MAGNETO

Orbital Debris Assessment Report
(ODAR)

Revision A
10/31/2019

Approved By

Prepared By

Prepared in accordance with 47 C.F.R. §5.64(b). DRAMA(Debris Risk Assessment and Mitigation Analysis) version 3.0.2

Table of Contents

Assessment Report Format

ODAR Technical Sections Format Requirements:
This ODAR follows the format NASA-STD-8719.14 Appendix A.1 and includes the content indicated at a minimum for each section 2 to 8 below fro MAGNETO satellite. Sections 9 - 14 apply to launch vehicle ODAR and are omitted.

ODAR Section 1: Program Management and Mission Review

Mission Description:
Our mission is to support scientific understanding of magnetic fields in low earth orbit and the launch vehicle environment. The primary goal is to use commercial off the shelf sensors (COTS) to measure the Earth's Magnetic Field in Low Earth Orbit (LEO). The secondary goal is to use an Ephemeris, a sun sensor, and gyros to measure the satellite's pose/position in orbit.

Launch Vehicle and Launch Date:

Proposed Launch date: February /March 2020

Mission Duration: 60 days

Launch and deployment profile , include all parking , transfer, and operational orbits with apogee, perigee and inclination:

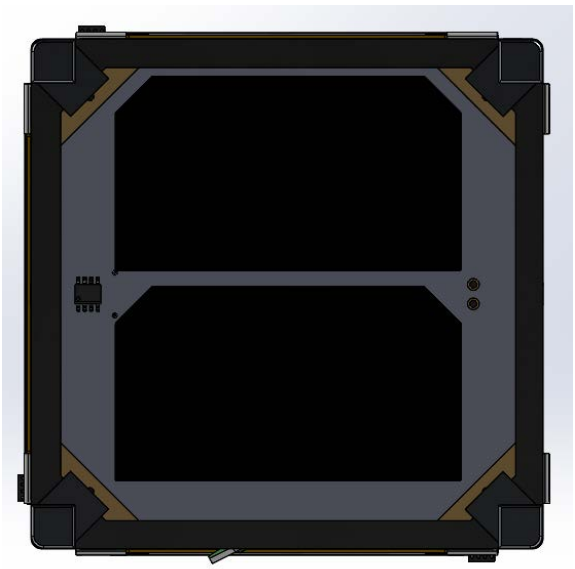
MAGNETO Orbital Elements:

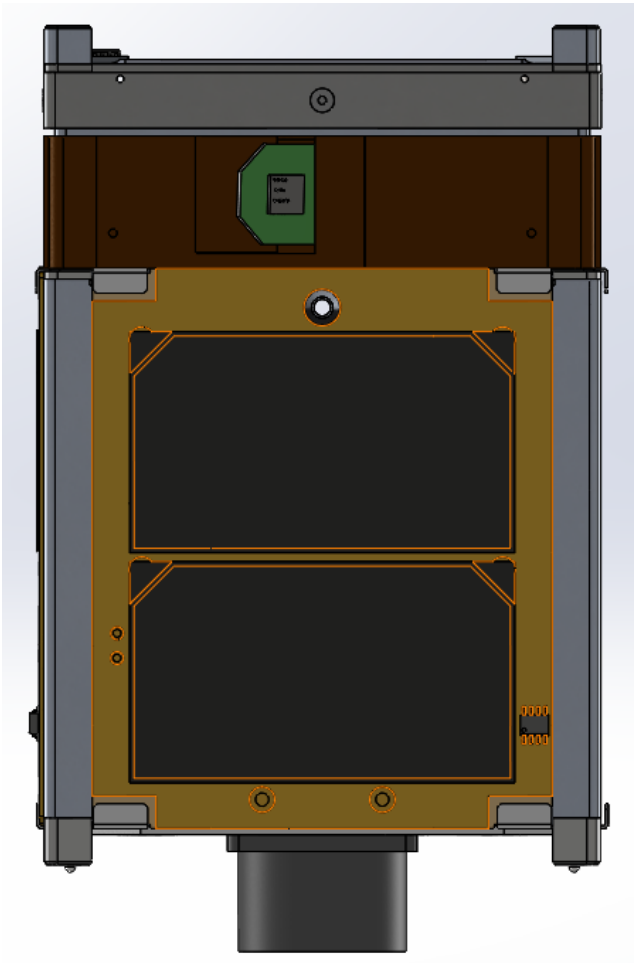
Apogee: 300km
Perigee: 300km
Inclination: 97 deg

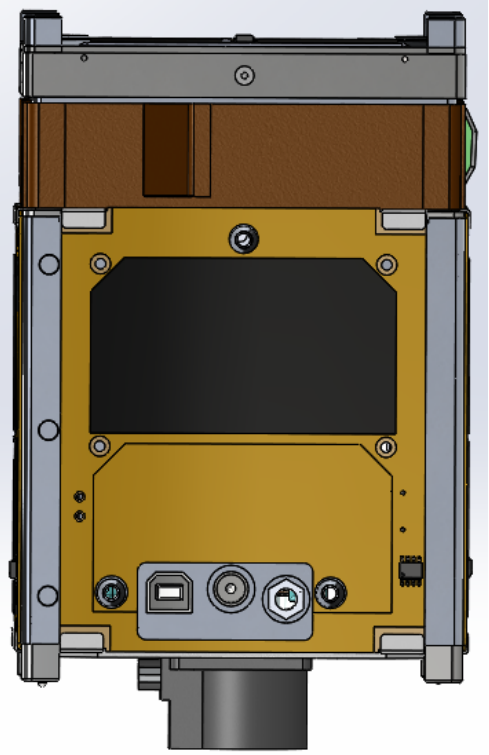
Due to absence of propulsion system, MAGNETO does not actively change orbits. No parking or transfer orbit.

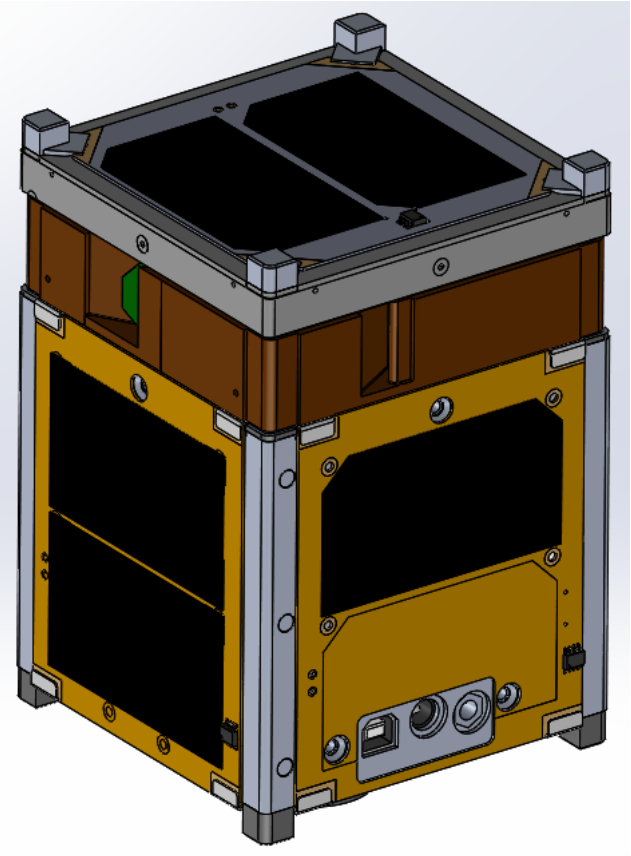
At present, there is no potential interaction or physical interaction between MAGNETO and any other operational spacecraft

Undeployed configuration:









