Project

Applied Orbital Mechanics

ASE 366L

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Cjl3282

Task 1

For Task 1, an orbit propagator was developed to determine the effects of different perturbations in different kinds of orbits: Low Earth Orbit (LEO), Medium Earth Orbit (MEO), Geostationary Orbit (GEO), and Molniya Orbit (MOL). The givens for the Task included the semi-major axis (a), eccentricity (e), inclination (i), longitude of the ascending node (Ω), argument of periapsis (ω), and the start time (t_p) shown in Table 1 below.

Parameter	**LEO**	**MEO**	**GEO**	**Molniya**
a (km)	6763	26,560	42,164	26,000
e	0.001	0.001	0.01	0.72
i (degrees)	50	55	0.5	75
Ω	0	0	-120	90
ω	0	0	0	-90
t_p	March 1, 2020 12:00:00 UTC			

Table 1: Given values for Orbital Parameters

The baseline solution for comparison of the effects of each perturbation was the two-body solution. This baseline would be used to determine the difference and effects of each kind of perturbation on the various types of orbits. The orbits were then propagated with the two-body solution and perturbations including J_2, J_3, atmospheric drag, Sun third-body perturbation, Moon third-body perturbation, and Solar Radiation Pressure (SRP). The propagation length was 5 days in increments of 10 minutes.

First, the perturbations were propagated in Low-Earth Orbit. The results of the difference in magnitude between the two-body solution and each perturbation propagation are shown in Figure 1 below. As shown, the J1 and J2 perturbations had the greatest impact on the orbit while the impact from the perturbations from the Sun and Moon were significantly smaller and almost identical. The perturbations from the solar radiation pressure were the smallest and rapidly oscillatory which makes sense as the spacecraft would be moving in and out of the umbra and penumbra of the Earth rapidly at such a low altitude.

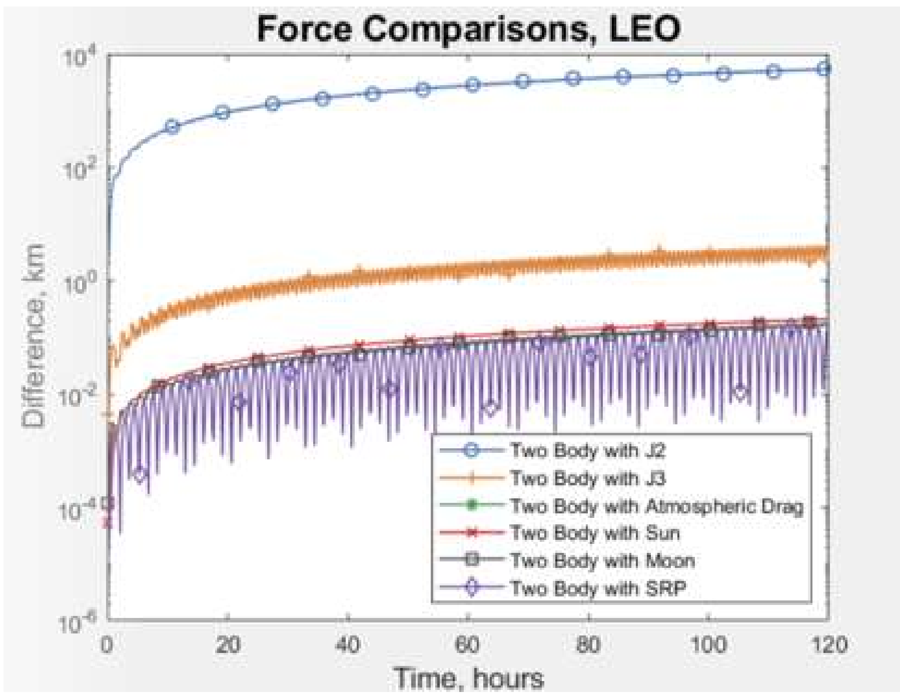

Figure 1: Result of difference in perturbation propagations from baseline in Low-Earth Orbit

Second, the perturbations were propagated in Medium-Earth Orbit. These are shown in Figure 2 below. Again, the effects of the J2 perturbations are significantly larger than the others. The perturbations caused by the Sun and Moon are now the next largest and are, again, almost identical. This makes sense as the orbital altitude is relatively similar to that of the LEO. The perturbations caused by the Moon do begin to oscillate as the MEO path would move the spacecraft closer to the Moon at its apoapsis. The Solar Radiation Pressure perturbations are the next strongest, but they oscillate much slower. This tracks with the fact that the orbital period is longer and the spacecraft would pass through the Earth's shadow less frequently. In MEO, unlike LEO, the J3 perturbations are by far the least impactful. Overall, the impact of each type of perturbation is significantly lower than those at LEO by an order of magnitude.

