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A3_2: Waving to the ISS

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Abstract

The aim of this paper was to determine how long it takes the ISS to repeat an orbit. We created an orbital simulation of the International Space Station (ISS) using official orbital data, from which we found that the time taken for the ISS to travel along a pre-travelled orbit (same latitude and within 1° longitude) was 6 days 21 hours and 21 minutes.

Introduction

The International Space Station (ISS) orbits Earth in a near circular orbit, with an eccentricity of 0.000741 [1]. As the ISS orbits around the planet, the planet rotates beneath it, and so the ISS does not travel above the same points on Earth with each orbit. The aim of this article is to determine how frequently the ISS passes directly above the same position on Earth, thus allowing you to wave directly upwards at the astronauts on board the ISS.

Theory

To perform this analysis we first obtained a recent Two Line Element set (TLE) [1] for the ISS's orbit. This is an industry standard format that contains the eccentricity, right ascension of the ascending node (RAAN), inclination, argument of perigee, mean anomaly as well as details on the identity of the satellite. The useful data from the TLE has been presented in Table 1.

We then took this information and entered it into the General Mission Analysis Tool (GMAT) and produced an orbital simulation for the ISS. GMAT is an open source piece of software that allows you to simulate orbits and gather meaningful data about the orbits. Figure 1 shows our simulation of the ISS after 12 hours. The orbital simulation was run until we observed the spacecraft following a pre-travelled orbital path. Please note, the ISS does not need to be directly overhead to be seen, and multiple different orbits can be observed from the same position on Earth. The aim of this study is to determine when exactly the ISS follows a previously travelled orbit, which we have defined as the point when two orbital paths are at the same latitude and within 1° longitude of each other.

Results

From our simulation we observed that the ISS follows an orbital path within 6° longitude of a previous path after just 23h 24m, and follows within 3° longitude of a previous path after 3d 14h 26m. It takes 6d 21h 21m for the ISS to orbit along a path that is within 1° longitude of a previous orbit, where all instances are at the same latitude.

Eccentricity	RAAN (°)	Inclination (°)	Arg. of Perigee (°)	Mean Anomaly (°)	Semi-Major Axis (km)
0.000741	208.4191	51.6447	93.1311	262.1433	6780

Table 1: Orbital elements of the ISS from the TLE [1], Semi-Major axis obtained from [2].

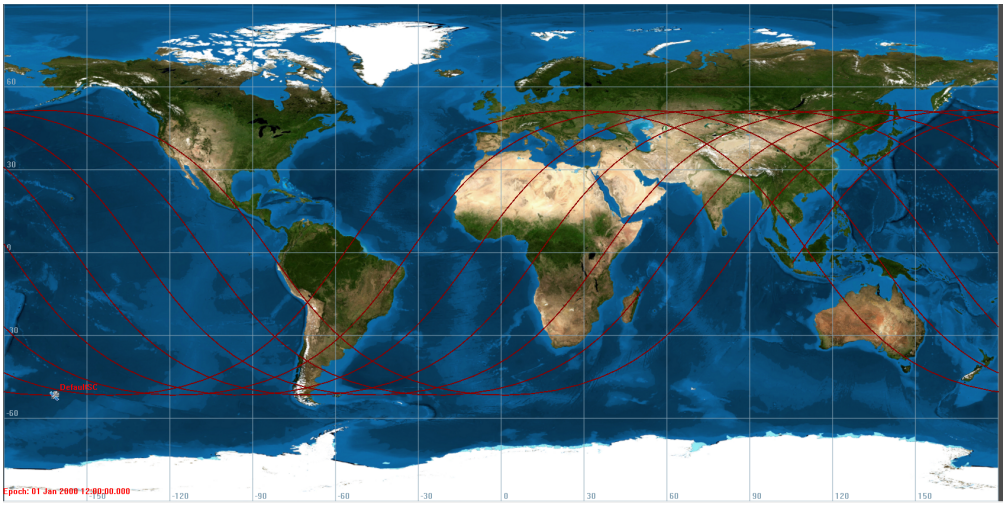

Figure 1: Example of the ISS orbit simulation

Discussion

The time taken for the orbital path of the ISS to repeat is 6 days, 21 hours and 21 minutes. We ran the simulation with a J2 perturbation model which mimics the effect of minor variations in the Earth's gravity [3] and all reasonable attempts were made within the software to simulate the conditions the ISS would experience. Despite this, we know our simulation cannot be totally accurate. First of all the ISS performs manoeuvres to avoid debris and to correct for orbital decay, meaning the orbital path does not remain constant. For our purposes we have assumed the orbit is stable and no decay occurs. Furthermore, our J2 model in GMAT is an estimation, and so it is not perfectly accurate. These factors will mean that our value is not the true value, but rather a reasonable estimate.

Conclusion

We found that the time taken for the ISS to repeat an orbit was 6 days, 21 hours and 21 minutes. In-depth error calculations for this study were not within the scope of this paper, as it would involve delving into uncertainties associated with the J2 model and calculating orbital decays for the time period. The aim of this paper was to produce a reasonable estimate. Future work could calculate the true value of the time taken to repeat an orbit, with a comprehensive calculation of the associated errors.

References

[1] `https://www.n2yo.com/satellite/?s=25544` [Accessed 28 September 2019]

[2] `https://www.heavens-above.com/orbit.aspx?satid=25544` [Accessed 28 September 2019]

[3] `https://www.vcalc.com/wiki/eng/J2+Perturbation+Acceleration` [Accessed 28 September 2019]

Acknowledgements

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