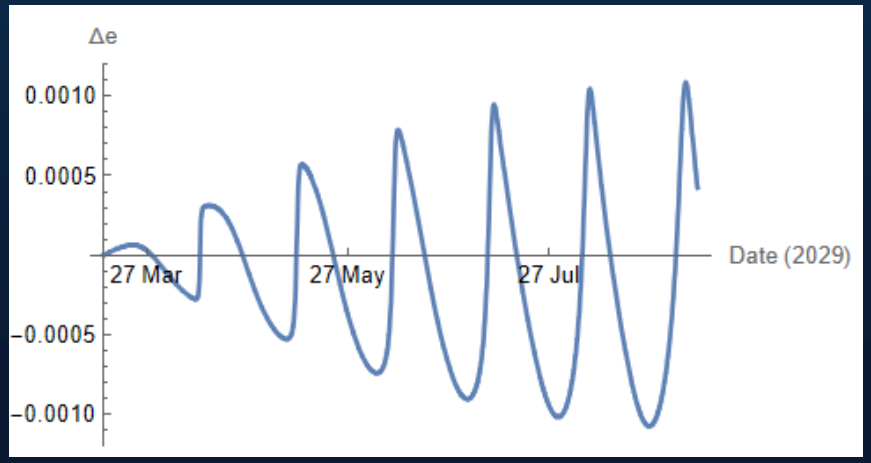
Moon



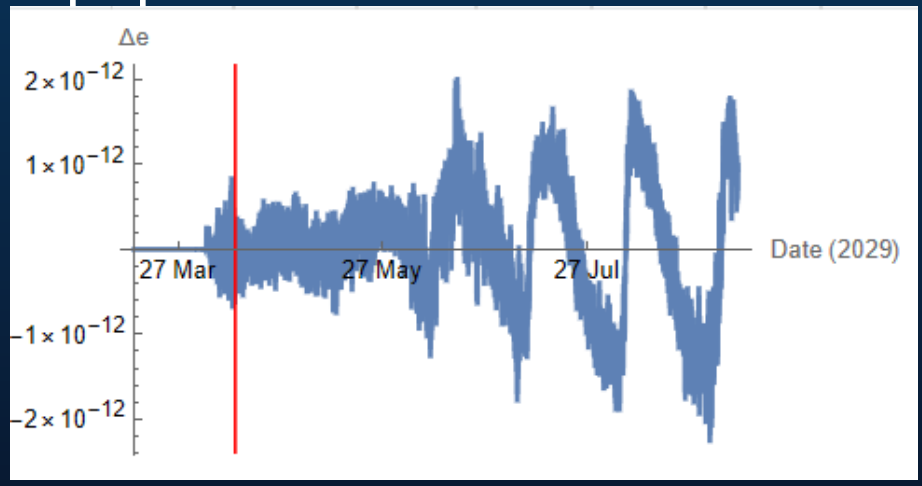
Non-sphericity (J_2 , $C_{2,2}$, $S_{2,2}$)



