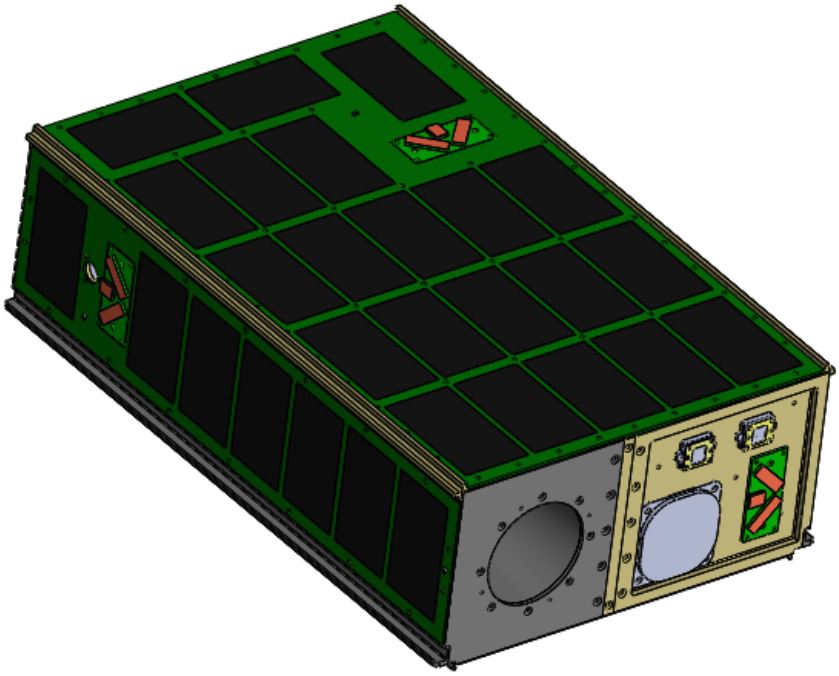
CuPID

(Cusp Plasma Imaging Detector)

Orbital Debris Assessment Report (ODAR)

Version Number 00001

02 October 2017



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Revisions

Rev	Description of Change	By	Approved	Date
-	Initial Release	Emil Atz	BW	10/2/17

Orbital Debris Assessment Report Evaluation: CuPID Mission

Requirement Number	Launch Vehicle				Spacecraft			Comments
	Compliant	Not Compliant	Incomplete	Standard Non-Compliant	Compliant or N/A	Not Compliant	Incomplete	
4.3-1.a			X		X			
4.3-1.b			X		X			
4.3-2			X		X			
4.4-2			X		X			
4.4-3			X		X			
4.4-4			X		X			
4.5-2			X		X			
4.5-2			X		X			
4.6-1(a)			X		X			
4.6-1(b)			X		X			
4.6-1(c)			X		X			
4.6-2			X		X			
4.6-3			X		X			
4.6-4			X		X			
4.7-1			X		X			
4.8-1					X			

Note 1:
CuPID is to be launched on a NASA specified launch vehicle that is yet to be determined. This ODAR is solely for the CuPID CubeSat spacecraft and does not pertain to the launch vehicle or other spacecraft associated with the launch vehicle.

Note 2:
The Debris Assessment Software used for this report was DAS 2.1.1, and will be referred to as DAS in this report.

1.0 Mission Overview

The CuPID (Cusp Plasma Imaging Detector) Cubesat Observatory is a 6U Cubesat designed to observe solar wind-magnetosphere coupling. This will be accomplished through measuring soft X-rays emitted during the process of charge exchange between solar wind ions and neutral atoms in Earth's upper atmosphere. This process happens around the entire magnetosphere, yet in the magnetospheric cusps, solar wind ions are capable of penetrating closer to Earth. CuPID will conduct its primary science experiment measuring through soft X-rays in the cusp, but it will also work to produce an all sky map of the magnetosphere in soft X-rays.

