Hermes CubeSat Orbital Debris Mitigation Plan

For the Federal Communications Commission

Project Manager
Dustin Martin

Lead Systems Engineer
Alicia Harris

Principal Investigator
Brian Sanders

Colorado Space Grant Consortium
University of Colorado-Boulder

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Referenced FCC Documents

FCC-04-130A1
DA-05-2698A1

Introduction

The following is the current orbital debris mitigation plan for the Colorado Space Grant Consortium's (COSGC) Hermes CubeSat. Hermes is a student designed and built, 1kg, 1000 cm^3 picosatellite which is designed with regards to the CubeSat Design Specification (CDS) document as published by California Polytechnic State University (CalPoly). Hermes is currently in the closing stages of development and midway through testing, and will be ready for delivery on April 1st, 2008. This satellite has been selected for a launch, and will launch from Vandenburg Air Force Base in the second quarter of 2009. This would yield a nearly circular, sun-synchronous orbit with mean altitude of 643.3km above sea level and an inclination of 97.94 degrees.

CubeSats are typically launched in sets of three from the CalPoly designed Poly Picosatellite Orbital Deployer (P-POD). The CubeSats ejected in a set are guaranteed not to collide with each other in flight because they are each given a small differential velocity relative to one another such that over time the distance between the three satellites will increase. Thus, the deployment, by design, will not allow the CubeSats to contact each other.

Hermes contains two separate communications systems: one that operates in the UHF band at 435 MHz and one that operates in the S-band at 2400 MHz. Frequency coordination for the UHF band transmission was obtained through the International Amateur Radio Union (IARU) and an experimental license is currently being filed for the S-band system.

Spacecraft Hardware Design: Control of Debris Released During Normal Operations; Selection of a Safe Operational Configuration; Collisions with Small Debris

Hermes is designed so that no debris will be released from the satellite during any stage of the mission or post-mission. The entire satellite is contained within the 10cm per side specifications of CalPoly with the exception of deployable antennae. The antenna for the S-band communication system is a 3.25 cm monopole. The antenna for the UHF communication system consists of a 17 cm monopole extending from one side of the cube. Both antenna will be deployed through the use of nichrome and plastic wires and will spring vertical upon release. At all times the antennae are still attached to the satellite at one end.

Due to the extremely small size and weight restrictions of the satellite, it is difficult to take measures to protect against collision with small orbital debris. However, because the satellite is so small, it decreases the probability of it being struck by small debris. Furthermore, numerous areas of redundancy are implemented on the satellite to eliminate single-event failures. This was done primarily due to radiation concerns, but it is also applicable in this context. Therefore, if one redundant element is rendered inoperable, the satellite can switch to the back-up and still have full capability. Unavoidably, the majority of the exposed surface of the satellite is covered with solar cells which will most likely fragment if struck by small debris. No special subsystems are used for post-mission disposal and therefore are not affected by collision with small debris.

Minimizing Debris Generated by Accidental Explosions

Due to its small size, the Hermes power subsystem operates at low currents and voltages in comparison to larger satellites. The maximum voltage onboard the satellite is 10V if the solar panels are receiving sunlight and 7.4V if batteries are providing all power. The Lithium-Ion batteries have a charge capacity of 650mAh each and are connected in series. There are no propellants, combustibles, high pressure fluids, or high kinetic energy sources onboard the satellite to generate an explosion. In accordance with good engineering practice, at the end of the mission life, the batteries will be drained completely and the charging mechanism shut down.

