MODELLING AND SIMULATIONS OF VERY LOW EARTH ORBITS

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Abstract

Flying a satellite a very low earth orbits, namely VLEO, is a technological challenge [1]. It can present several advantages, such as increase resolution in optical payloads, reduce costs of launch, enhance the use of air breathing propulsion and specular materials, and be an opportunity to open new markets with small satellites. However, the density of the atmosphere at these altitudes is much higher, behaving as a free molecular flow. This has severe implications in the increase of drag torques and forces that has to be analyzed in depth. In this work, we analyze the effects of flying at VLEO by implementing and analyzing realistic models of the space environment at VLEO: magnetic, atmospheric and atmospheric wind models [1][2][3]. They are also analyzed as perturbations to small satellites, affecting their dynamics, performance and lifetime. This work is part of the H2020 DISCOVERER project. Project ID 737183.

Keywords:* *VLEO, aerospace, atmospheric model, magnetic model, disturbances, model design, satellite simulation, open source.

1. Introduction

In the last years the interest in VLEO has increased because of the advantages of orbits in altitudes lower than 450 km [1]. Flying at these altitudes increases the signal to noise ratio for the communications, revisit time can be increased, optical payloads can provide higher resolution imagery, VLEO orbits have less population of space debris and have less propagation delay than higher orbits, among others. However, VLEO missions must face challenges due to the change in the atmosphere density and composition at low altitudes such as reduced lifetime, free molecular flow gas-surface interactions and corrosion produced by atomic oxygen. These gas-surface interactions increase the drag forces and torques affecting a satellite flying at these low altitudes and, for instance, their operations can be significantly different compared with satellites flying at higher orbits. In this paper we present the characteristics of the VLEO environment and how it affects to the performance of a satellite. Results comparing a satellite flying at LEO and at VLEO are shown, and the main differences are highlighted.

2. Perturbations and models

The tool used to run the simulations was Scilab with its graphical modelling tool Xcos. The following models were integrated in the tool: the DTM2013 atmospheric model [3], the IGRF12 magnetic model [2] and the HWM14 horizontal wind model [4]. These three models accurately emulate the space environment at VLEO. From them the main perturbations (aerodynamic torque, magnetic dipole and gravitational torque) affecting the satellite dynamics were also computed. Solar radiation is not considered because of its low influence at VLEO.

Figures 1 shows the atmospheric density at 350 km (left) and 700 km (right). Figure 2 and Figure 3 show the magnetic field and atmospheric wind at 700 km and at 350 km altitude respectively. Notice that the atmospheric density highly increases at VLEO , while the magnetic field and the wind is in the same order of magnitude. Even though the wind is the same, the higher density of particules produces higher gas-surface interaction. This explains the importance of aerodynamic torques and forces at VLEO.