The soft X-ray imager will use a slumped micro-pore channel reflector, also known as Lobster Eye Optics. With this reflector lens, the soft X-ray imager has a field of view of 4.6° x 4.6°.

CuPID will also fly two radiation dosimeters. The dosimeters will measure energetic ions and electrons along CuPID's orbit.

1.1 Project Management

The project is a collaboration between 8 institutions (Boston University, Drexel University, NASA Goddard Space Flight Center, John's Hopkins University, Merrimack College, Adcole Maryland Aerospace, Aerospace Corporation and Flexitech Aerospace) The Principal Investigator is Brian Walsh (Boston University) and Project Manager is Joe Kujawski (Drexel University). This spacecraft will be flown with avionics produced by Adcole Maryland Aerospace (AMA). Ed Kozlosky (AMA) is the Lead Systems Engineering and Ken Bocam (AMA) is the Spacecraft Program Manager. The spacecraft structure is developed by NASA Goddard and will be launched by a NASA associated rocket though the Cubesat Launch Initiative (CSLI).

The CDR for CuPID took place August 28th and 29th 2017. Launch is estimated to be June 1st 2019. Should this launch date be accomplished, commissioning will take place the week after from June 1st to June 8th. Primary mission operation will begin June 9th.

1.2 Mission Requirements

The CuPID spacecraft must image the cusp from a vantage point up the cusp footprint at least 15 times during the 90 day (0.25 year) mission duration. To image the cusp, the spacecraft must image with full position sensing from the soft X-ray imager and collect energetic charged particle measurements. Secondly, when not imaging the cusp, CuPID measurements will contribute to an all sky map of the magnetosphere in soft X-rays. Pointing knowledge during the secondary objective is less restricted than that of the primary science in the cusp.

In order to achieve these science requirements, the spacecraft must orbit in an inclination between 65° and 90°. Once a specific launch vehicle is determined, an accurate final altitude

will be known. It is required that the final altitude is between 450 km and 550 km. The mission duration is required to be 90 days (3 months), and extended mission is 1 year.

2.0 Spacecraft Description

CuPID is a 6U cubesat designed to be launched out of a Canisterized Satellite Dispenser (CSD). The spacecraft is split into two sections in order to accommodate the technology associated with the mission. Shown in Figure 2 is a CAD rendering of the spacecraft.

