STANFORD ENGINEERING

SSDL
Space and Systems Development Laboratory

QB50 US03 Discovery
Orbital Debris Assesment Report

Rev. C, 11 March 2016

Prepared using NASA DAS 2.0
In compliance with NASA-STD-8719-14A
Stephen West, Systems Lead

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Orbital Debris Assesment Report Evaluation: QB50 US03 Discovery

Requirement	Launch Vehicle	Spacecraft	Comments
4.3-1.a	Incomplete	Compliant	
4.3-1.b	Incomplete	Compliant	
4.3-2	Incomplete	Compliant	
4.4-1	Incomplete	Compliant	
4.4-2	Incomplete	Compliant	
4.4-3	Incomplete	Compliant	
4.4-4	Incomplete	Compliant	
4.5-1	Incomplete	Compliant	
4.5-2	Incomplete	Compliant	
4.6-1a	Incomplete	Compliant	
4.6-1b	Incomplete	N.A.	
4.6-1c	Incomplete	N.A.	
4.6-2	Incomplete	N.A.	
4.6-3	Incomplete	N.A.	
4.6-4	Incomplete	Compliant	
4.7-1	Incomplete	Compliant	
4.8-1	N.A.	N.A.	

Note: This ODAR applies to the Discovery 2U CubeSat only. An ODAR for the launch vehicle/Nanoracks CubeSat Deployer will be furnished separately.

Document History

Rev.	Date	Pages	Author	Description
A	29 February 2016	All	Stephen West	Document Created
B	29 February 2016	1-2, 6-7, 9, 11, 13-15	Stephen West	Updated signature block and schedule, corrected deployable panel description and general typos
C	11 March 2016	All	Nicolas Lee	Formatting, footer

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ODAR Section 1: Program Management and Mission Overview

Discovery is a 2U CubeSat, designed, developed, and operated by the Space and Systems Development Laboratory at Stanford University. Funded by the National Science Foundation, Discovery is intended to participate in the Von Karman institute led QB50 project to study Earth's lower thermosphere.

Program Management, Engineering and Science Leads:

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Foreign Government or Space Agency Participation:

The overall QB50 project is supported through the European Commision's FP7 program.

Summary of NASA Responsibility:

N. A.

Schedule

NET 2 May 2016	Spacecraft Delivery to Integrator
NET July 2016	Launch (NanoRacks/ISS)

Mission Overview

Discovery carries the Ion-Neutral Mass Spectrometer (INMS), developed by Mullard Space Science Laboratory at University College London, as its primary payload. An experimental sun sensor, developed by Stanford's Extreme Environment Microsystems Laboratory, is carried as a secondary payload and technology demonstration. Deployed by NanoRacks from the International Space Station, Discovery will orbit in LEO until atmospheric reentry. The nominal mission duration is six months, but actual mission duration is dependent upon rate of orbit decay. Discovery's initial orbit upon release from ISS will have an apogee of 407 km, perigee of 401 km, and inclination of 51.6 degrees. Discovery does not have any propulsive capability and will experience natural orbit decay. No interaction or interference is known or expected between Discovery and any other operational spacecraft.

ODAR Section 2: Spacecraft Description

Discovery is a 2U CubeSat consisting of a PC104-type electronics stack housed in a 6061 aluminum chassis. Surface mounted and deployable PCB's host sensors (payload and bus) and solar cells. Aluminum end plates (6061) provide rigidity to the chassis and mounting points for the INMS (velocity end) and deployable solar panels (anti-velocity end). Discovery has three deployable solar panels, one deployable exterior panel, and a deployable antenna. Two solar panels are attached with side-hinges to the zenith face of the satellite. An additional solar panel is attached with end-hinges to the anti-velocity end plate. The fourth deployable panel (omitted from figure 1, for clarity) mirrors the end-plate hinged solar panel and hosts the magnetometer. A deployable monopole antenna ("tape measure" antenna) deploys from the nadir face of the satellite.

Discovery conforms to constraints imposed by the NanoRacks CubeSat Deployer (NRCSD).