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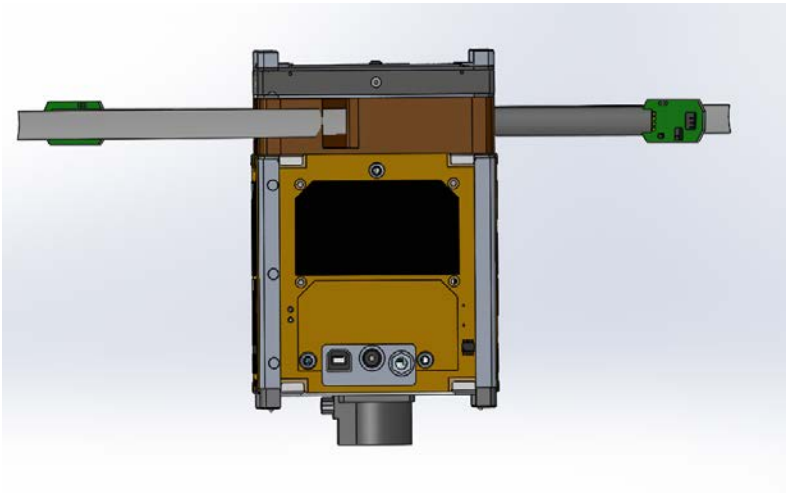

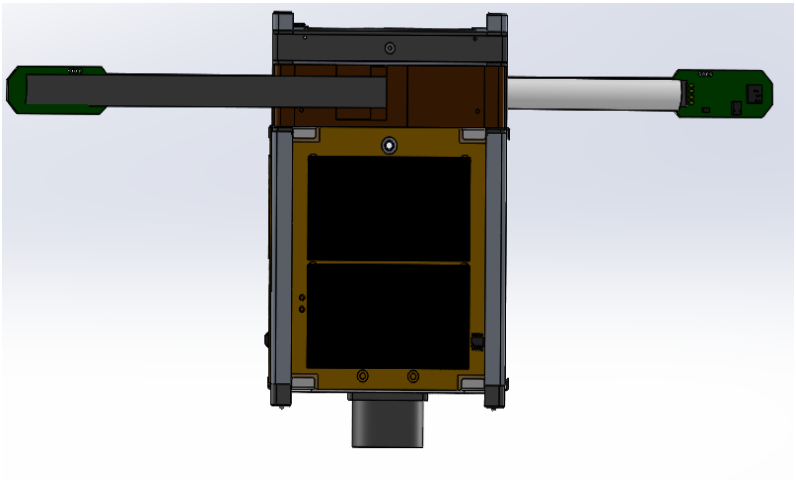

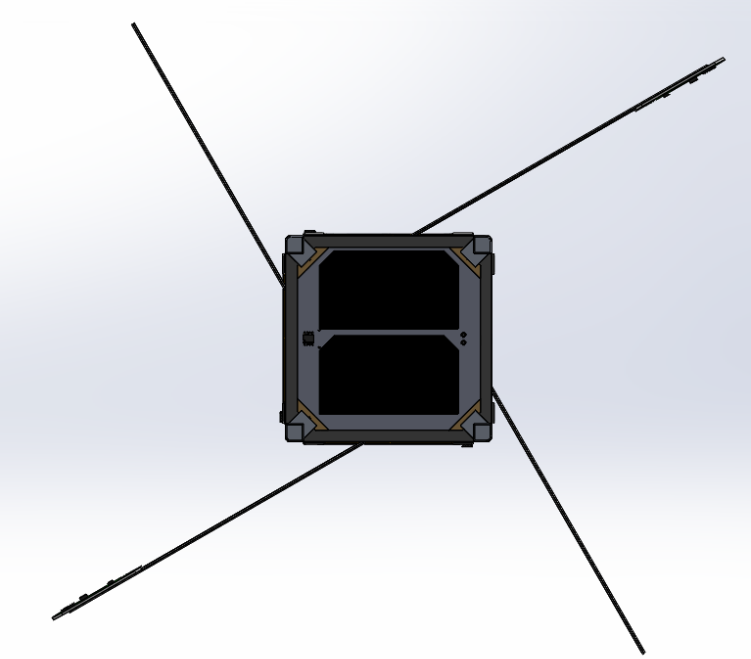

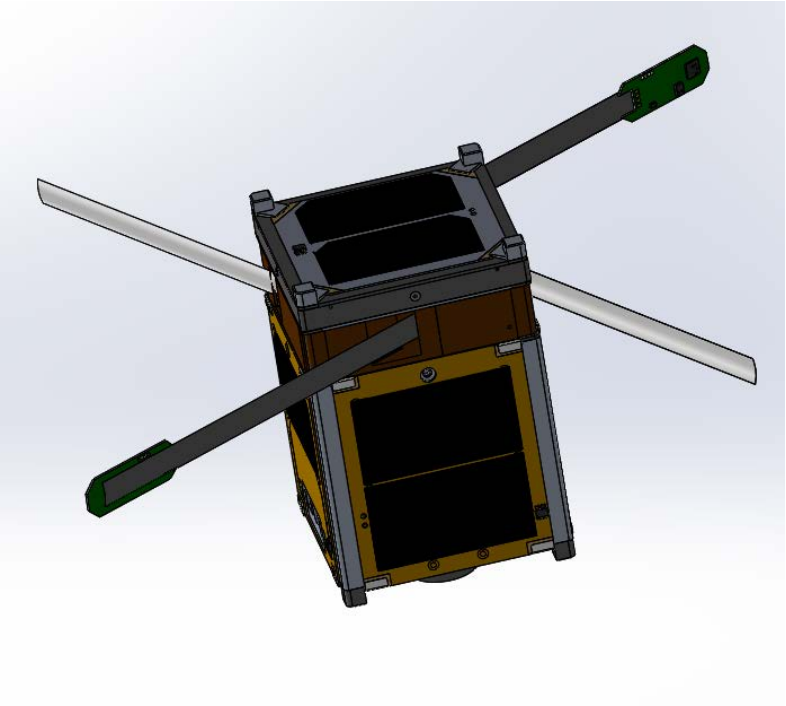

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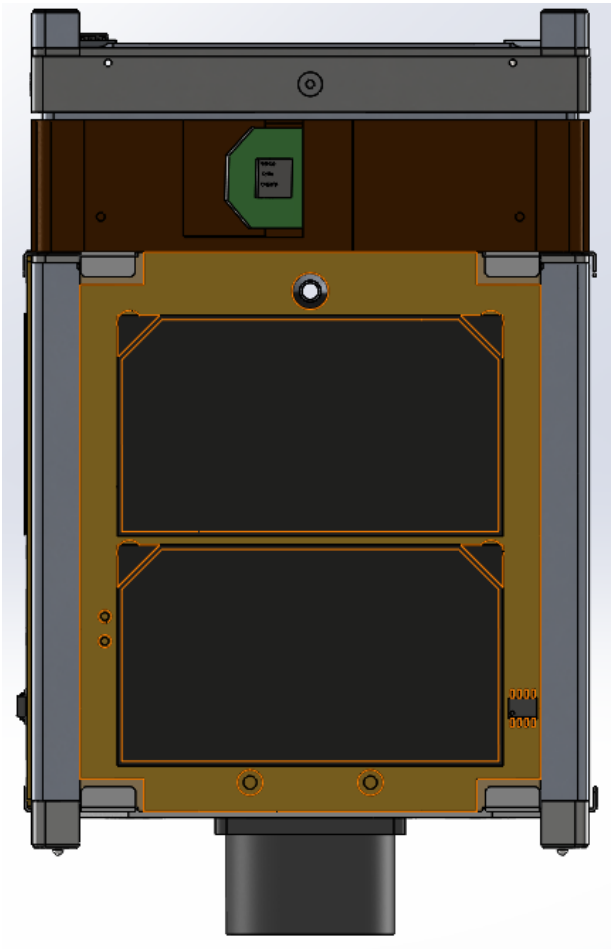

