SASSI2 Formal Orbital Debris Assessment Report (ODAR)

In accordance with NPR 8715.6A, this report is presented as compliance with the required reporting format per NASA-STD-8719.14, APPENDIX A

Report Version: B (8/29/2018)

DAS Software Used in This Analysis: DAS v2.1.1

This document is part of the SASSI2 CubeSat mission at the University of Illinois at Urbana-Champaign. All documents are controlled and managed under the direction of personnel at the University of Illinois at Urbana-Champaign.

Version Approval

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1. Table of Contents

2. Assessment Report Format

ODAR Technical Sections Format Requirements:

This ODAR follows the format in NASA-STD-8719.14, Appendix A.1 and includes the content indicated at a minimum in each section 2 through 8 below for the SASSI2 satellite. Sections 9 through 14 apply to the launch vehicle ODAR and are not covered here. This document was produced under the example document ODAR provided on the FCC website.

3. Mission Description

The Student Aerothermal Spectrometer Satellite of Illinois and Indiana (SASSI2) will be stowed in a Canisterized Satellite Dispenser (CSD) on the second stage of the Antares launch vehicle. SASSI2 is a secondary payload, part of the Cygnus NG-10E mission. There are three primary components to the payload of SASSI2: a spectrometer, a suite of three pressure sensors, and a heat flux sensor. The payload is meant to characterize the atmospheric conditions of re-entry to better inform re-entry simulation software and to validate the CubeSat platform's ability to complete a mission like this.

The satellite will be launched from the second stage of the Antares launch vehicle on November 17, 2018. It will be inserted into an orbit that is approximately 187 km by 295 km, at an inclination of 51.6°. Transmission of data will begin no sooner than 46.5 minutes after deployment. Atmospheric drag will deorbit SASSI2 approximately 11 days after deployment and the mission will be concluded.

Launch vehicle and launch site: Antares, Wallops Flight Facility

Proposed launch date: November 17, 2018

Mission duration: Until de-orbit (11 days post-launch)

Launch and deployment profile, including all parking, transfer, and operational orbits with apogee, perigee, ad inclination:
The launch profile provided by Northrop Grumman in Figure 1 provides a detailed timeline of launch and deployment relevant for the SASSI2 mission.

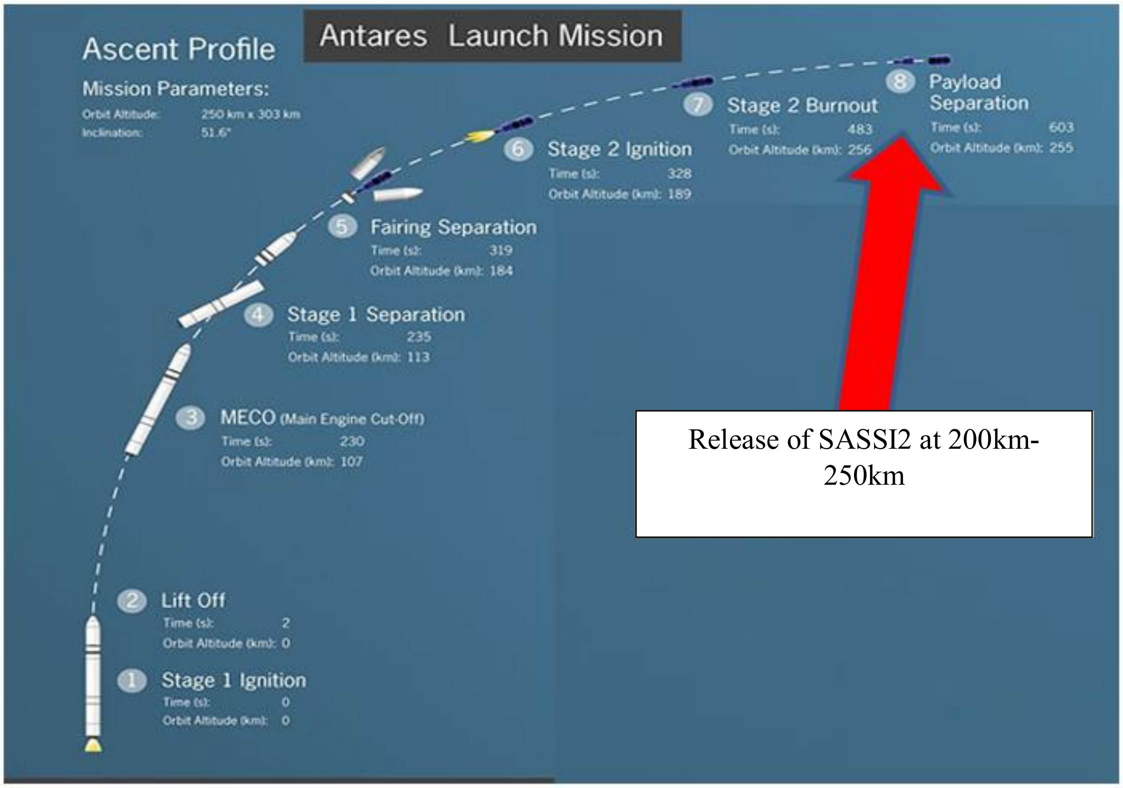


Figure 1. Launch and deployment profile relevant for SASSI2 mission.