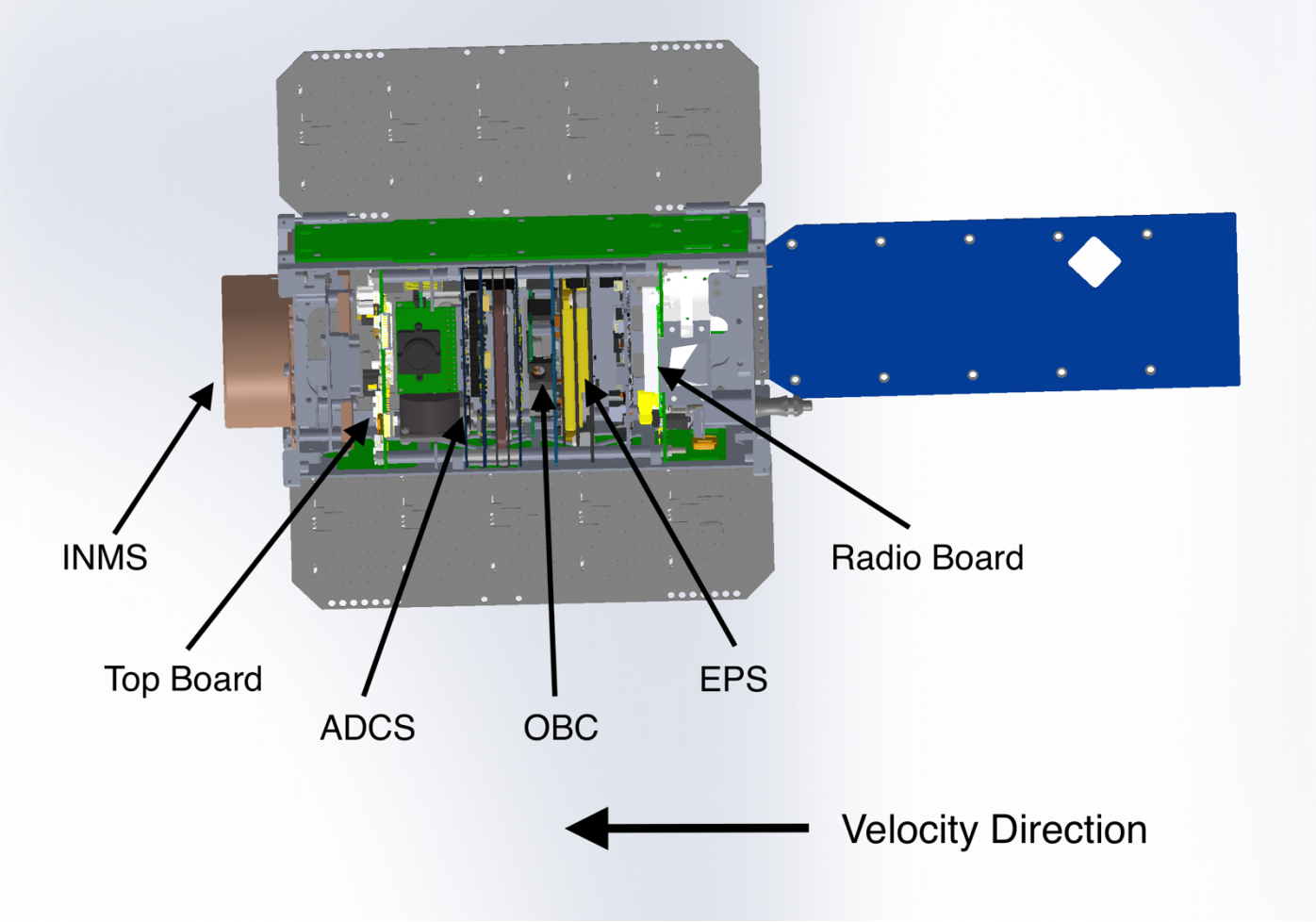

Figure 1 Discovery in Mission Configuration with Internal Component Locations

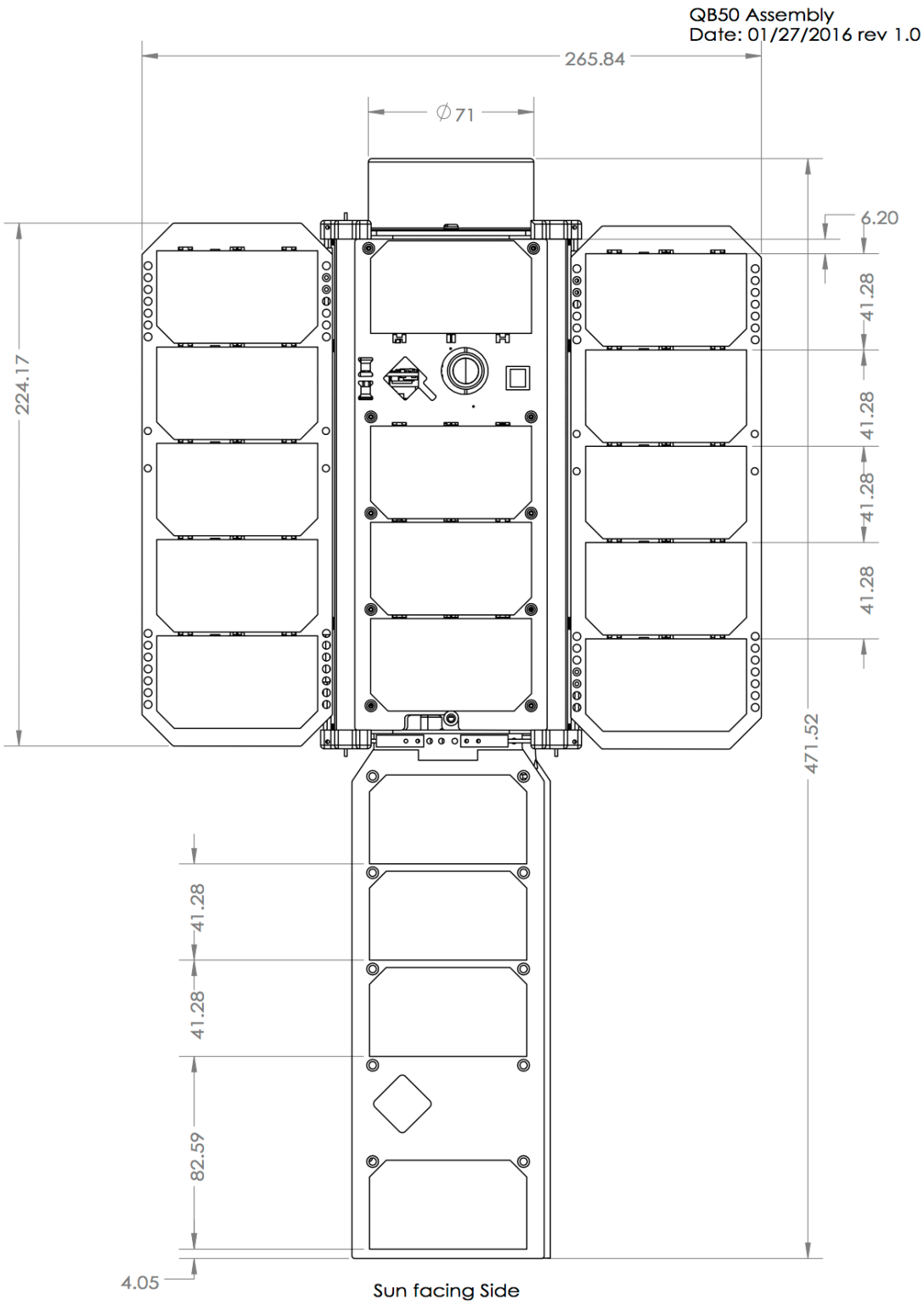

Figure 2 Discovery with Overall Dimensions

The spacecraft is expected to weigh approximately 1.9 kg at launch. Discovery carries no on-board fluids or propulsion systems, so the dry and total launch mass are identical.

Attitude control for Discovery is actively provided by an attitude determination and control system (ADCS) manufactured by Surrey Space Center for the QB50 project. The ADCS includes a single momentum wheel and two magnetic torque actuators. Two 180 degree FOV cameras serve as a sun-sensor and Earth limb sensor. A magnetometer, coarse sun sensor, and GPS provide additional position/orientation information. The ADCS computer is independent from the main flight computer.

Electrical power is provided by 18 SpectroLab UTJ CIC solar cells charging a 20 Watt-hour lithium ion battery pack manufactured by Clyde Space. A Clyde Space Electrical Power System (EPS) manages the battery pack's state of charge. Multiple safeguards are in place to prevent overcharging and excessive discharge. A small coin cell battery (Panasonic BR1225) is included to power a real time clock for the flight computer.

Discovery has no range safety or other pyrotechnic devices. No radioactive materials fly on Discovery and, beyond the aforementioned battery pack and coin cell, there are no other sources of stored energy.

ODAR Section 3: Assessment of Spacecraft Debris Released during Normal Operations

No objects (> 1mm) are expected to be released from the spacecraft at any time after launch. As such, Discovery is deemed COMPLIANT with requirements 4.3-1 and 4.3-2.