SRP

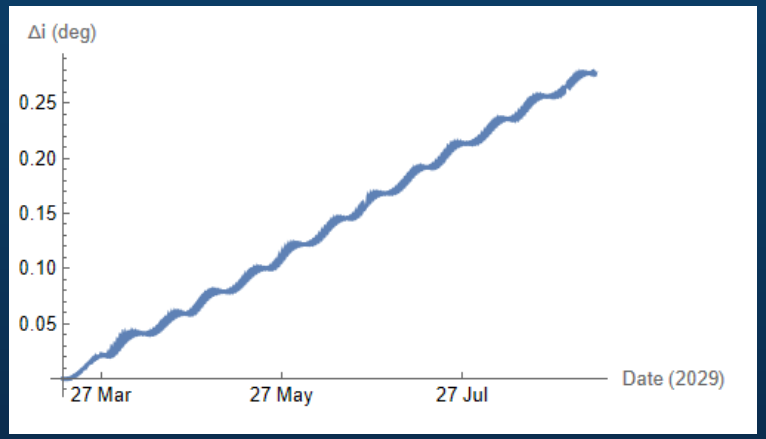


Apophis

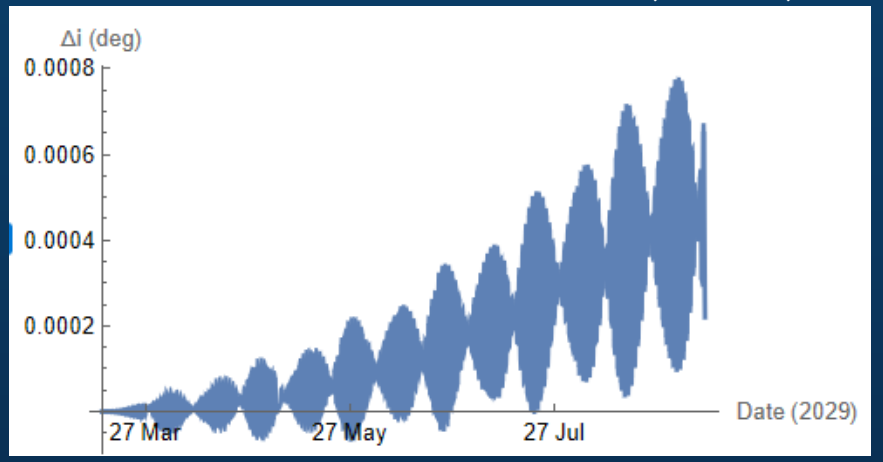


Sun-Earth-S/C VS perturbation (inclination)

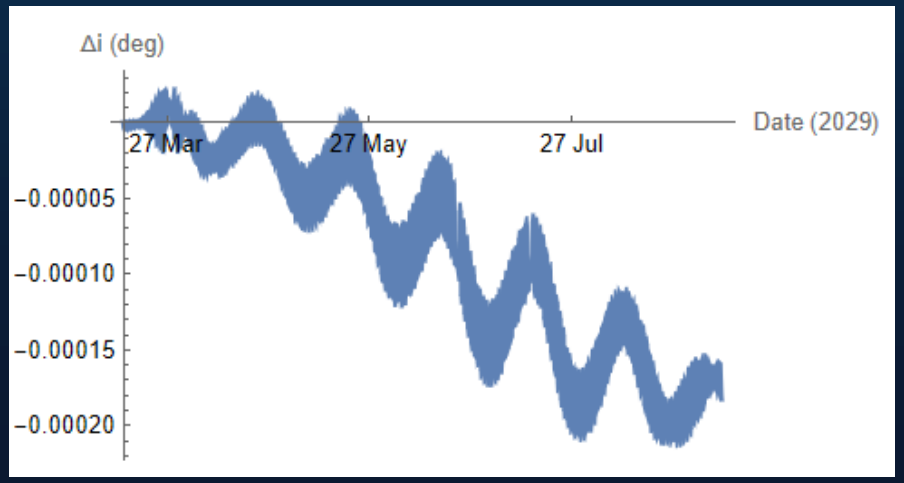
Moon



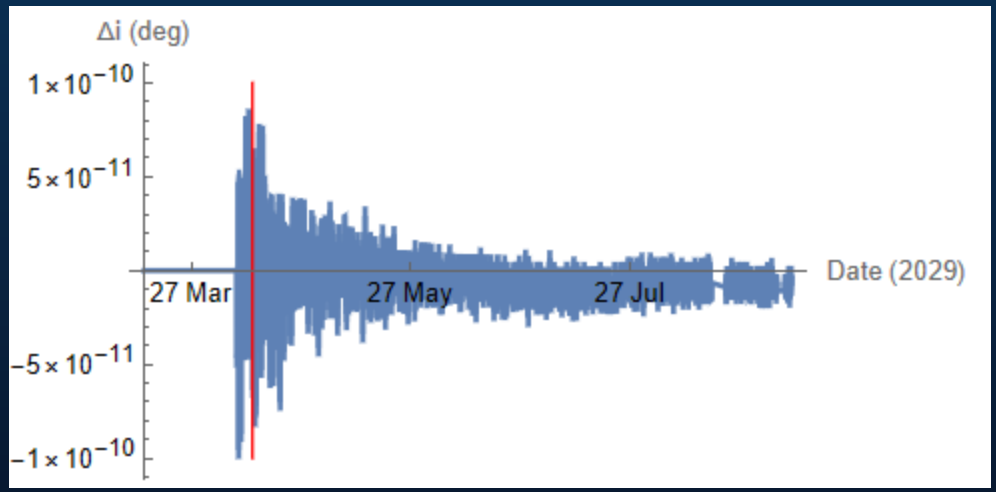
Non-sphericity (J_2 , $C_{2,2}$, $S_{2,2}$)