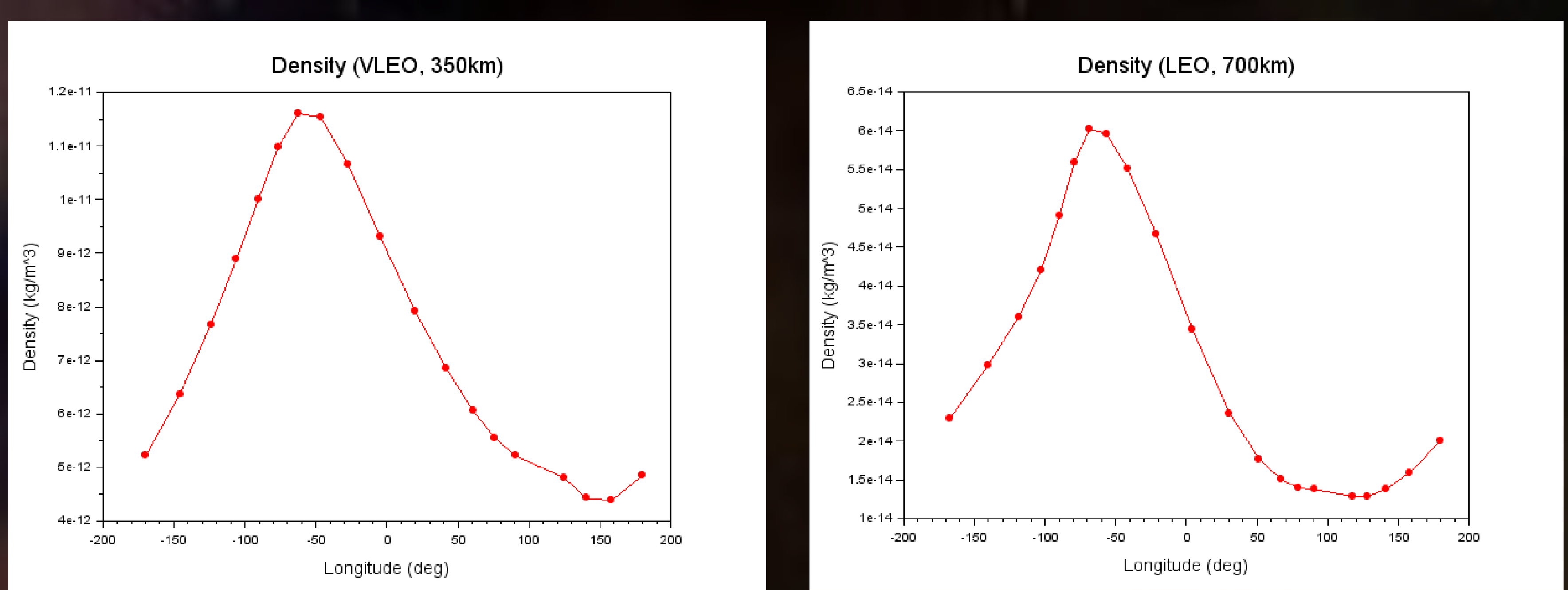

Figure 1: Atmospheric density. (left) at VLEO orbit (350 km) (right) at LEO orbit (700 km)