Safe Flight Profiles: Collisions with Larger Objects

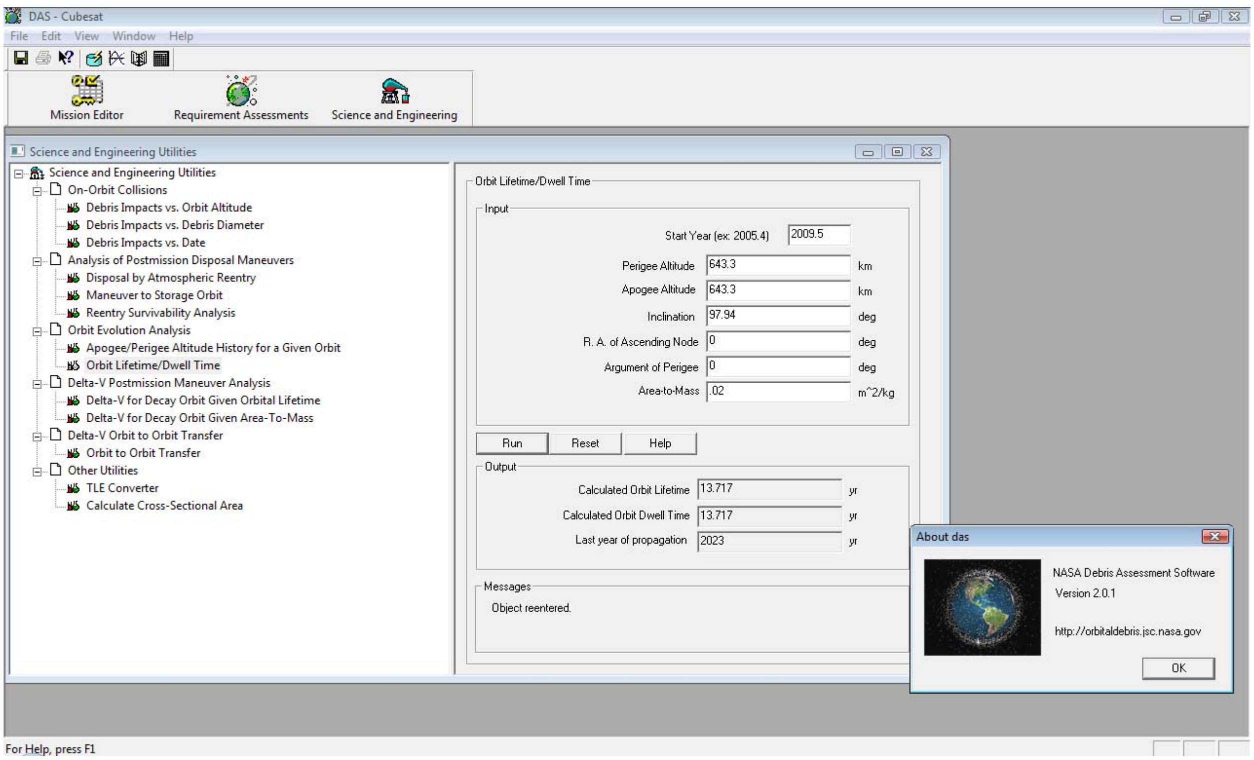
Hermes is designed to operate in Low Earth Orbit (LEO) at altitudes between 400km and 800km. As mentioned in the introduction, the current primary launch opportunity is a nearly circular orbit at 643.3km. The satellite contains no means of orbit keeping and therefore the orbit will degrade due to atmospheric drag over time. It follows, therefore, that evasive maneuvers to avoid collisions are also not possible for Hermes.