SRP

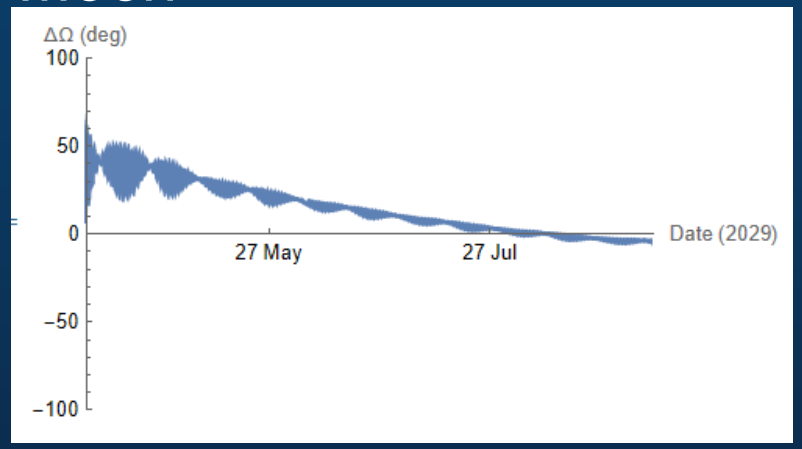


Apophis

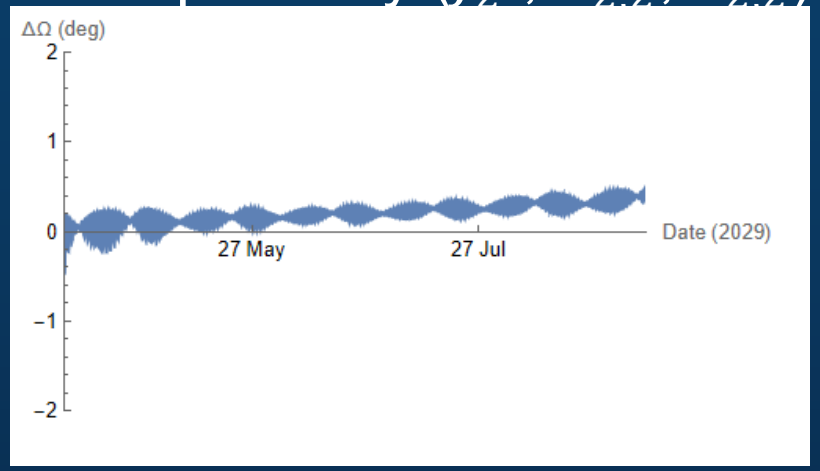


Sun-Earth-S/C VS perturbation (RAAN)