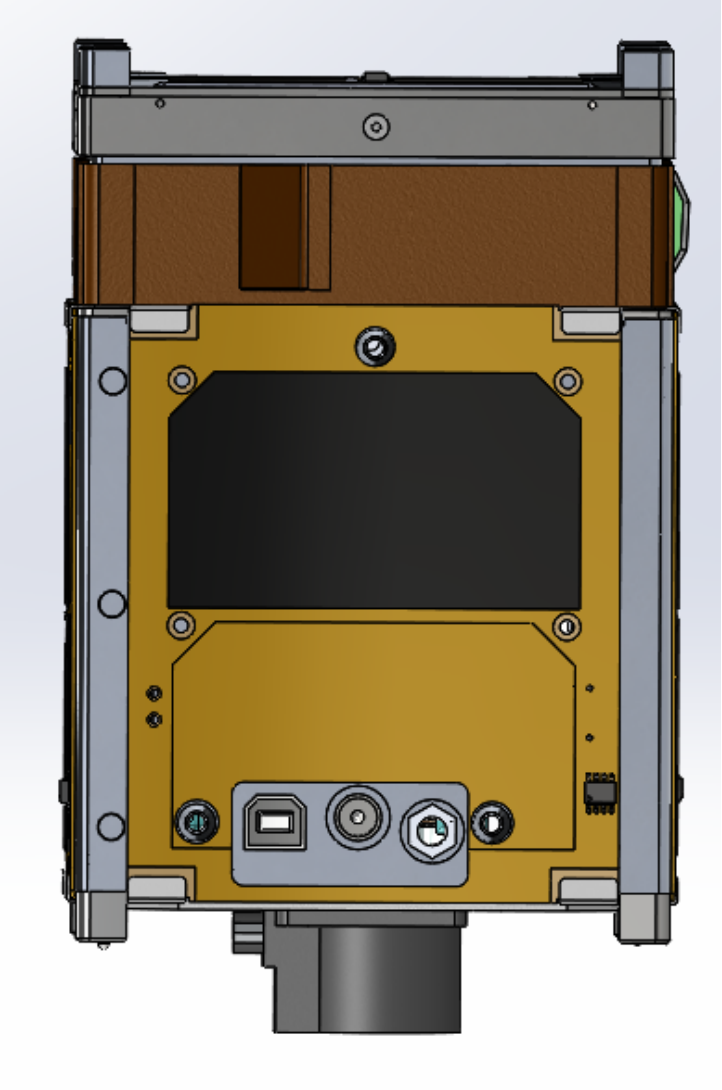

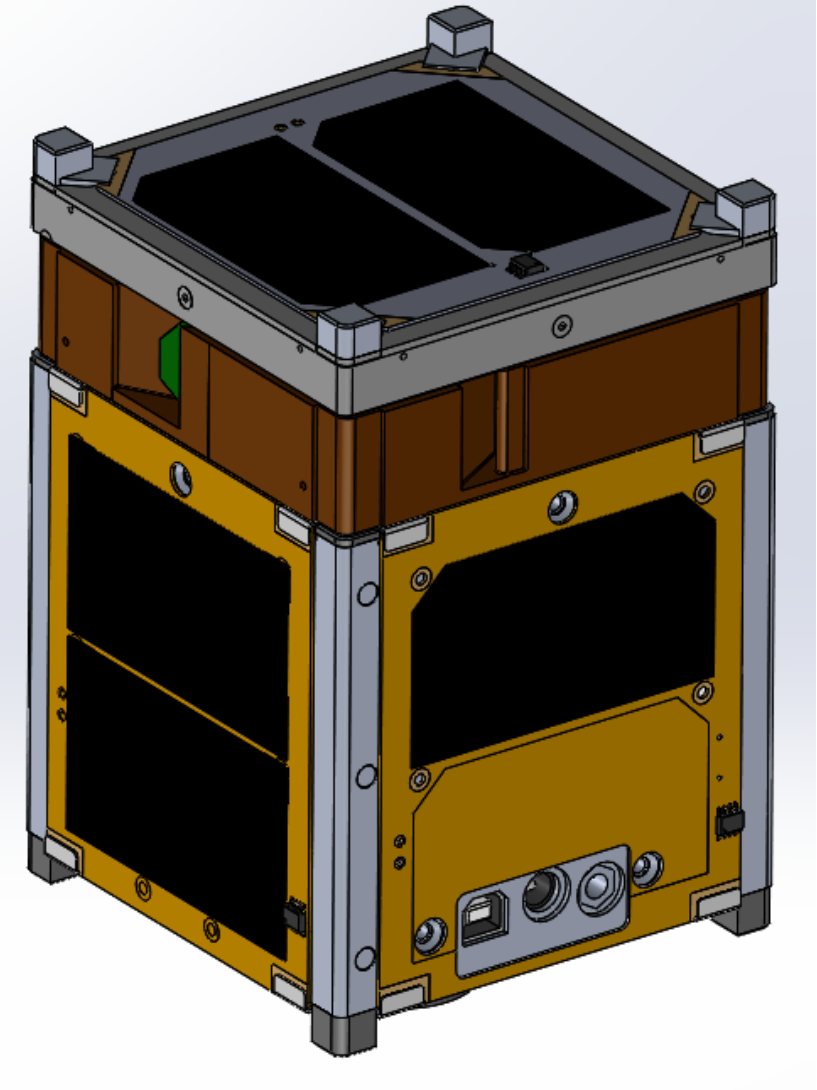

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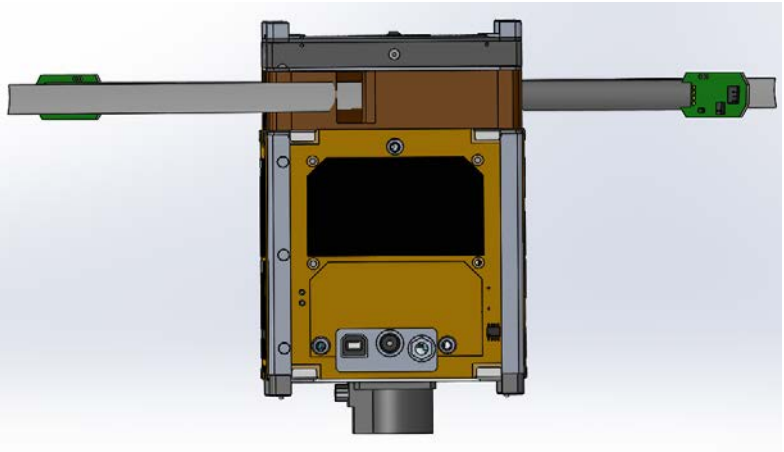
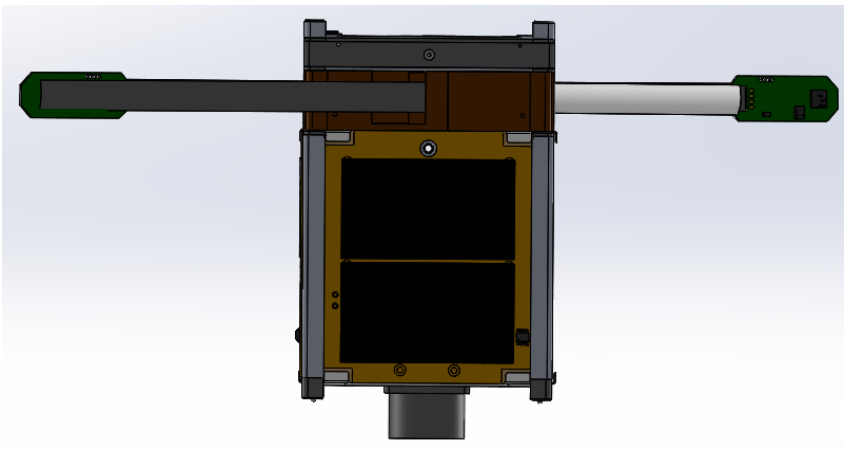
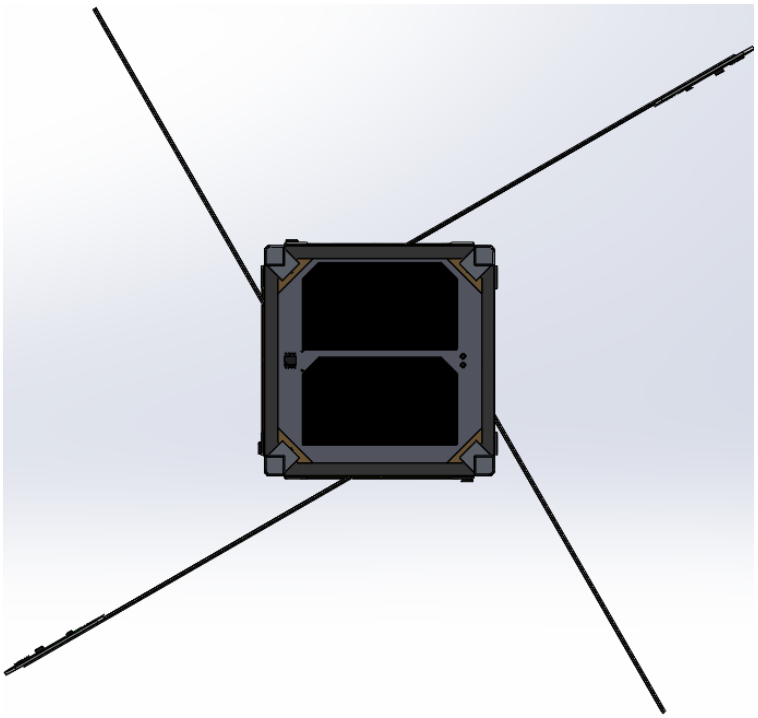
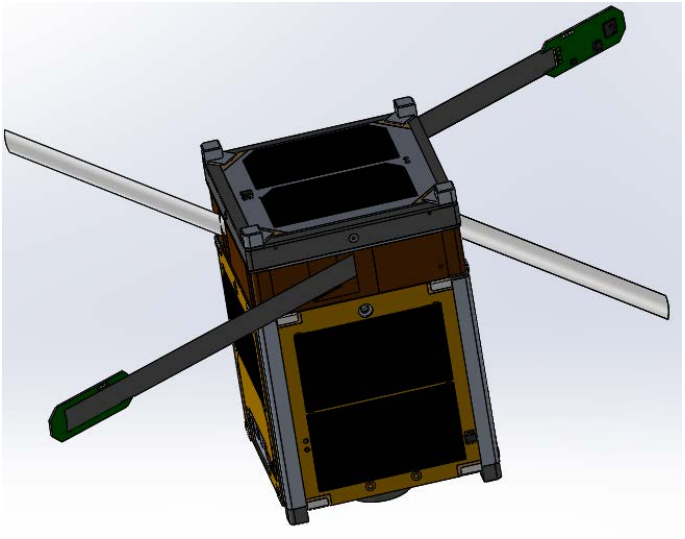








Interaction or potential physical interference with other operational spacecraft:

Project Management:

- **Principal Investigator: David Barnhart**

Key Engineering Personnel:

- **Structures Lead: Abdul Eissa**
- **Manufacturing Lead : José Anaya López**
- **Flight Software Lead :Everett Maness**
- **C&DH and Electronics Lead : Yaashia Gautam**
- **Integration & Test Lead : Kevin Decker**
- **System Engineering and Analysis : Taylor Gaines**
- **Power System Lead : Evan Gabrielson**
- **TT&C Lead : Soundarya Sampathkumar**
- **Mission Ops Lead :Amrit Singh**
- **Thermal Simulations Lead: Dammy Adeoye**

Foreign Government or Space Agency participation:

- No foreign agency participating in mission currently.

Summary of NASA's responsibility under the governing agreement(s):

- N/A

Schedule of Mission design and Development Milestones:

Section 2: Spacecraft Description:

Physical Description of Spacecraft:

The overall dimensions of our CubeSat are 10 cm x 10 cm x 150.84 cm and a total mass of 1239g. This consists of a quad deployer, a shell/spacer, and a sun sensor, in addition to our main structure.

MAGNETO satellite will contain the following systems

- Solar Panels
- EPS
- Whip antennas
- Magnetometers

Total Satellite mass at launch, including propellent and fluids:

- 1239g

Dry mass of satellite at launch

- 1239 g

Description of all propulsion system

- No propulsion system on MAGNETO

Identification , including mass and pressure , of all fluids (liquids and gases) planned to be on board and a description of the fluid loading plan or strategies , excluding fluids in sealed heat pipes:

- N/A

Fluids in Pressurized Batteries: None. Cells flown previously on USC AENEAS, intermediary was Varda Rechargeable Lithium -Polymer

Description of attitude control system and indication of the normal attitude of the spacecraft with respect to the velocity vector:

Description of any range safety or other pyrotechnic devices:

Description of the electrical generation and storage system:

- Magneto utilizes the COTS Clyde Space Deployable 3U EPS (DEPS) power system. The DEPS is a Peak Power Tracking (PPT) design and provides unregulated battery voltage and regulated +5V and +3.3V to the CubeSat Kit bus. The DEPS contains a 8W Battery Charge Regulator (BCR). The BCR is paired with four solar array panels, where only one can be lit by sunlight at any time.
- The CubeSat is powered by 5 solar panels manufactured by Pumpkin, each containing 2 Spectrolab UTJ-class solar cells. This system of panels is connected to the BCR which delegates where the power will be distributed via the DEPS power system.

Identification of any other sources of stored energy not noted above:

- N/A

Identification of any radioactive material on board:

- **N/A**

ODAR Section 3: Assessment of Spacecraft debris released during normal operations

Identification of any object (>1 mm) expected to be released from the spacecraft any time after launch, including object dimensions, mass, and material:

- None

Rationale/necessity for release of each object: N/A. Time of release of each object, relative to launch time:

- N/A.

Release velocity of each object with respect to spacecraft: N/A. Expected orbital parameters (apogee, perigee, and inclination) of each object after release:

- N/A.

Calculated orbital lifetime of each object, including time spent in Low Earth Orbit (LEO):

- N/A.

Assessment of spacecraft compliance with Requirements 4.3-1 and 4.3-2:

- **4.3-1, Mission Related Debris Passing Through LEO:** COMPLIANT
- **4.3-2, Mission Related Debris Passing Near GEO:** COMPLIANT

ODAR Section 4 : Assessment of Spacecraft Intentional Breakups and Potential for Explosions:

In case of MAGNETO, no intentional breakup is planned during deployment

Potential causes of spacecraft breakup during deployment and mission operations: Summary of failure modes and effects analyses of all credible failure modes which may lead to an accidental explosion:

Very low possibility of battery explosion . Owing to very small mass of the satellite and their short orbital lifetimes, effect of explosion is very minute/negligible.

Detailed plan for any designed spacecraft breakup,including explosions and intentional collisions:

No plans for designed spacecraft breakups,explosions or intentional collisions on MAGNETO mission.

List of components which shall be passivated at the End of Mission (EOM) including method of passivation and amount of which cannot be passivated:
No passivation of components planned at EOM.