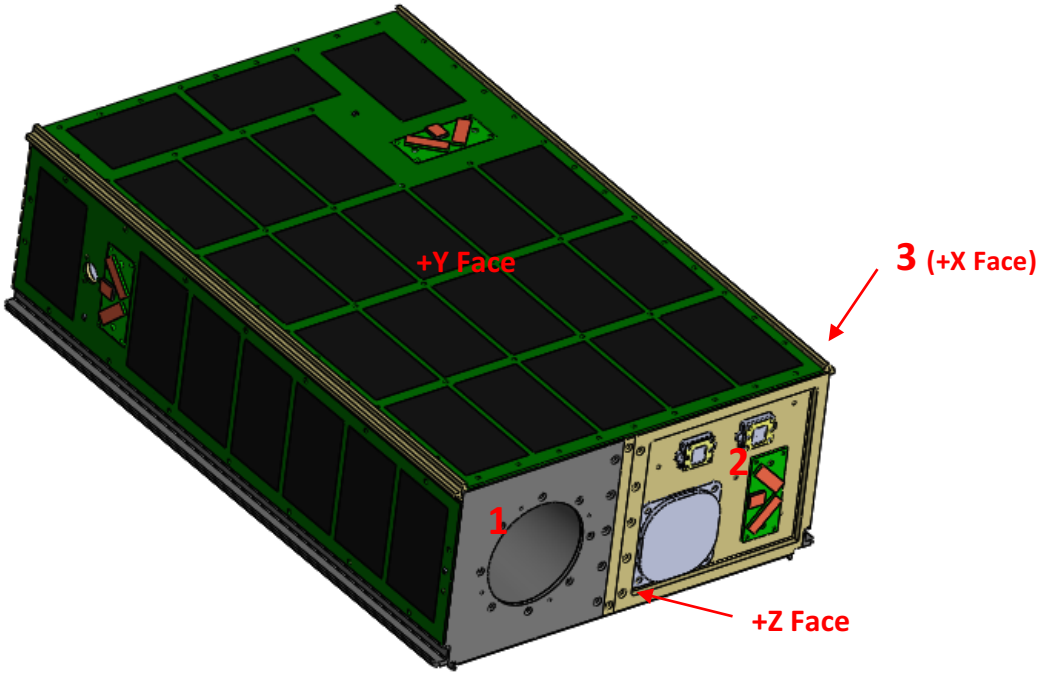

Figure 1: CuPID spacecraft

The soft X-ray telescope and imager are located in the section number 1, seen by the circular opening in the end cap. The avionics and computer are located in the section number 2. The antenna is located on the hidden face shown by number 3. The antenna is a 14-inch deployable spring antenna.

The structure of the spacecraft is built with aluminum 6061 and 7075 and a majority of the parts are covered with gold alodine. The parts covering the soft X-ray telescope are black anodized. The slumped micro-pore reflector, a part of the soft X-ray telescope, is made of glass. The structure components of the spacecraft are fastened with a variety of sized stainless steel screws. The other parts in the spacecraft are commercial off the shelf (COTS) materials, such as PCBs, solar cells and electrical components. The batteries are Panasonic 18650b lithium ion rechargeable. There are no radioactive materials used. In total, the spacecraft will weigh 12 kg at BOL and 12 kg at EOL.

The spacecraft contains no propellants or fluids and does not have a propulsion system. The attitude control system developed by Adcole Maryland Aerospace contains reaction wheels and magnetorquers to properly align the telescope field of view (+Z face) zenith.

3.0 Spacecraft Debris Released during Normal Operations

No objects (>1 mm) are expected to be released from the spacecraft at any time after launch. Any occurrence of objects greater than 1 mm being released from the spacecraft would be during an unexpected event.

The spacecraft is compliant with 4.3-1 (Mission Related Debris Passing Through LEO) and 4.3-2 (Mission Related Debris Passing Near GEO) because no objects will be released from the spacecraft during normal operations.

4.0 Spacecraft Intentional Breakups and Potential for Explosions

Through deployment there are minimal potential causes of unexpected breakups. At the end of the 90-day mission, CuPID will run an extended mission to its EOL when it re-enters. No components will be passivated.

During the mission, there are several potential failure modes. Each one is outlined below with accompanying reasoning.

Failure Mode 1: Battery Explosion
Through flight heritage and a rigorous design process, it is highly unlikely that the Panasonic 18650b batteries will experience an unexpected rupture. Additionally, the batteries are enclosed within aluminum casing designed to capture any debris should there be an anomalous rupture.

Failure Mode 2: Internal Short Circuit
Throughout development, CuPID will undergo multiple environment tests including vibration, thermal and vacuum tests. After each of these tests, the spacecraft will be tested for its function and operation. Through the varying tests an internal short circuit is very unlikely.

Failure Mode 3: Exceeding Thermal Limits (Internal/External)
In the event that the spacecraft components exceed the operational ranges, elements will be turned off until the spacecraft reaches reasonable temperature.

Requirement 4.4-1: Limiting the risk to other space systems from accidental explosions during deployment and mission operations while in orbit around Earth or the Moon. Probability must be less than 0.001. Expected probability is 0.000, therefore compliant.

Requirement 4.4-2: Design for passivation after completion of mission operation while in orbit about Earth or the Moon. Passivation is unnecessary due to the small size of the battery and the minimal potential for explosion, thus CuPID is compliant.

Requirement 4.4-3/4: Limiting the long-term/short-term risk to other space systems from planned breakups. CuPID does not have any planned breakups. Any breakups would be unexpected. CuPID is compliant with these requirements.