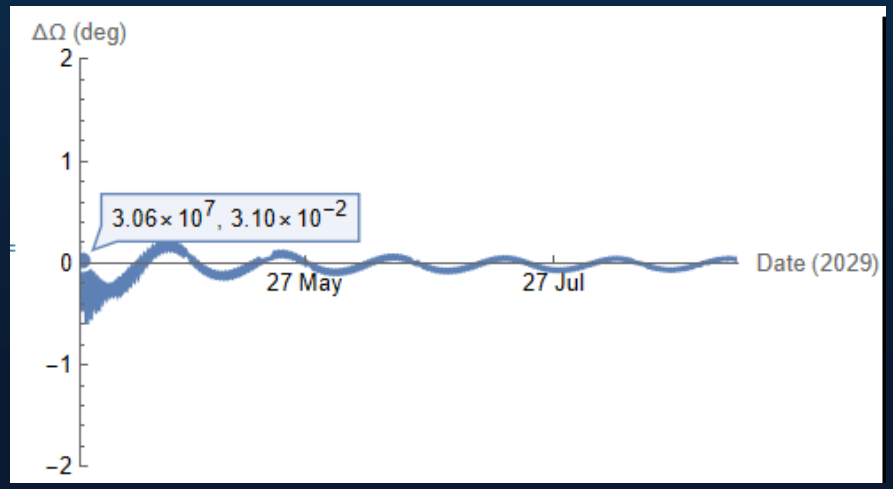
Moon



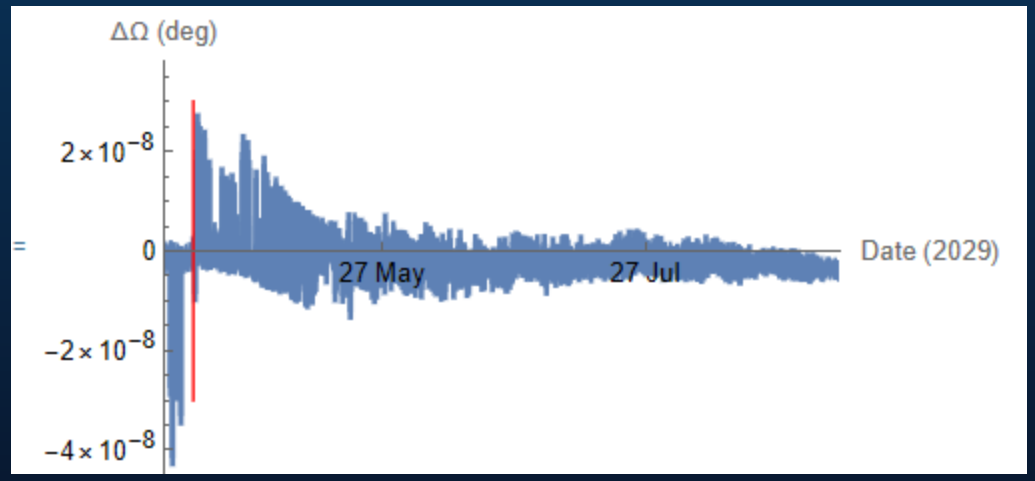
Non-sphericity (J_2 , $C_{2,2}$, $S_{2,2}$)