The CSD uses a spring mechanism to eject SASSI2 at a velocity less than 3 m/sec and at an angle near perpendicular to the flight path angle of the second stage. This deployment will create the following initial orbital parameters for SASSI2:

Apogee: 295 km

Perigee: 187 km

Inclination: 51.6°

SASSI2 has no propulsion system and will therefore not actively change orbit. Instead, SASSI2 will be affected by atmospheric drag, losing altitude, and eventually deorbiting after approximately 11 days from deployment.

4. ODAR Section 1: Program Management and Mission Overview

Senior Scientist: Zachary R. Putnam, University of Illinois at Urbana-Champaign

Senior Management: Zachary R. Putnam, University of Illinois at Urbana-Champaign

Undergraduate Student Lead: Nicholas Zuiker, University of Illinois at Urbana-Champaign

Graduate Student Mentor: James Williams, University of Illinois at Urbana-Champaign

Foreign Government or space agency involvement: None.

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

NASA is providing launch and integration services through Virginia Space Consortium, as well as technical expertise.

Schedule of mission design and development milestones including spacecraft PDR and CDR (or equivalent) dates:

Item	*Date*
Project selection	Mar. 2016
Project start	Aug. 2016
SRR	Oct. 2016
PDR	Apr. 2017
CDR	Sep. 2017
Vehicle delivery to launch integrator	Sep. 2018
Launch (NG-10)	Nov. 17, 2018
Mission complete	Launch + 12 days

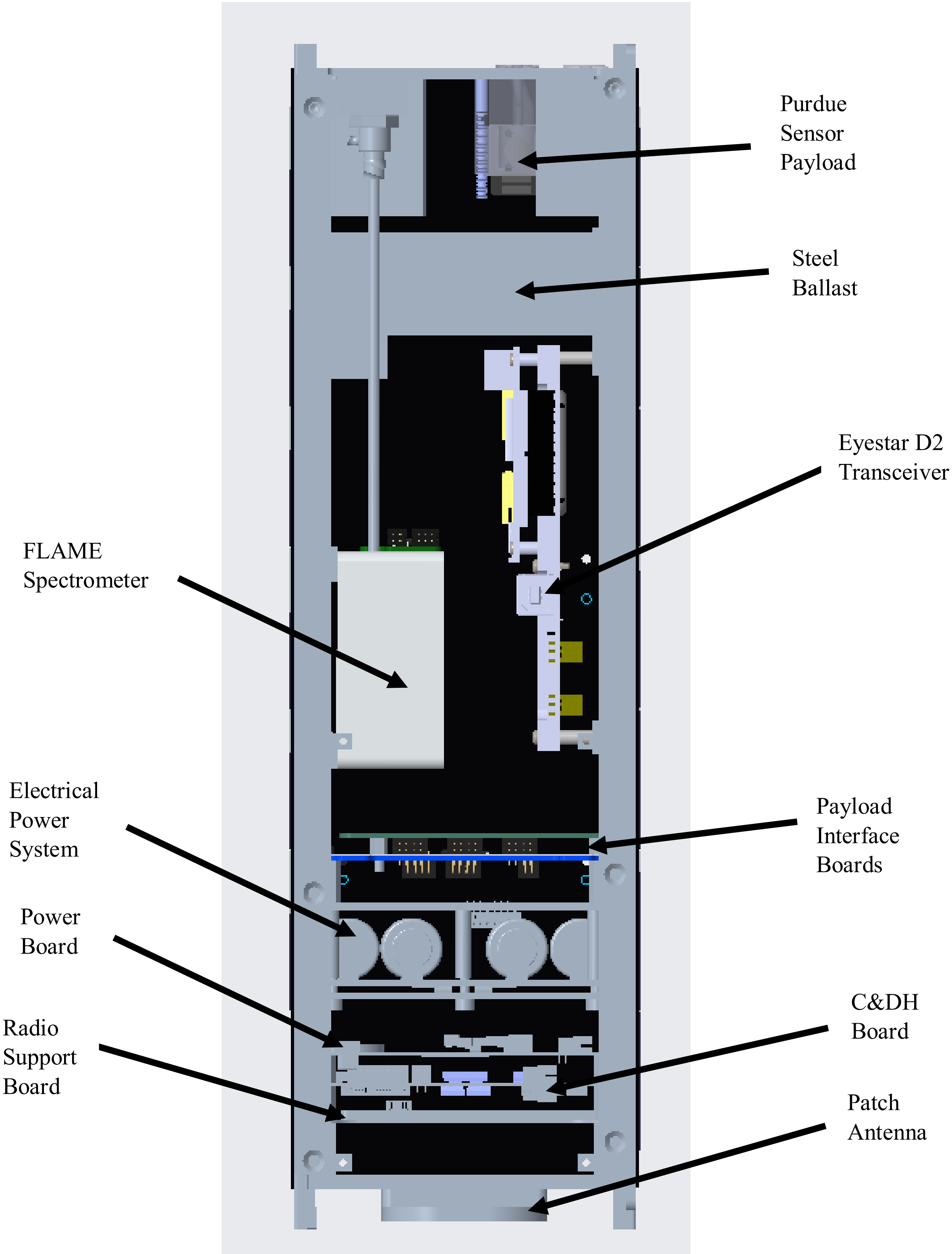
5. ODAR Section 2: Spacecraft Description