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

Discovery contains four lithium-ion battery cells in a 20 W-hr battery pack manufactured by ClydeSpace, Ltd., Glasgow, UK. Like all lithium-ion battery cells, there is potential (albeit very limited) for an over-pressure event to cause unplanned venting of the cell. ClydeSpace battery packs are specifically designed for use in space applications. Testing is performed after manufacturing and before flight (to comply with ISS lithium-ion battery testing), including capacity under vacuum at various temperatures and shock/vibration. The battery pack has an integrated heater to maintain acceptable temperatures. Over-charge, over-discharge, and over-current protection is built in to prevent conditions that could cause the battery to fail. Furthermore, should the battery suffer a failure, it is expected only to vent gases with most debris contained by the chassis. There is no credible failure mode with potential to produce orbital debris. As such, Discovery is deemed COMPLIANT with requirement 4.4-1.

As Discovery contains no pressurized fluids or other components needing passivation, there are no plans to passivate components at EOM. There is no danger posed from the battery's reentry, but if desired, the stored energy in the battery could be depleted by commanding the EPS to stop charging. Discovery is deemed COMPLIANT with requirement 4.4-2.

No intentional breakups, explosions, or collisions are planned for Discovery. Therefore, Discovery is deemed COMPLIANT with requirement 4.4-3 and 4.4-4.

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

In its stowed configuration, Discovery has a convex shape (no one face is obscured by any other). The cross sectional area is given by:

$$MeanCSA = \frac{\sum SurfaceArea}{4} = \frac{2[(wl) + (wh) + (hl)]}{4}$$

$$MeanCSA = \frac{2[(22.6 * 11.2) + (11.2 * 11.2) + (11.2 * 22.6)]}{4} = 315.84\ cm^2$$

In its deployed configuration, Discovery has a complex shape. The cross sectional area is given by:

$$MeanCSA = \frac{A_{max} + A_1 + A_2}{2}$$

$$MeanCSA = \frac{(26.5 * 22.4 + 22.4 * 8.1) + (11.2 * 22.6) + (11.2 * 11.2)}{2} = 576.8\ cm^2$$

The collision probability of Discovery with large space objects (>10 cm), computed using NASA DAS 2.0.2 software, is 0.00000. Discovery is COMPLIANT with requirement 4.5-1.

Discovery's post-mission disposal plan relies on natural orbital decay. As such, collision with small space objects will not interfere with postmission disposal. Discovery is deemed COMPLIANT with requirement 4.5-2.

ODAR Section 6: Postmission Disposal of Space Structures

Discovery will be disposed of via passive atmospheric reentry. This does not require a post-mission disposal operation. Spacecraft disposal complies with requirement 4.6-1a, leaving the spacecraft in an orbit in which the natural forces will lead to an atmospheric reentry within 25 years of the completion of the mission and no more than 30 years after launch. Discovery is COMPLIANT with requirement 4.6-1a. Requirements 4.6-1b and 4.6-1c do not apply.