SRP

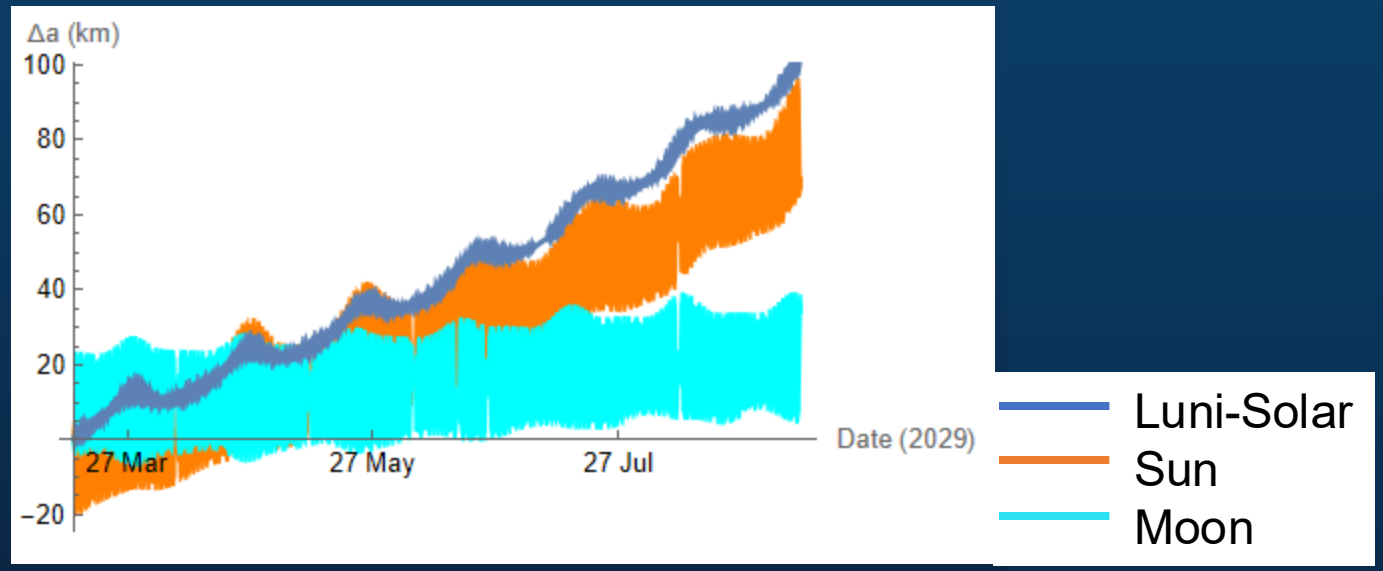


Apophis



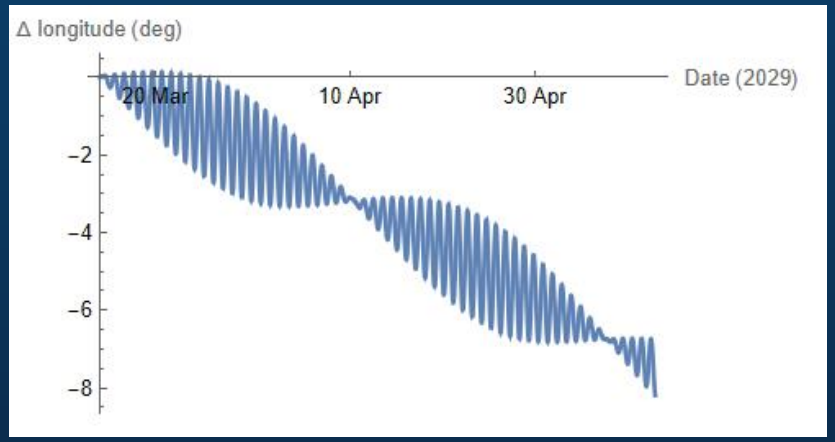
Sun-Earth-S/C VS perturbation (semimajor axis)