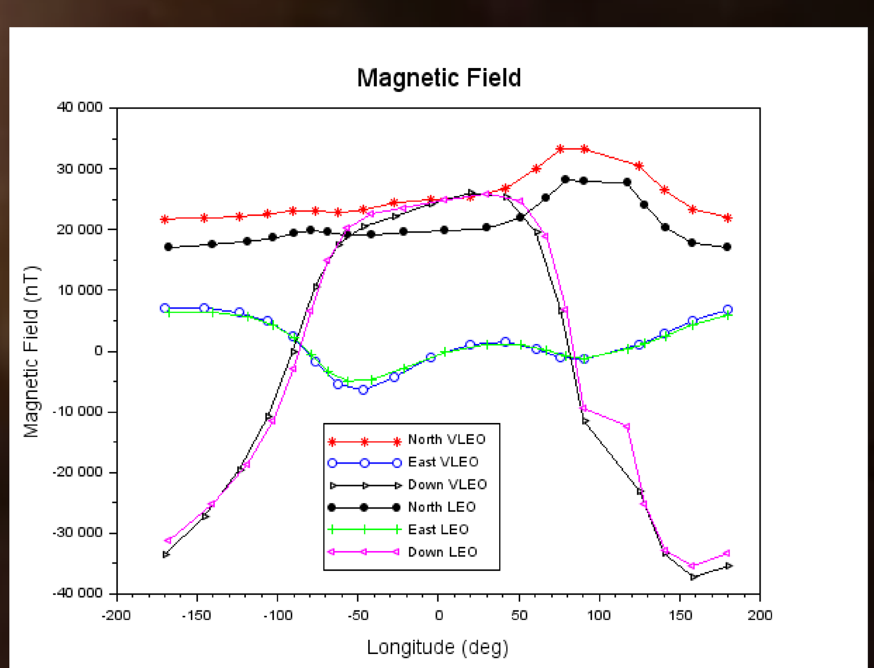

Figure 2: Magnetic field

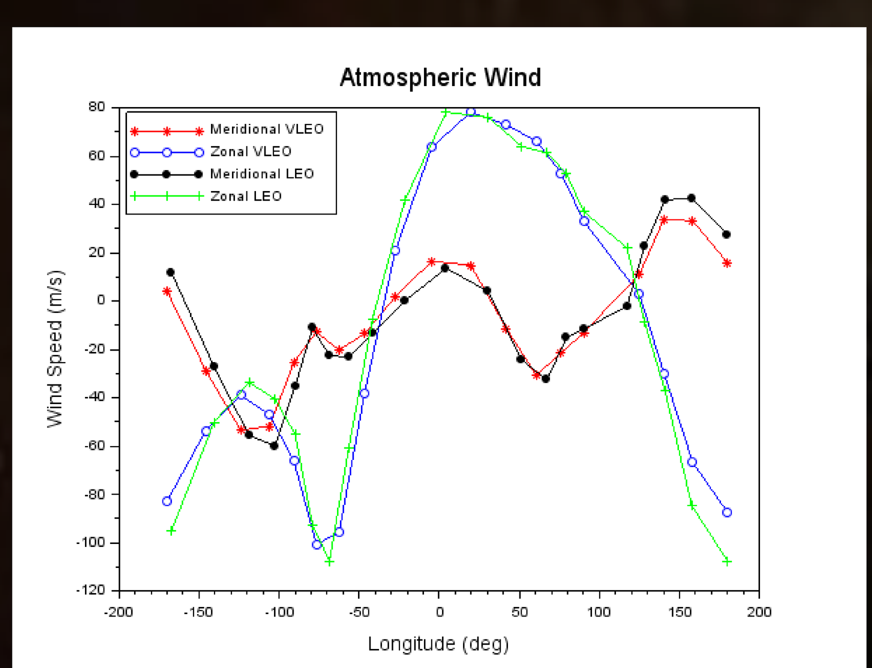

Figure 3: Atmospheric wind

3. Results

Figure 4 shows how the lifetime of a 1U CubeSat changes for flying in the range 700km-400km and its lifetime at VLEO in the range 350-100km.
Figure 5 shows how the geometric shape of a satellite affects its lifetime at VLEO. It shows different typical CubeSat types.