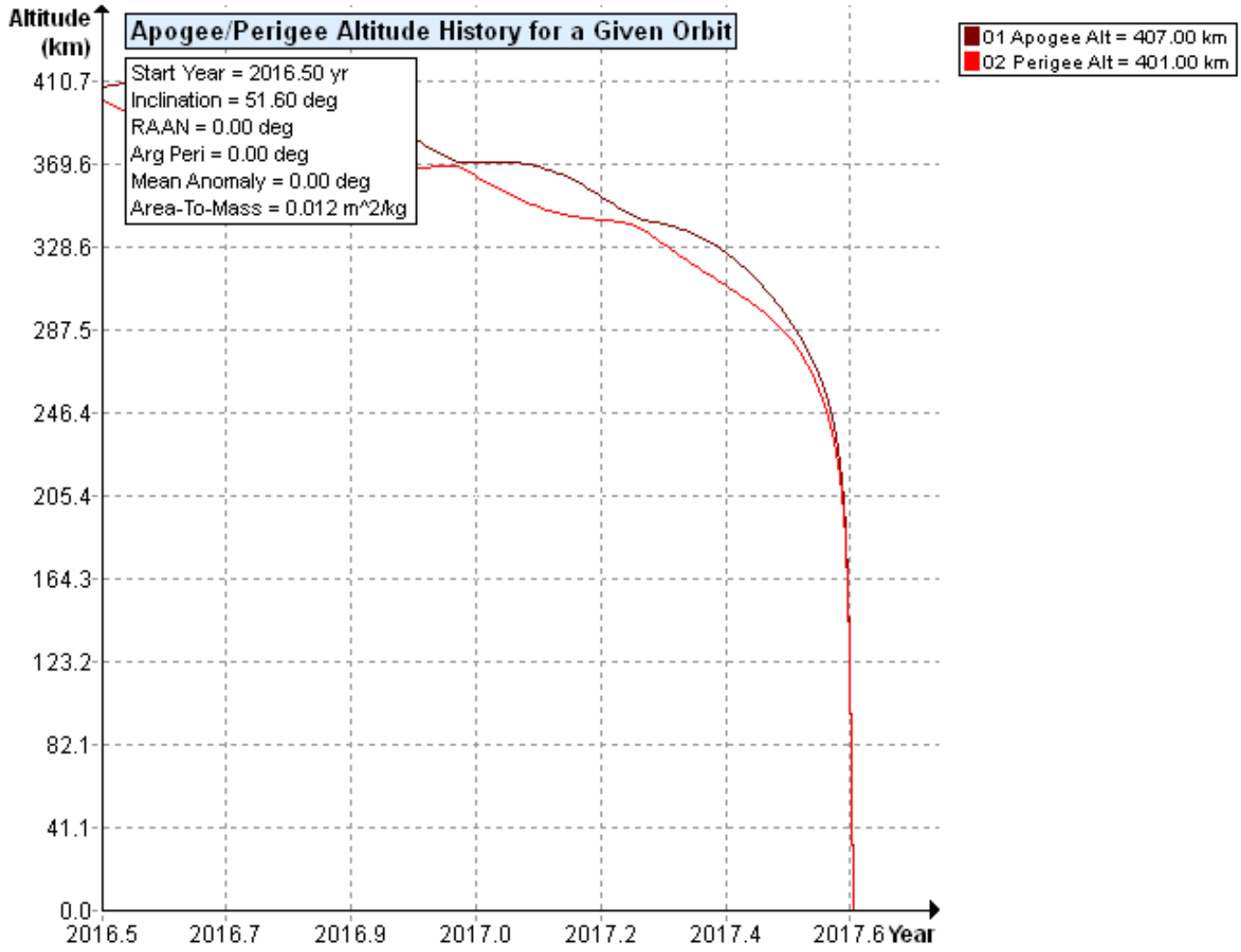

Figure 3 Orbit History for Discovery in Stowed Configuration

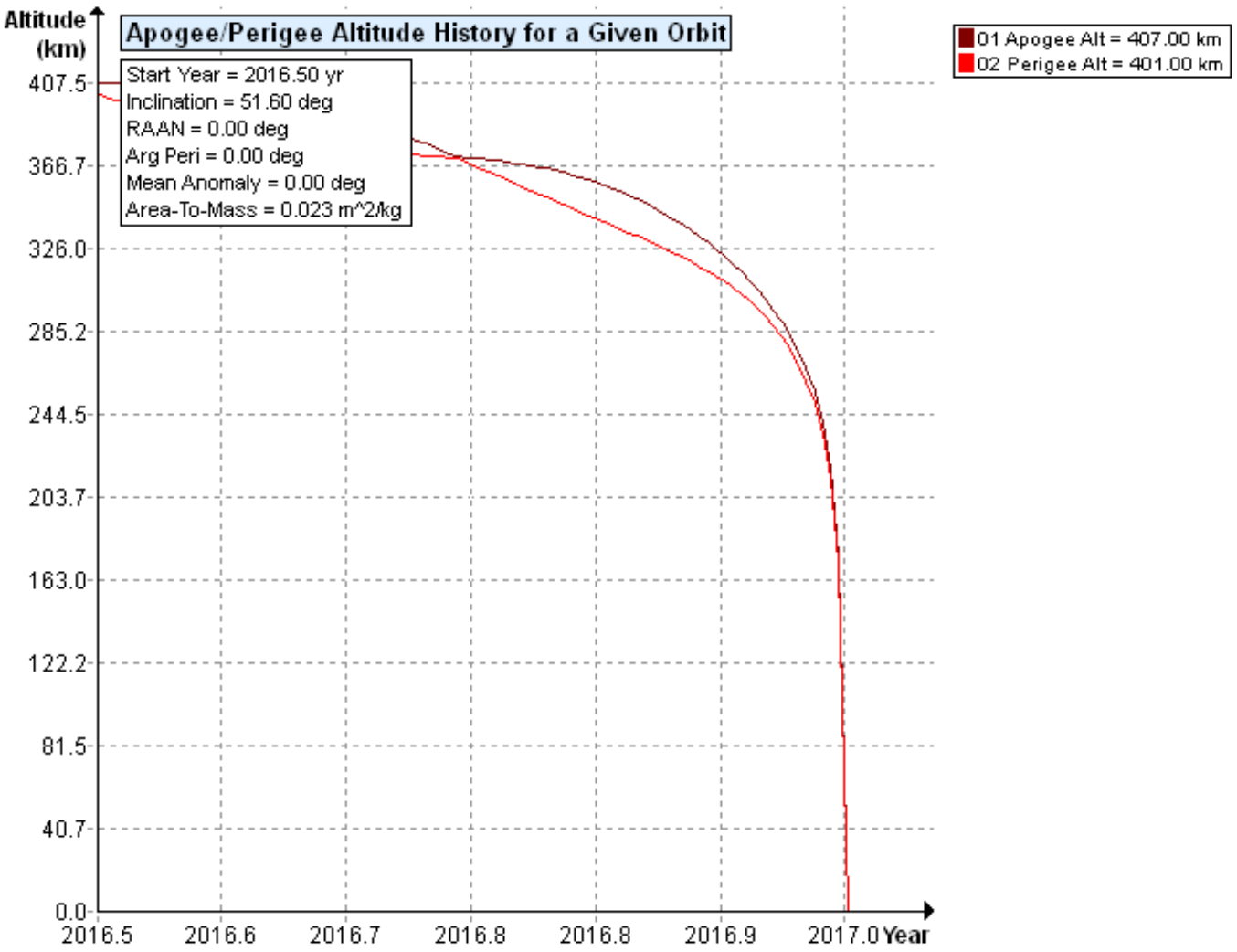

Figure 4 Orbital Evolution for Discovery in Deployed Configuration

Discovery is not near GEO, therefore requirement 4.6-2 does not apply.

Discovery is in LEO, therefore requirement 4.6-3 does not apply.

Discovery deorbits within 0.5 years (deployed)/1.1 years (panels fail to deploy). Both satisfy the 25 year disposal requirement, therefore Discovery is COMPLIANT with requirement 4.6-4.

ODAR Section 7: Survival of Debris From the Postmission Disposal Earth Atmospheric Reentry Option

All components of Discovery will be destroyed during atmospheric reentry. The probability of human casualty due to uncontrolled reentry is 0.00. Results from NASA DAS v2.0.2 are shown below. Discovery is COMPLIANT with requirement 4.7-1.

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materialID = 8
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Thermal Mass = 2.500000
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Length = 0.220000
Height = 0.100000

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quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 1.626000
Thermal Mass = 0.800000
Diameter/Width = 0.100000
Length = 0.220000
Height = 0.100000

name = Surrey Space Center ADCS
quantity = 1
parent = 2
materialID = 23
type = Box
Aero Mass = 0.365000
Thermal Mass = 0.365000
Diameter/Width = 0.095000
Length = 0.095000
Height = 0.050000

name = ClydeSpace 3U EPS