Luni-Solar

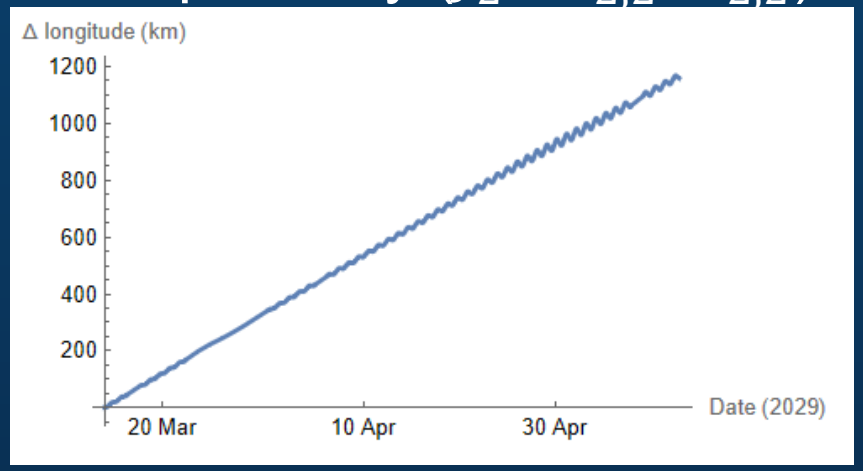


East-West drift

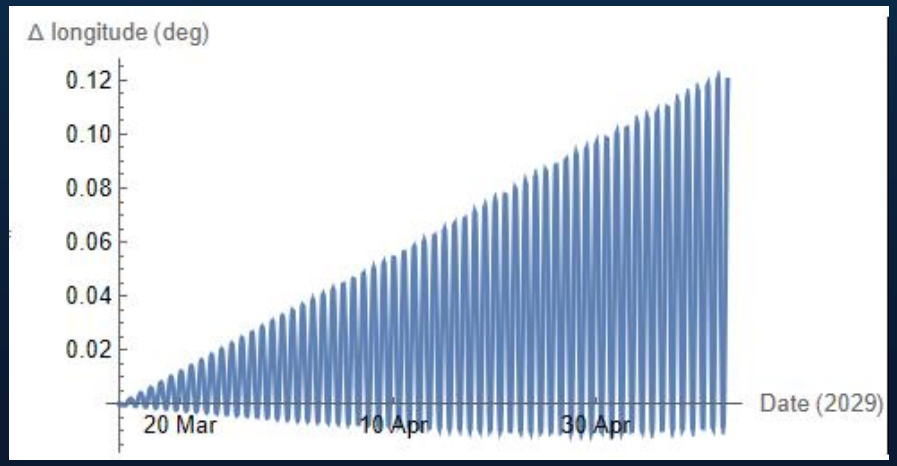
Moon



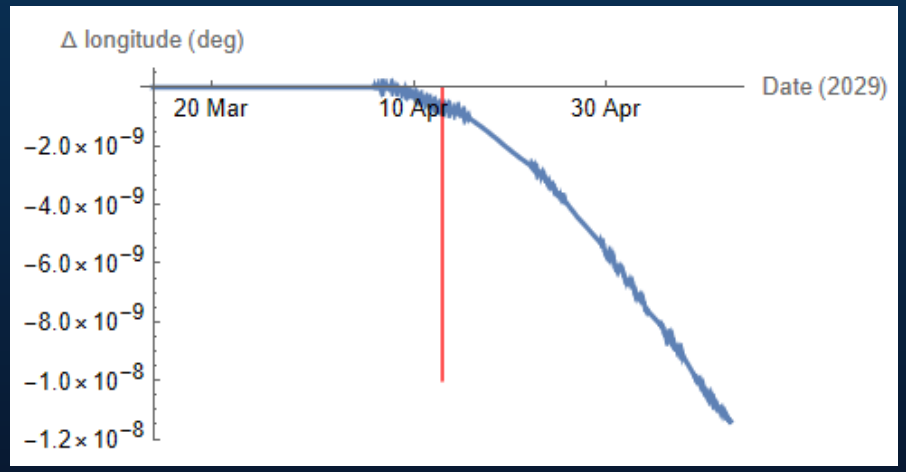
Non-sphericity (J_2 , $C_{2,2}$, $S_{2,2}$)