Physical description of the spacecraft:

SASSI2 is a 3U CubeSat with base dimensions of 10 cm x 10 cm x 30 cm and a total mass of approximately 3.87 kg. The exterior structure is comprised of anodized aluminum and there is some steel ballast mass in the front end of the satellite.

SASSI2 has three payloads (spectrometer, pressure sensors, heat flux sensor), supporting payload interface boards, an EyeStar D2 radio and supporting radio board, ADCS with magnetometers, gyros, sun sensors, and magnetorquers, a C&DH board, and an EPS featuring batteries, battery support board, and power board.

- The payload section is primarily comprised of COTS products, the primary payload being the FLAME spectrometer from Ocean Optics.
- The payload interface boards support C&DH operations from the primary C&DH board to each payload.
- The EyeStar D2 radio communicates with the Globalstar network.
- The ADCS supports SASSI2 in rate damping oscillations caused by the atmosphere and providing contextual data for the payload.
- The C&DH board handles almost all processes on the satellite and performs regular health monitoring.
- The EPS controls and monitors the onboard batteries and battery heaters. Overcharge protection, cell balancing, and over-discharge protection is built in and does not rely on C&DH to handle these features.



Total satellite mass at launch, including all propellants and fluids: 3.87 kg

Dry mass of satellite at launch, excluding solid rocket motor propellants: 3.87 kg

Description of all propulsion systems (cold gas, mono-propellant, bi-propellant, electric, nuclear): There is no propulsion system on SASSI2.

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: There are no fluids on board SASSI2.

Fluids in pressurized batteries: SASSI2 uses standard COTS Lithium-ion battery cells. SASSI2 has no pressurized batteries.

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

SASSI2 uses magnetorquers for control, there are two on each axis of the satellite. The normal attitude of the spacecraft is that of the front plate facing the direction of the velocity vector (ram direction) for the duration of the mission. This ensures the payload can acquire mission critical data and that the rear mounted antenna can maintain pointing towards the Globalstar network. The vector perpendicular to the front plate should remain with 30° of the velocity vector once the detumble phase has ended after approximately 4 orbits post-deployment.

Description of any range safety or other pyrotechnic devices: SASSI2 has no pyrotechnic devices.

Description of the electrical generation and storage system: The power system consists of 4 face-mounted solar arrays, lithium-ion batteries, power board, and electrical protection system. The batteries used are UL certified and flight acceptance tested LG INR18650MJ1 cells.

Identification of any other sources of stored energy not noted above: Not applicable, there are none.

Identification of any radioactive materials on board: Not applicable, there are none.

6. ODAR Section 3: Assessment of Spacecraft Debris during Normal Operations

Identifications of any object (>1 mm) expected to be released from the spacecraft any time after launch, including object dimensions, mass, and material: There are no intentional releases for the SASSI2 mission.

Rationale/necessity for release of each object: Not applicable.

Time of release of each object, relative to launch time: Not applicable.

Release velocity of each object, with respect to the spacecraft: Not applicable.

Expected orbital parameters (apogee, perigee, and inclination) of each object after release: Not applicable.

Calculated orbital lifetime of each object, including time spent in Low Earth Orbit (LEO): Not applicable.

Calculated orbital lifetime of each object, including time spent in Geostationary Earth Orbit (GEO): Not applicable.