quantity = 1
parent = 2
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materialID = 23
type = Flat Plate
Aero Mass = 0.083000
Thermal Mass = 0.083000
Diameter/Width = 0.095000
Length = 0.095000

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quantity = 1
parent = 2
materialID = 23
type = Box
Aero Mass = 0.204000
Thermal Mass = 0.204000
Diameter/Width = 0.095000
Length = 0.095000
Height = 0.030000

name = Motherboard
quantity = 1
parent = 2
materialID = 23
type = Flat Plate
Aero Mass = 0.077000
Thermal Mass = 0.077000
Diameter/Width = 0.095000
Length = 0.095000

name = PPM
quantity = 1
parent = 2
materialID = 23
type = Flat Plate
Aero Mass = 0.017000
Thermal Mass = 0.017000
Diameter/Width = 0.095000
Length = 0.095000

name = Radio Board
quantity = 1
parent = 2
materialID = 23
type = Flat Plate
Aero Mass = 0.050000
Thermal Mass = 0.050000
Diameter/Width = 0.095000
Length = 0.095000

name = Top Board
quantity = 1
parent = 2
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materialID = 23
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materialID = 24
type = Flat Plate
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name = End Plates
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parent = 1
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************************************

=============== End of Requirement 4.7-1 ===============
```

ODAR Section 8: Additional Assesment Requirements for Tether Missions

Discovery is not a tether mission, therefore requirement 4.8-1 does not apply.