5.0 Spacecraft Potential for On-Orbit Collisions

Using DAS, a mission and orbit parameters were generated. These parameters are general parameters of the potential orbit that CuPID will be launched into. Table 1 shows the parameters used in DAS. The perigee and apogee are representative of an undetermined actual orbit. Orbit parameters will be adjusted once a launch vehicle has been approved.

Table 1: DAS Input Parameters

Parameter	Value	Units
Perigee Altitude	500	km
Apogee Altitude	500	km
Inclination	80	degrees
RAAN	0.0	degrees
Argument of Perigee	0.0	degrees
Mean Anomaly	0.0	degrees
Area to Mass Ratio	0.003056	m^2/kg
Start Year	2019.000	years
Initial Mass	12	kg
Final Mass	12	kg
Duration	0.25	N/A
Station-Kept	False	N/A
Abandoned	True	N/A

The average cross sectional area was calculated by $\frac{(1U*2U)+(1U*3U)+(2U*3U)}{3}$ where the *U* denotes the Cubesat unit side of 10 cm. Through DAS, it was shown that with these parameters, CuPID is compliant with Requirements 4.5-1 (Probability of Collision with Large Objects) and 4.5-2 (Probability of Damage from Small Objects).

```
09 20 2017; 14:11:43PM     Processing Requirement 4.5-1:     Return Status :  Passed

==============
Run Data
==============

**INPUT**

       Space Structure Name = CuPID Spacecraft
       Space Structure Type = Payload
       Perigee Altitude = 500.000000 (km)
       Apogee Altitude = 500.000000 (km)
       Inclination = 80.000000 (deg)
       RAAN = 0.000000 (deg)
       Argument of Perigee = 0.000000 (deg)
       Mean Anomaly = 0.000000 (deg)
```

```
       Final Area-To-Mass Ratio = 0.003056 (m^2/kg)
       Start Year = 2019.000000 (yr)
       Initial Mass = 12.000000 (kg)
       Final Mass = 12.000000 (kg)
       Duration = 0.250000 (yr)
       Station-Kept = False
       Abandoned = True
       PMD Perigee Altitude = -1.000000 (km)
       PMD Apogee Altitude = -1.000000 (km)
       PMD Inclination = 0.000000 (deg)
       PMD RAAN = 0.000000 (deg)
       PMD Argument of Perigee = 0.000000 (deg)
       PMD Mean Anomaly = 0.000000 (deg)

**OUTPUT**

       Collision Probability = 0.000000
       Returned Error Message: Normal Processing
       Date Range Error Message: Normal Date Range
       Status = Pass

==============

=============== End of Requirement 4.5-1 ===============

09 20 2017; 14:11:50PM     Requirement 4.5-2:  Compliant
```

6.0 Spacecraft Postmission Disposal Plans and Procedures

CuPID will deorbit by re-entry into the atmosphere. Shown in the plot below, Figure 3, CuPID will deorbit after 13 years.