SRP

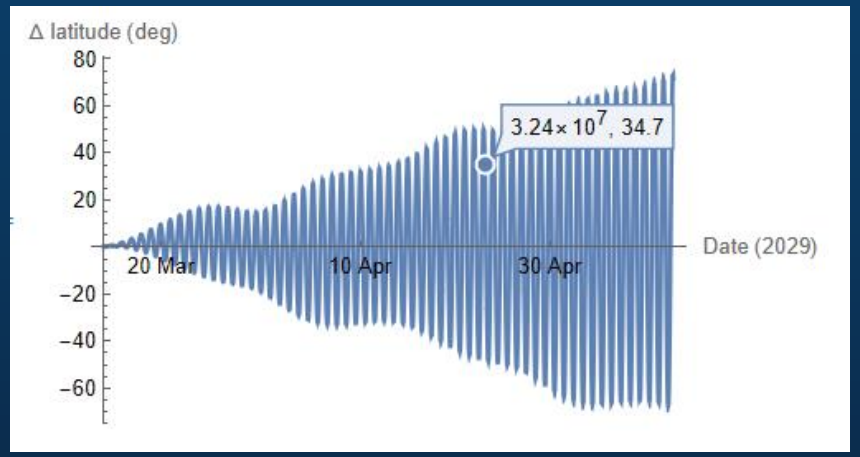


Apophis

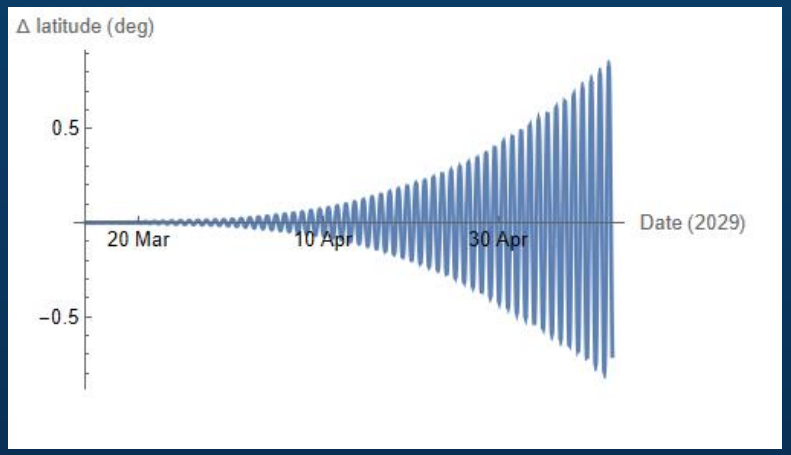


North-South drift (km)

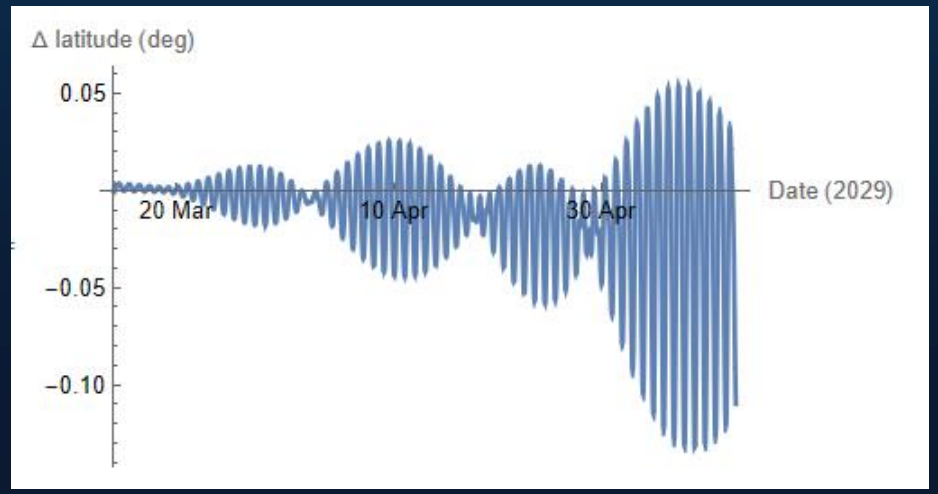
Moon



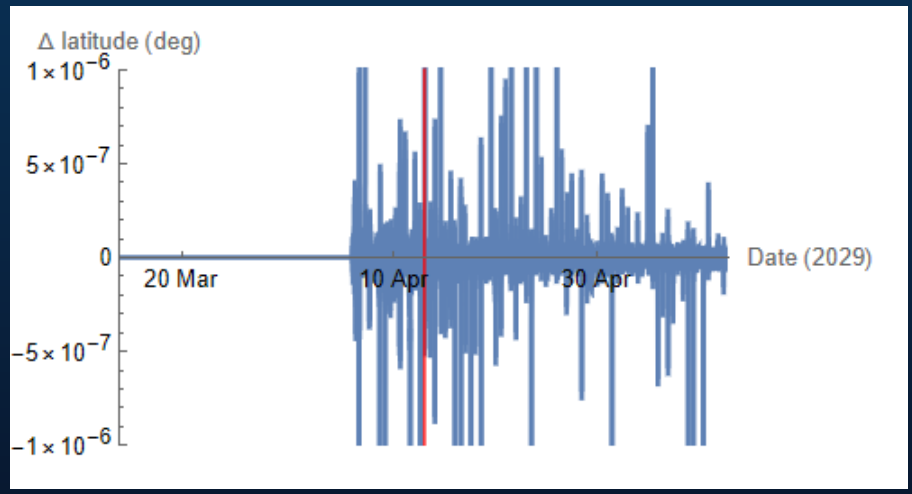
Non-sphericity (J_2 , $C_{2,2}$, $S_{2,2}$)