Post-Mission Disposal

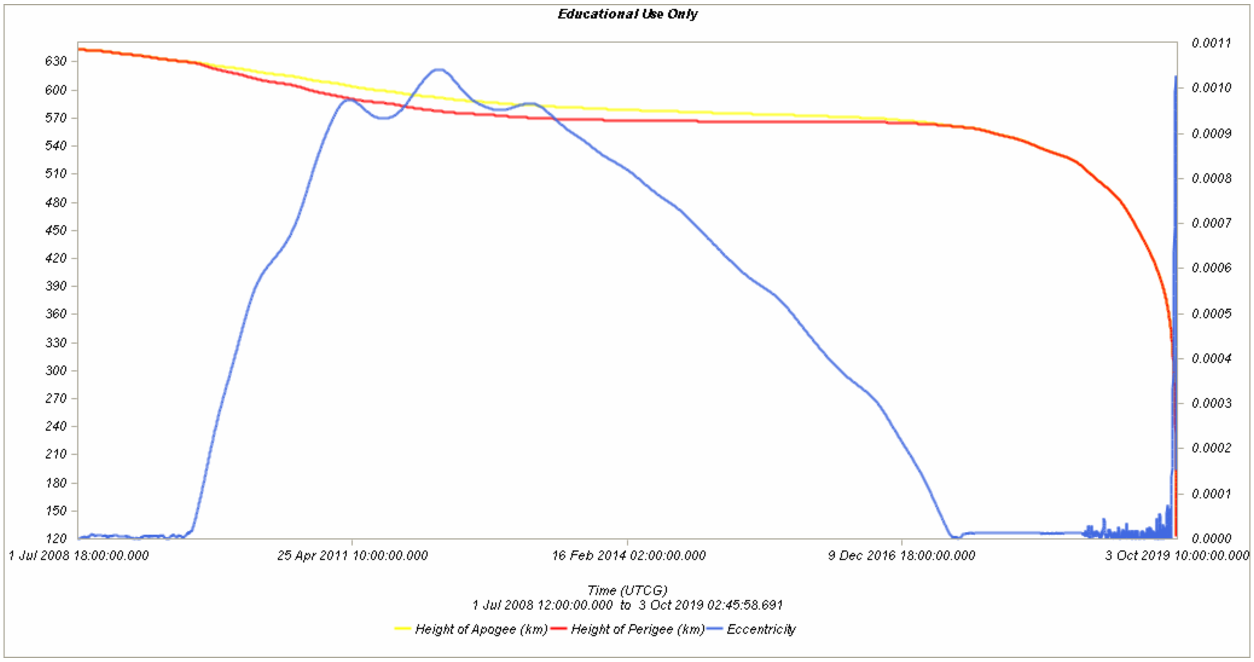
Because of the lack of a propulsion system, the post-mission plan for Hermes is to allow it to re-enter Earth's atmosphere and disintegrate. For a satellite of such small size and weight, there is no risk of human casualty as no debris will ever reach the surface. No extra measures are planned for hastening orbit degradation, again primarily due to a lack of room on the small satellite.

The planned mission life for Hermes is one calendar year with mission extensions likely to at least two years if the satellite is still operating. Radiation estimates indicate that it will take at least five years or more for even the least radiation tolerant components to fail from total ionizing dose.

The expected orbital lifetime depends heavily on the achieved orbit. Assuming that the target altitude of 643.3 km and inclination of 97.94 deg is reached, the orbital lifetime of the Hermes satellite will be 13.717 years. This estimate was produced using the NASA Debris Assessment Software, Version 2.0.1 (http://orbitaldebris.jsc.nasa.gov). It was calculated with a launch date of June 2009, an altitude of 643.3 km, an inclination of 97.94 degrees, a mass of 1 kg, and an average cross sectional area of 0.02 m^2 when tumbling. This orbital lifetime is less than the maximum allowed of 25 years, and thus meets the requirements for debris mitigation. With a worst-case orbital altitude of 690 km, and the same parameters as given above, the lifetime of the satellite will be 24.257 years, as calculated by the NASA Debris Assessment Software. Below is a figure of the software that was used to calculate the orbital lifetime of the satellite. Entered in the shown window are the parameters used and the resulting orbital lifetime.



To verify the accuracy of this analysis, a similar analysis was completed using Satellite Tool Kit. The satellite was modeled with the same parameters of an altitude of 643.3 km, inclination of 97.94 degrees, effective area of 0.2 m^2, mass of 1 kg, drag coefficient of 2.2, and a reflection coefficient of 1. When this analysis is performed with STK, the resulting orbital lifetime is 11.3 years, which is close to the result given by the NASA Debris Assessment Software. Below is a graph of the orbital altitude over the lifetime of the satellite created by Satellite Tool Kit.


Educational Use Only
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0.0000
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25 Apr 2011 10:00:00.000
16 Feb 2014 02:00:00.000
9 Dec 2016 18:00:00.000
3 Oct 2019 10:00:00.000
Time (UTCG)
1 Jul 2008 12:00:00.000 to 3 Oct 2019 02:45:58.691
Height of Apogee (km)
Height of Perigee (km)
Eccentricity