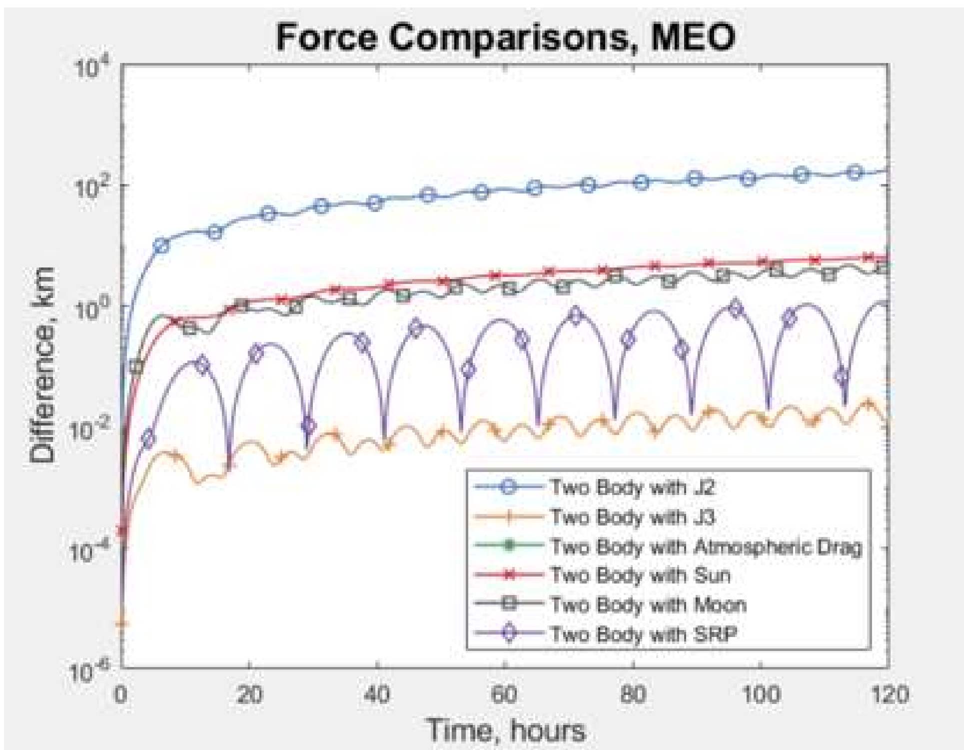

Figure 2: Result of difference in perturbation propagations from baseline in Medium-Earth Orbit

Next, the perturbations were propagated in Geosynchronous Orbit. These are shown in Figure 3 below. Again, the effects of the J2 perturbations are larger than the others, though less significantly than in LEO and MEO. The perturbations caused by the Sun and Moon are again the next largest and similar. The perturbations caused by the Moon do oscillate more significantly as the GEO path would move the spacecraft much closer to the Moon at its apoapsis than MEO and LEO. As such, the perturbations caused by the Moon frequently become larger than those of the Sun. The Solar Radiation Pressure perturbations are, again, the next strongest. In GEO, the J3 perturbations are also by far the least impactful and almost negligibly small. They do begin to become more oscillatory. In GEO, the impact of the J3, Sun, and Moon perturbations are slightly larger than those at MEO.