Rationale for all items which are required to be passivated, but cannot be due to their design:

N/A

Assessment of Spacecraft compliance with requirements 4.4-1 through 4.4-4:

Requirement 4.4-1: Limiting the risk to other space systems from accidental explosions during deployment and mission operations while in orbit about Earth or Moon:

Compliance statement:

Required Probability: 0.001

Expected Probability:0.000

Supporting Rationale and FMEA details:

Battery Explosion

Effect:

All failure modes below might result in battery explosion with the possibility of orbital debris generation. However, in the unlikely event that a battery cell does explosively rupture, the small size, mass and potential energy, of these small batteries is such that while the spacecraft could be expected to vent gases, most debris from the battery rupture should be contained within the vessel due to the lack of penetration energy.

Probability:

VERY LOW. Less than 0.01% given that multiple independent (not common mode) faults must occur for each failure mode to cause the ultimate effect(explosion).

Failure mode 1: Internal short circuit.

Mitigation 1:

Combined faults required for realized failure:

Failure Mode 2: Internal thermal rise due to high load discharge rate

Mitigation 2:

Combined faults required for realized failure:

Failure Mode 3: Overcharging and excessive charge rate

Mitigation 3:

Combined faults required for realized failure:

Failure Mode 4: Excess temperatures due to orbital environment and high discharge combined.

Mitigation 8: The spacecraft thermal design will negate this possibility. Thermal rise has been analyzed in combination with space environment temperatures showing that batteries do not exceed normal allowable operating temperatures which are well below temperatures of concern for explosions.

Combined faults required for realized failure: Thermal analysis **AND** thermal design **AND** mission

simulations in thermal-vacuum chamber testing **AND** over- current monitoring and control must all fail for this failure mode to occur.

ODAR Section 5 : Assessment of Spacecraft Potential for On-Orbit collisions

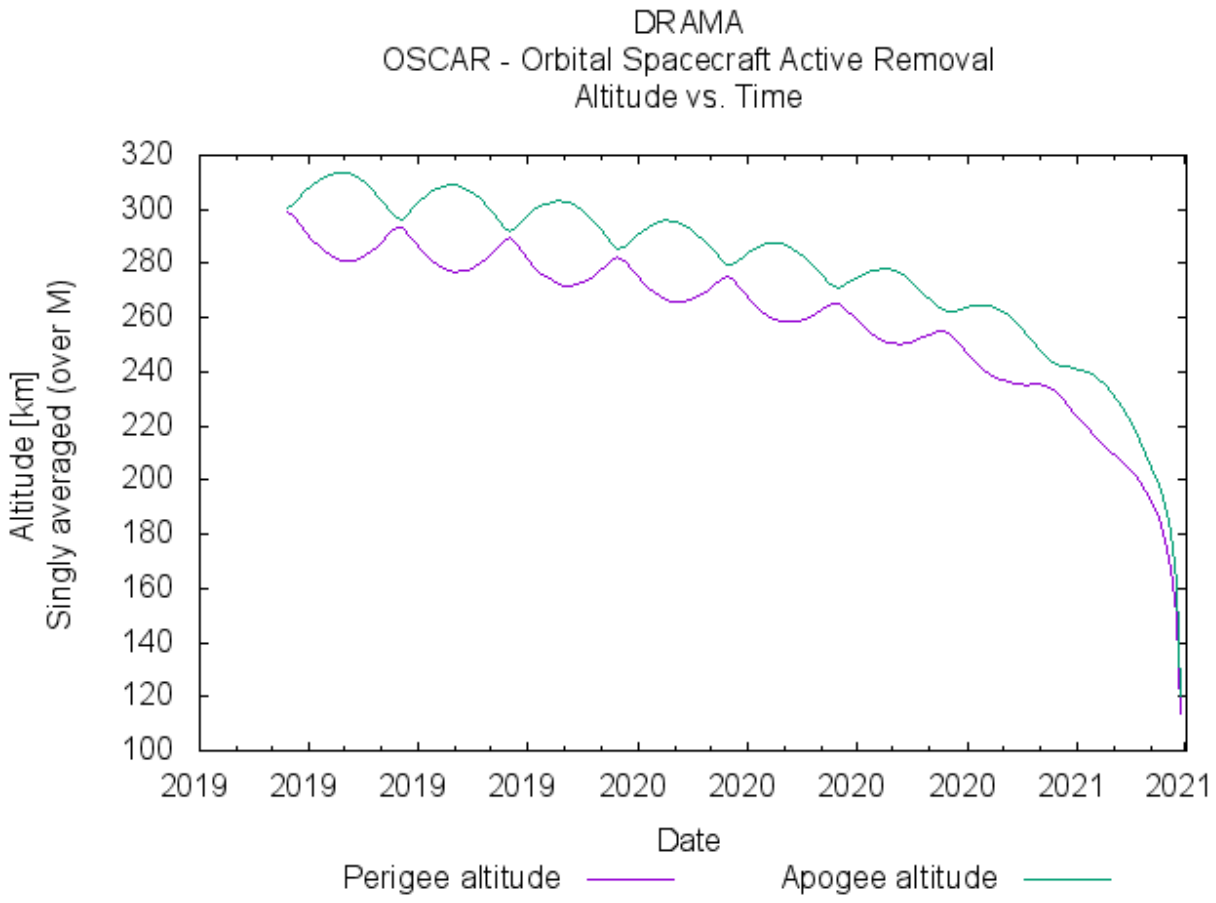
Assessment of spacecraft compliance with Requirements 4.5-1 and 4.5-2:

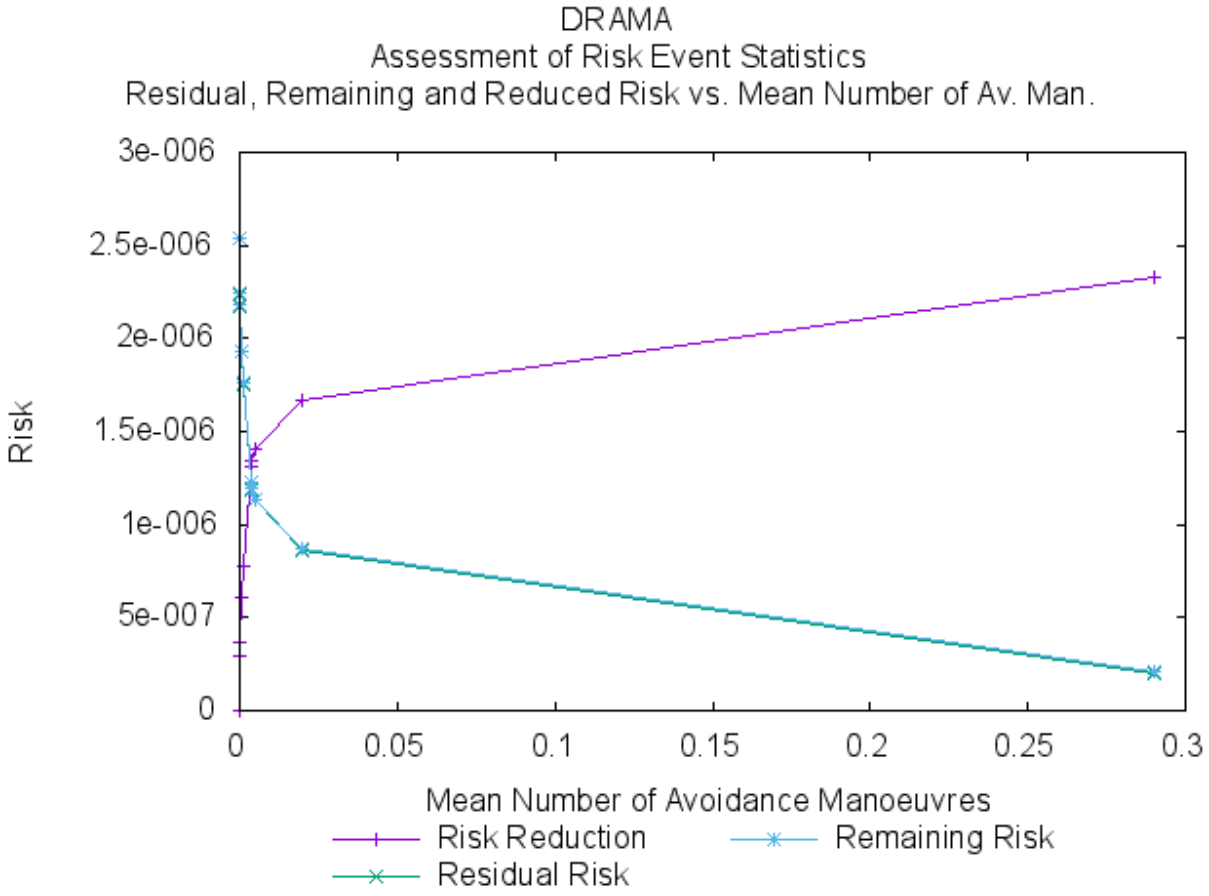
- **Requirement 4.5-1. Limiting debris generated by collisions with large objects when operating in Earth orbit:**