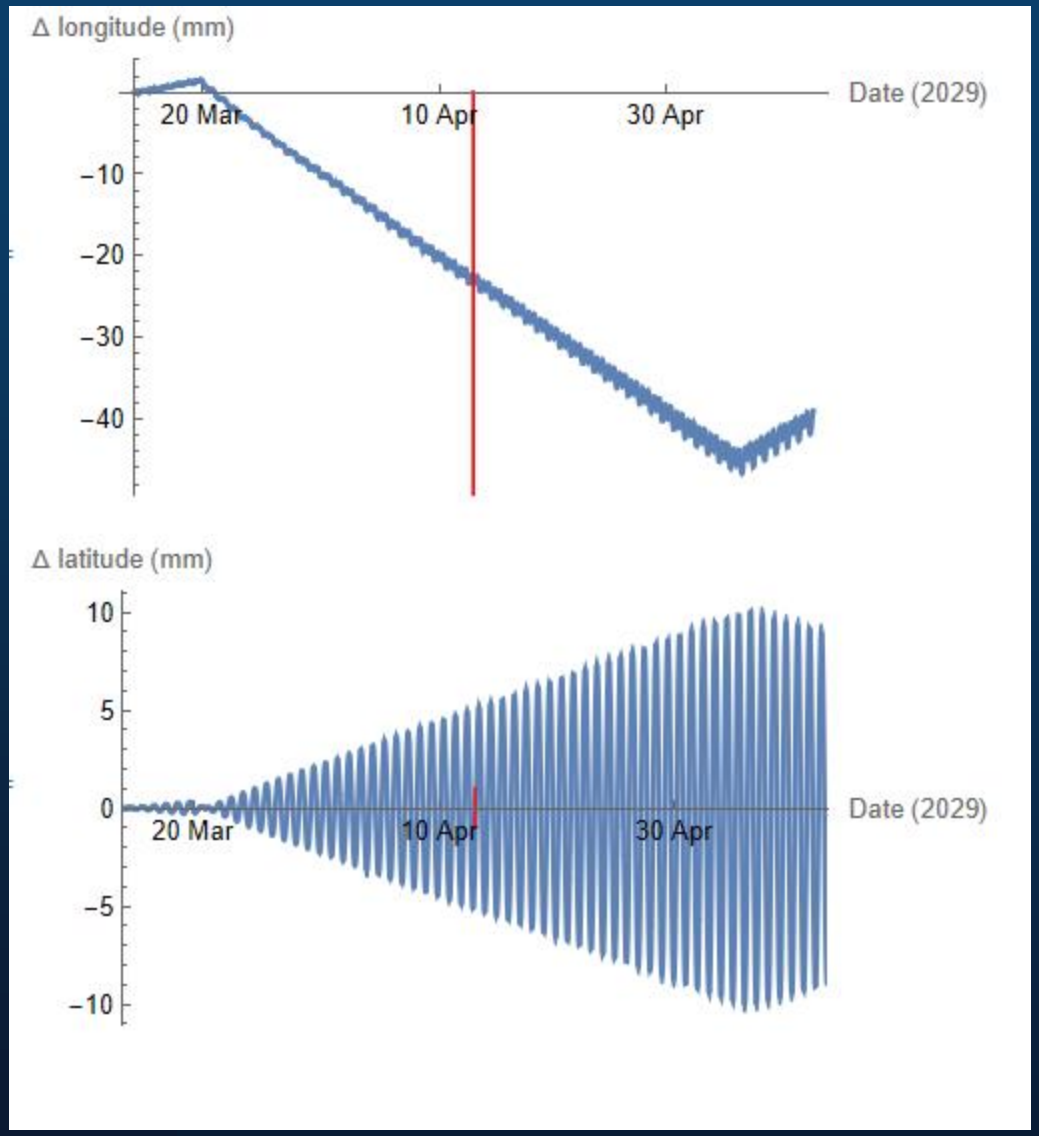
SRP



Apophis



Inmarsat drift



Intelsat 603 (1990- 2015)

- Mass 4.2 kg
- Height 5.2 m