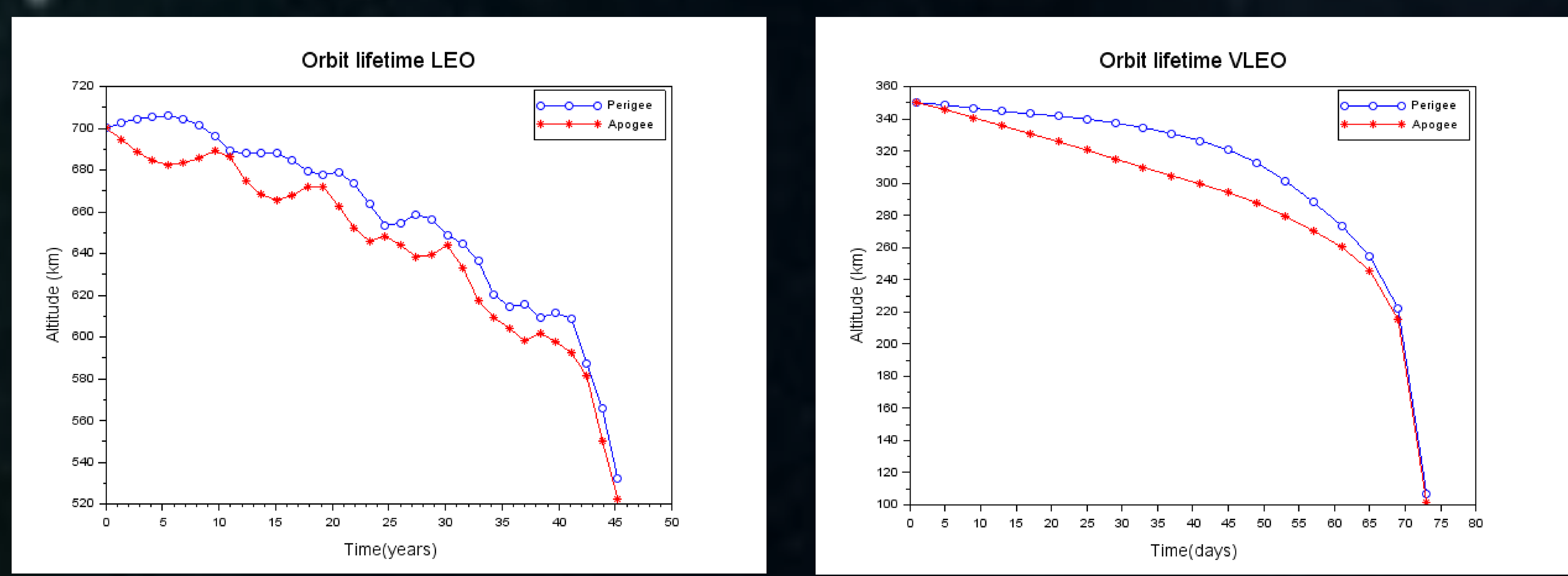

Figure 4: Orbit lifetime for a 1U CubeSat

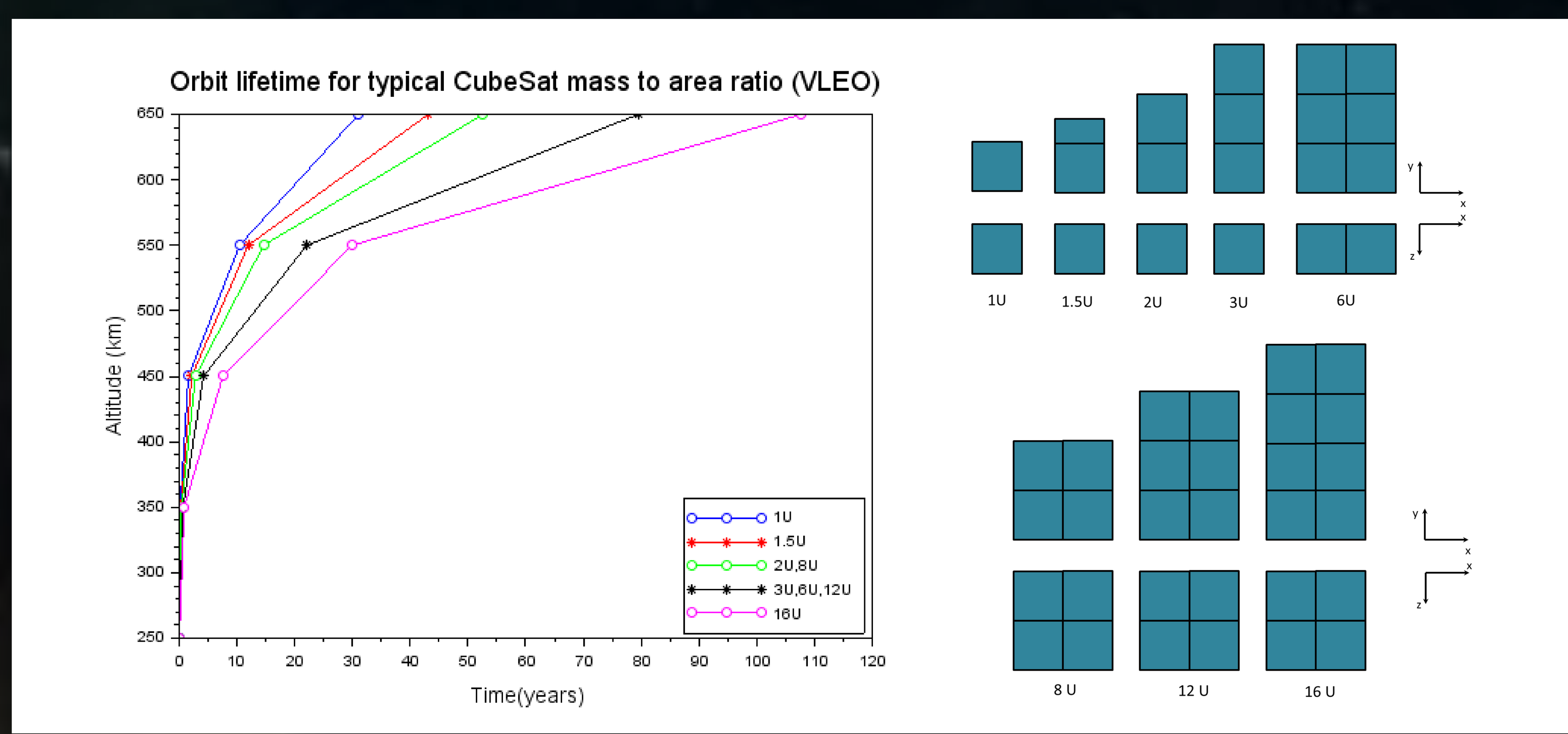

Figure 5: Orbit lifetime in VLEO for several CubeSat types

4. Conclusions

The results show that the lifetime of a satellite flying at VLEO is drastically reduced because the higher atmospheric density produces a higher gas-surface interaction and increases drag torques and forces. A 1U CubeSat flying at VLEO would reenter after 73 days while at LEO would reenter after 45 years. Furthermore, the mass to area ratio of the satellite also affects the lifetime. Flying with the minimum drag position a 1U CubeSat would reenter earlier than the rest of CubeSat configurations, and the higher the mass to area ratio the longer the lifetime.

6. References

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