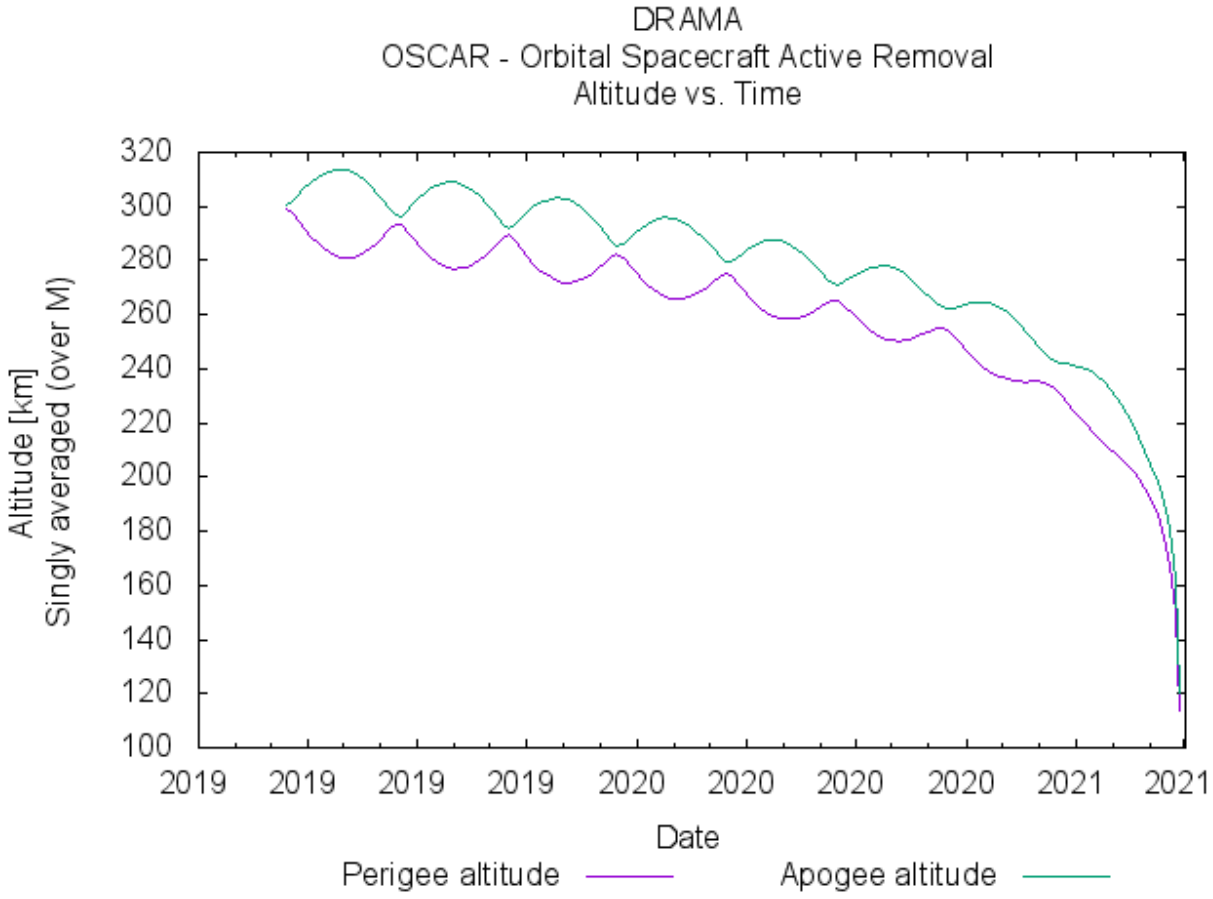
Large Object Impact and Debris Generation Probability:

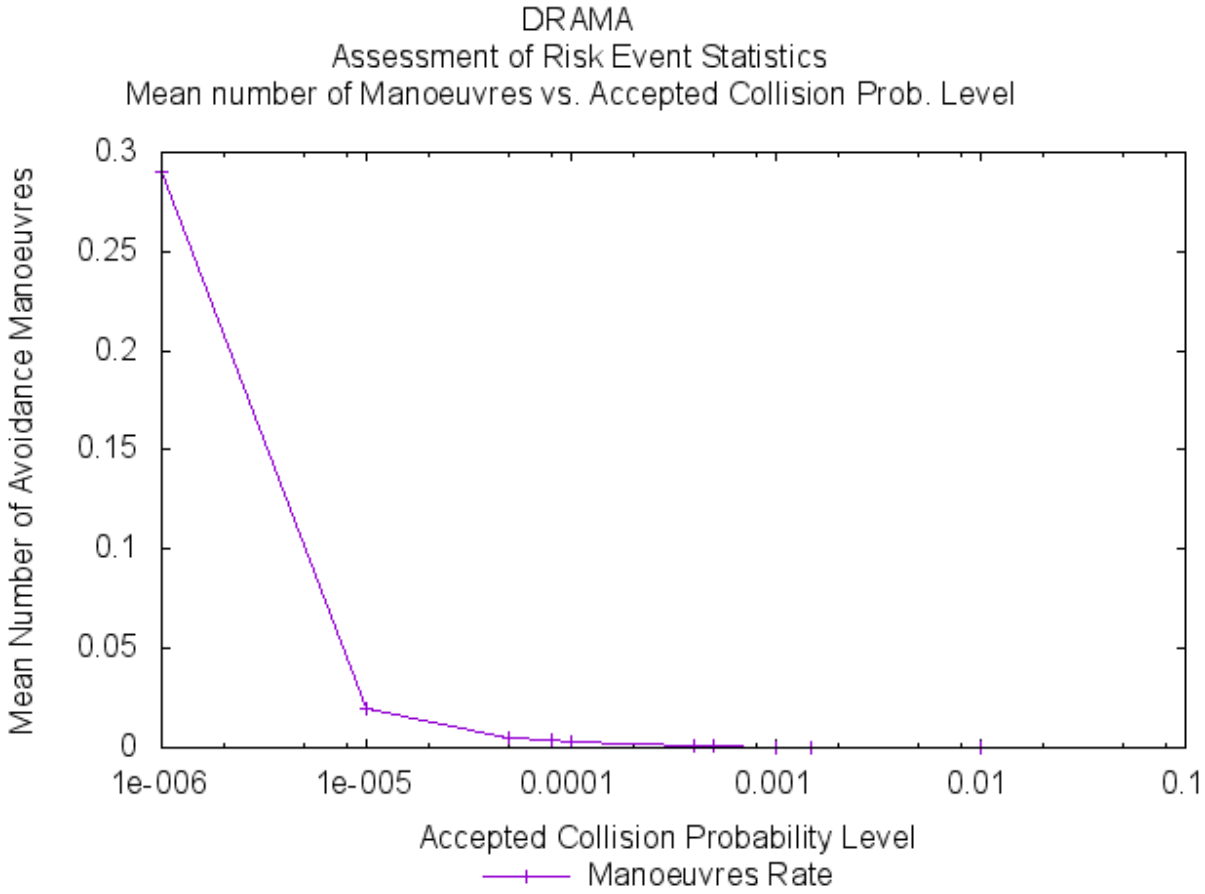
- **Requirement 4.5-2. Limiting debris generated by collisions with small objects when operating in Earth or lunar orbit:**