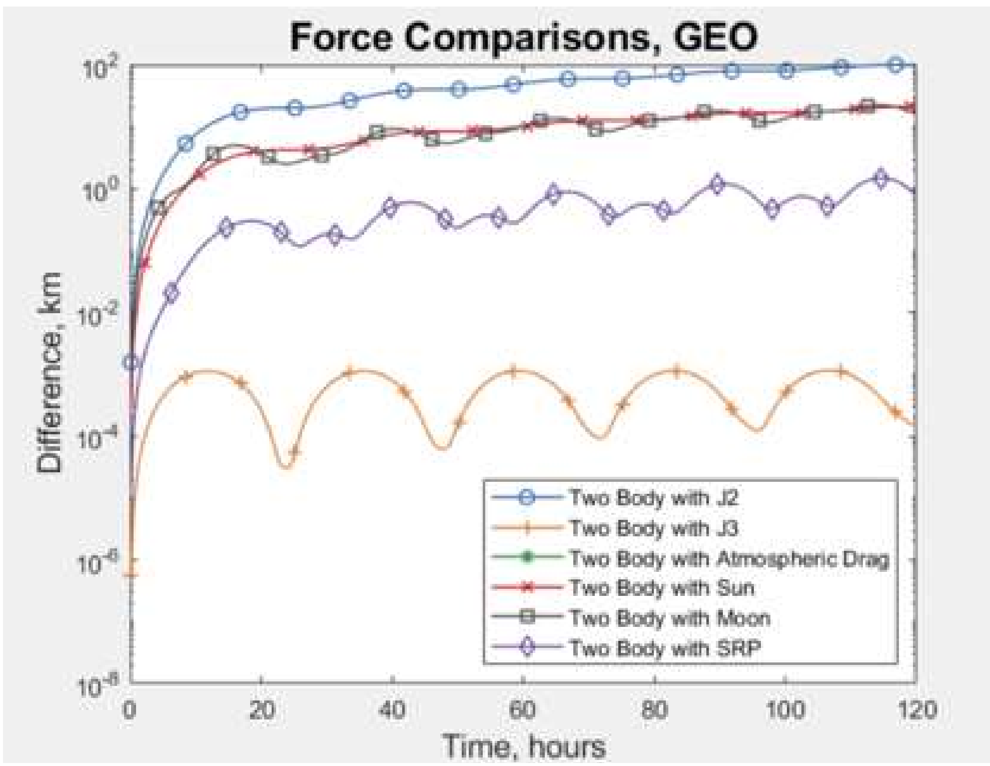

Figure 3: Result of difference in perturbation propagations from baseline in Geosynchronous Orbit

Lastly, the perturbations were propagated in a Molniya. These are shown in Figure 4 below. As with all the other orbits, the effects of the J2 perturbations are larger than the others, but it became much more oscillatory. The perturbations caused by the Sun, Moon, and J2 are the next largest and similar. However, unlike all the other orbits, they are significantly oscillatory in a Molniya orbit. This makes sense as the Molniya orbit is highly elliptical, so all the perturbations should be significantly oscillatory with the massive variations of altitude. The SRP perturbations are the smallest and largely oscillatory. The sharp peaks experienced in the oscillation of all the forces makes sense given the very short period of time in which the spacecraft is proximate to the Earth.

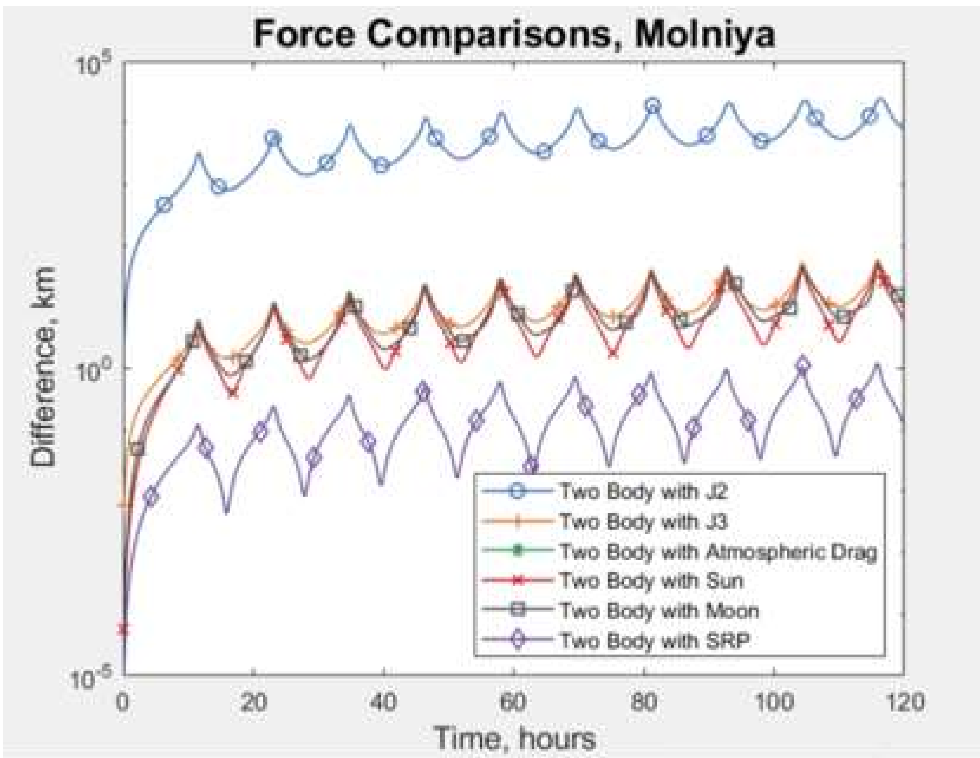

Figure 4: Result of difference in perturbation propagations from baseline in a Molniya Orbit

In each type of orbit, the J2 perturbations were the largest. The J3 perturbations, on the other hand were only really significant in LEO and a Molinya orbit. Across all the orbits, the perturbations from the Sun and Moon were similar and small compared to J2. The SRP perturbation effects were universally relatively small and almost negligible. Additionally, the SRP effects were universally oscillatory, the rapidity of which was depended on the orbital/revolutionary period.