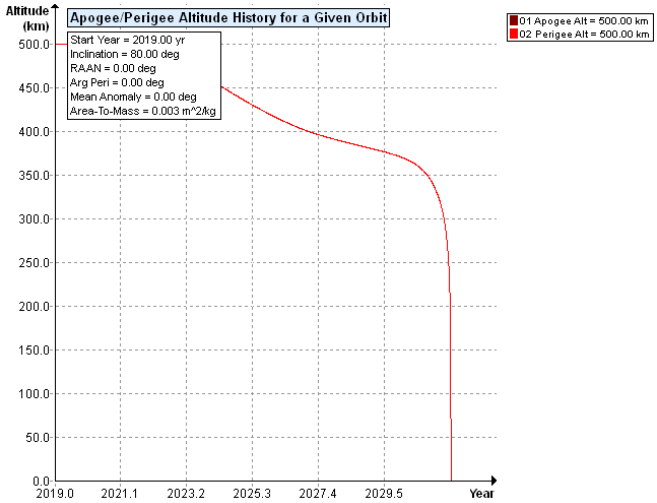

Figure 2: CuPID orbit decay

Through DAS, it was shown that CuPID is compliant with Requirements 4.6-1 to 4.6-3. CuPID is also compliant with 4.6-4 (Reliability of Postmission Disposal Operations) because the passive reentry of the spacecraft is chosen as the postmission disposal plan.

```
09 20 2017; 14:22:53PM     Processing Requirement 4.6 Return Status :  Passed

==============
Project Data
```

```
==============

**INPUT**

       Space Structure Name = CuPID Spacecraft
       Space Structure Type = Payload

       Perigee Altitude = 500.000000 (km)
       Apogee Altitude = 500.000000 (km)
       Inclination = 80.000000 (deg)
       RAAN = 0.000000 (deg)
       Argument of Perigee = 0.000000 (deg)
       Mean Anomaly = 0.000000 (deg)
       Area-To-Mass Ratio = 0.003056 (m^2/kg)
       Start Year = 2019.000000 (yr)
       Initial Mass = 12.000000 (kg)
       Final Mass = 12.000000 (kg)
       Duration = 0.250000 (yr)
       Station Kept = False
       Abandoned = True
       PMD Perigee Altitude = 499.898279 (km)
       PMD Apogee Altitude = 499.898279 (km)
       PMD Inclination = 79.997779 (deg)
       PMD RAAN = 239.102608 (deg)
       PMD Argument of Perigee = 337.360470 (deg)
       PMD Mean Anomaly = 0.000000 (deg)

**OUTPUT**

       Suggested Perigee Altitude = 499.898279 (km)
       Suggested Apogee Altitude = 499.898279 (km)
       Returned Error Message = Passes LEO reentry orbit criteria.

       Released Year = 2031 (yr)
       Requirement = 61
       Compliance Status = Pass

==============

=============== End of Requirement 4.6 ===============
```

7.0 Spacecraft Reentry Hazards

As written in Section 2.0, the spacecraft structure is aluminum with the largest parts being that of the external cladding. The other components are small FR-4 circuit boards as well as copper wires. Steel screws, of various sizes, are also used. It was found that CuPID had a risk of human casualty from surviving reentry debris to be 0.0000. CuPID is compliant with requirement 4.7-1.

```
09 20 2017; 14:22:53PM     *********Processing Requirement 4.7-1
       Return Status :  Passed

***********INPUT****
 Item Number = 1

name = CuPID Spacecraft
quantity = 1
parent = 0
materialID = 8
type = Box
```

```
Aero Mass = 12.000000
Thermal Mass = 12.000000
Diameter/Width = 0.200000
Length = 0.300000
Height = 0.100000

**************OUTPUT****
Item Number = 1

name = CuPID Spacecraft
Demise Altitude = 77.995483
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************

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

8.0 Tether Missions

No tethers will be used during the CuPID mission. Requirement 4.8-1 is not applicable.

Appendix

DAS Technical Results

Compliance tests only for the applicable tests shown in Figure 4 were conducted. Figure 4 shows the software's 'green check' approval of the requirements.

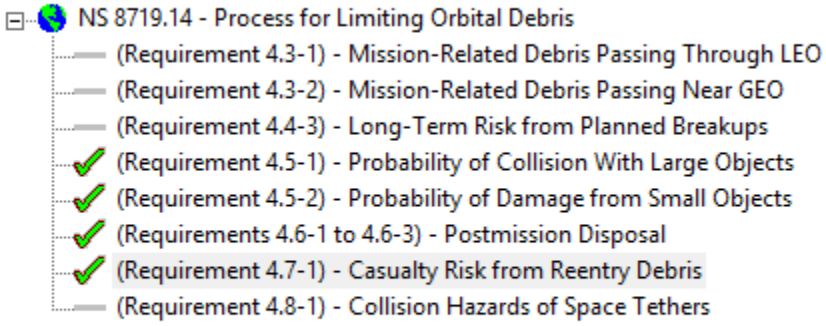

Figure 3: DAS compliance check marks