Small Object Impact and Debris Generation Probability:




DRAMA
Assessment of Risk Event Statistics
Residual, Remaining and Reduced Risk vs. Mean Number of Av. Man.
Risk
3e-006
2.5e-006
2e-006
1.5e-006
1e-006
5e-007
0
0
0.05
0.1
0.15
0.2
0.25
0.3
Mean Number of Avoidance Manoeuvres
Risk Reduction
Remaining Risk
Residual Risk


DRAMA
OSCAR - Orbital Spacecraft Active Removal
Altitude vs. Time
Altitude [km]
Singly averaged (over M)
320
300
280
260
240
220
200
180
160
140
120
100
2019
2019
2019
2019
2020
2020
2020
2020
2021
2021
Date
Perigee altitude
Apogee altitude



ODAR Section 6: Assessment of Spacecraft Postmission Disposal Plans and Procedures:

6.1 Description of spacecraft disposal option selected:

- The satellite will de-orbit naturally by atmospheric re-entry. There is no propulsion system.

6.2 Plan for any spacecraft maneuvers required to accomplish postmission disposal:

- **None**

6.3 Calculation of area-to-mass ratio after postmission disposal, if the controlled reentry option is not selected:

- **Spacecraft Mass:1.29 kg**

ODAR Section 7 : Assessment of Spacecraft Reentry Hazards

Assessment of Spacecraft compliance with Requirement 4.7-1:

Requirement 4.7-1. Limit the risk of human casualty: The potential for human casualty is assumed for any object with an impacting kinetic energy in excess of ------- Joules:

```
--<DRAMA/OSCAR/oscar.oop>--------------------<TUBS-ILR/VB>-<11/2012>---
#
#              _/_/      _/_/_/    _/_/_/    _/_/    _/_/_/
#           _/    _/  _/       _/       _/    _/  _/    _/
#          _/    _/    _/_/    _/       _/_/_/_/  _/_/_/
#         _/    _/       _/  _/       _/    _/  _/    _/
#          _/_/    _/_/_/      _/_/_/  _/    _/  _/    _/
#
#       Debris Risk Assessment and Mitigation Analysis Tool Suite
#                  Orbital Spacecraft Active Removal
#                      DRAMA - OSCAR (v2.3.1)
#-----------------------------------------------------------------------
# This file was generated by the program OSCAR
# on 2019-10-31 at 11:27:08.097
#-----------------------------------------------------------------------
# Comment:
# DRAMA
# OSCAR - Orbital Spacecraft Active Removal
#-----------------------------------------------------------------------
# Input data:
#
# Begin date (YYYY-MM-DD hh:mm:ss): 2019-03-15 14:00:00
#
# Target orbit :
#    6678.000 - semi-major axis [km]
#    0.000100 - eccentricity [-]
#    97.00000 - inclination [deg]
#     0.00000 - right ascension of the ascending node [deg]
#     0.00000 - argument of perigee [deg]
#
# Spacecraft parameters:
#      0.001 - cross-sectional area [m**2]
#      1.300 - dry mass [kg]
#   2.200000 - drag coefficient [-]
#   1.300000 - reflectivity coefficient [-]
#
# Disposal option: none
#
# 100.000000 - Propagation span [years]
#
# Solar and geomagnetic activity:
#
# Scenario: Latest prediction
```

```
# Solar & geomagnetic activity data used: ESA
#
#-------------------------------------------------------------------------
#
#  Title  : General output
#
#-------------------------------------------------------------------------
#
# Final date and singly averaged (wrt. M) Kepler elements:
#
#  2021-03-27 18:25:35 - Date (YYYY-MM-DD hh:mm:ss)
#             6495.15 - Semi-major axis (km)
#           0.0004609 - Eccentricity
#               97.03 - Inclination (deg)
#               61.48 - Right ascension of ascending node (deg)
#              111.89 - Argument of perigee (deg)
#               98.26 - Mean anomaly (deg)
#
#-------------------------------------------------------------------------
#
# Force model used with FOCUS v2.5.4:
#
# Geopotential: GEM-T1 (6x6)
# Drag:         NRLMSISE-00
#
#-------------------------------------------------------------------------
#
#       2.14 - Remaining lifetime of target orbit (yrs)
#              (incl. margin of 5.00 % according to ISO 27852:2011.)
#
#-------------------------------------------------------------------------
#
#  ESA Space Debris Mitigation Requirements compliance check:
#
#  Compliant through natural orbital lifetime
#
#-------------------------------------------------------------------------
#
```

ODAR SECTION 7A: Assessment of Spacecraft Hazardous Materials

// N/A : There are no hazardous materials contained on the spaccecraft.

ODAR SECTION 8: Assessment of Tether Missions

// N/A. There are no tethers in the MAGNETO mission.

END OF ODAR FOR MAGNETO

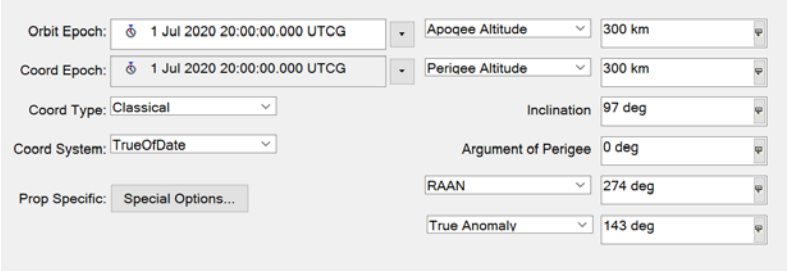
Magneto Orbit Decay Analysis Using STK's Lifetime Tool

Assumptions

- Drag coefficient Cd = 2.2 (suggested value by STK)
- Cr = 1 for total absorption of solar radiation pressure, Cr = 1.33 for specular reflection of SRP
- Mass = 1.3868 kg
- Area exposed to sun would be same as cross-sectional area since spacecraft will likely be tumbling and therefore constantly changing orientation with respect to sun (so assume greatest cross-sectional area exposed to sun for worst case, at any given moment)
- Solar Flux File was updated in STK using Data Update Utility

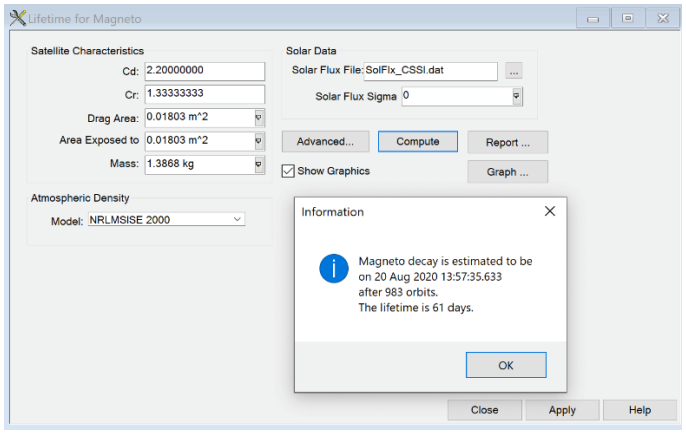
Orbit epoch and simulation start time: 1 Jul 2020 20:00:00.000 UTC

Orbit parameters:



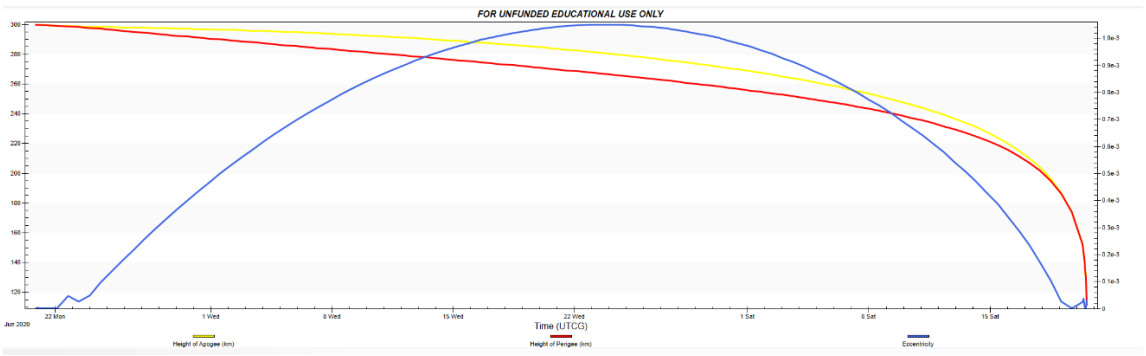
Various Scenarios

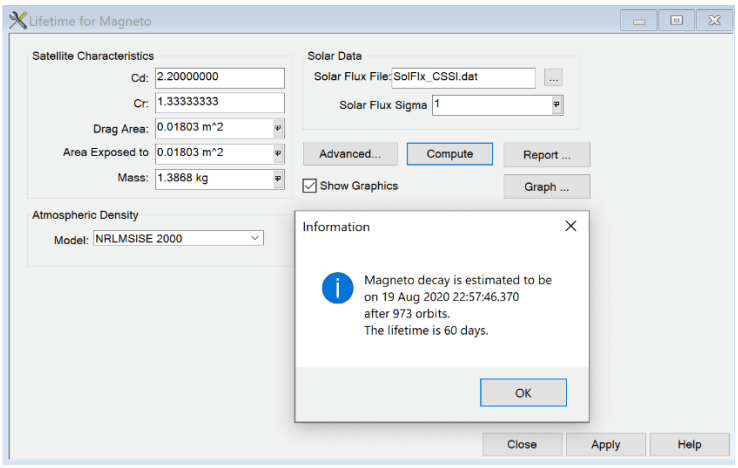
Varying Solar Flux Sigma



Decay Time

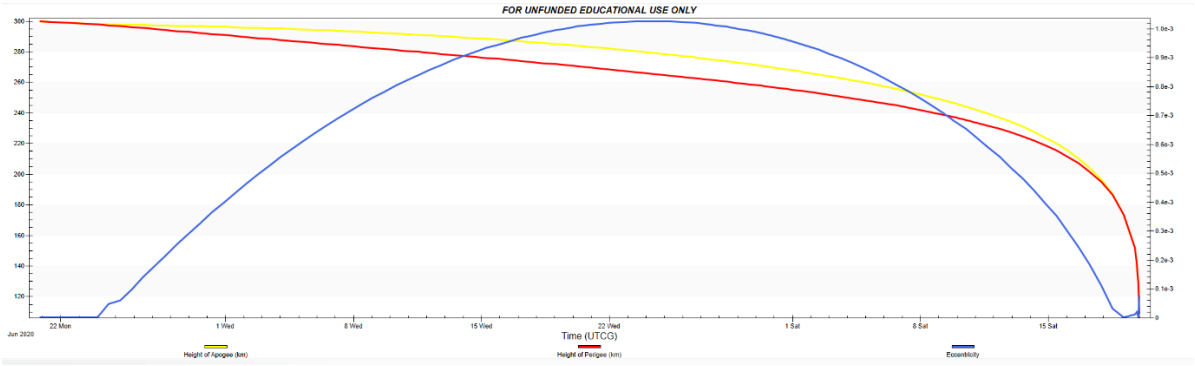
61 days

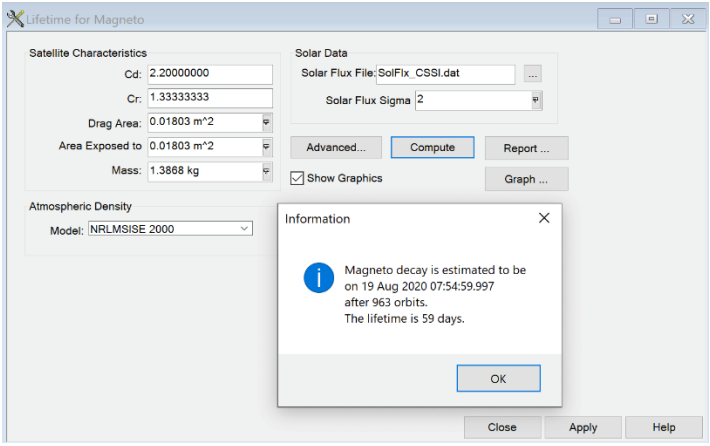




Decay Time

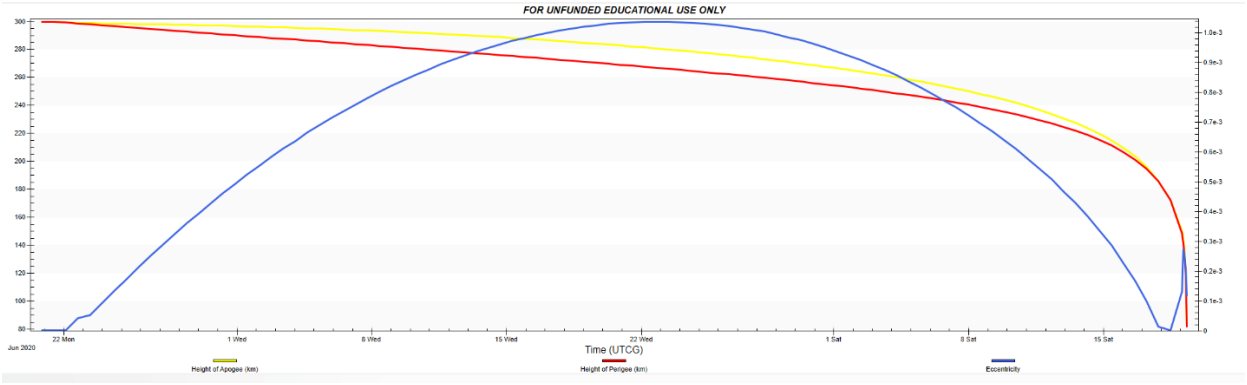
60 days



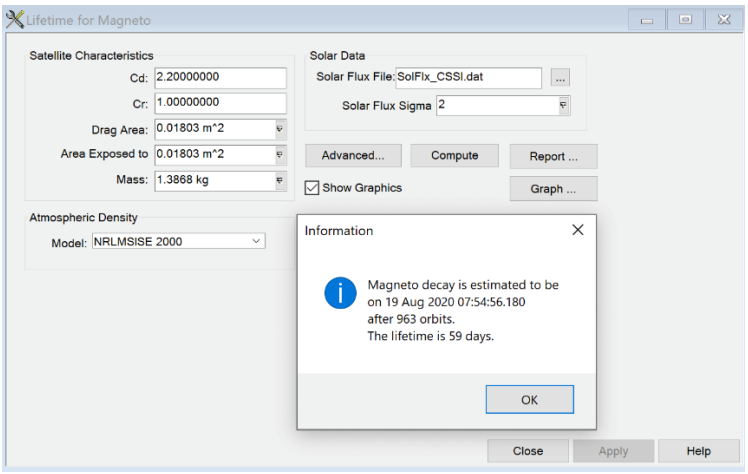


Decay Time

59 days



Cr = 1.0 (perfect absorptance)



Decay Time

59 days