Assessment of spacecraft compliance with Requirements 4.3-1 and 4.3-2 (per DAS v2.1.1):

4.3-1: Mission Related Debris Passing Through LEO: Compliant

4.3-1: Mission Related Debris Passing Near GEO: Compliant

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

Potential causes of spacecraft breakup during deployment and mission operations:

There is no scenario which results in a credible reason for unexpected breakup in deployment or in normal operations.

Summary of failure modes and effects analyses of all credible failure modes which may lead to an accidental explosion:

Failure of the battery cell protection in the EPS on SASSI2 could result in a very small chance of accidental cell rupture. The EPS, and more specifically the batteries, discussed in the failure mode analysis explain the failure modes that could lead to a small chance of battery rupture and the faults that must occur for those failure modes to be realized. This rupture would not lead to release of material from the spacecraft.

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

There are no planned breakups for SASSI2.

List of components which shall be passivated at End of Mission (EOM) including method of passivation and amount which cannot be passivated:

Not applicable (None).

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

SASSI2 will be disposed of by atmospheric re-entry after 11 days in orbit. It will operate into the final stages of demise. Therefore, no passivation will be performed.

Assessment of spacecraft compliance with Requirements 4.4-1 through 4.4-4:

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

For each spacecraft and launch vehicle orbital stage employed for a mission, the program or project shall demonstrate, via failure mode and effects analyses or equivalent analyses, that the integrated probability of explosion for all credible failure modes of each spacecraft and launch vehicle is less than 0.001 (excluding small particle impacts) (Requirement 56449).

Compliance Statement:

Required Probability: 0.001

Expected Probability: 0.000

Supporting Rationale and FMEA details:

Payload Pressure Vessel Failure:

SASSI2 has no pressure vessels on board.

Battery Explosion:

Effect: The failure modes explored below may result in battery explosion with possible generation of orbital debris. This is, however, unlikely; even in the event of battery explosion, the cells are small with relatively low potential energy and it's likely that most debris would be contained within the spacecraft in the small chance that an explosion occurs.

Probability: Miniscule. It is believed that there is a chance less than 0.1% since there are multiple faults that must occur for each conceived failure mode to lead to an explosion.

Failure Mode 1: Battery internal short circuit

Mitigation: Completion of protoflight level environmental testing along with UL certification of the LG INR18650MJ1 battery cells. Environmental testing includes shock, vibration, thermal cycling, and vacuum tests. Battery health was monitored before and after all environmental tests and no failures were discovered.

Combined faults required for realized failure: Environmental testing proved inadequate **AND** electrical protection system is damaged.

Failure Mode 2: Rapid heating caused by high discharge rate

Mitigation: Cell balancing on board the electrical protection system monitors battery discharge rates while thermocouples measure temperature to ensure that in the event of high thermal gradients batteries will be closed by system to prevent over discharge. This has been tested in a laboratory environment.

Combined faults required for realized failure: Spacecraft thermal design is inadequate **AND** tested electrical protection system fails.

Failure Mode 3: Overcharging and excessive charge rate

Mitigation: The electrical protection system allows for monitoring of cell voltage and the power board has MPPT resistors designed to limit the charge rate of the cells in orbit. The resistors and overcharge capabilities of the protection system have been tested in laboratory conditions with help of a solar simulator for power generation. Orbital simulations of expected power generation the solar simulator power generation are similar and provide confidence that MPPT resistors are the right resistance for orbit.

Combined faults required for realized failure: The tested electrical protection system fails **AND** MPPT resistors have too low resistance to prevent high charge rates because the orbital simulation provides incorrect power generation estimates **AND** the solar simulator power generation is inadequate for the satellite in orbit.

Failure Mode 4: Polarity reversal caused by continuous discharge in periods of low power generation and high power consumption

Mitigation: Under nominal operation, the spacecraft schedules use of power-consuming systems and balances them with expected power generation such that battery charge never drops below 50%. If the battery charge does drop below 50%, the C&DH system will enter the satellite into a power saving state, where the satellite ceases nominal operations and waits to charge.

Combined faults required for realized failure: C&DH must not respond to low battery charge **AND** power generation must be lower than simulated **AND** power consumption must be higher than tested in laboratory settings **AND** tested schedule logic must fault to keep power-consuming system on.

Requirement 4.4-2: Design for passivation after completion of mission operations while in orbit about Earth or the Moon:

Design of all spacecraft and launch vehicle orbital stages shall include the ability to deplete all onboard sources of stored energy and disconnect all energy generation sources when they are no longer required for mission operations or post mission disposal or control to a level which cannot cause an explosion or deflagration large enough to release orbital debris or break up the spacecraft (Requirement 56450).

Compliance Statement:

Since SASSI2 will orbit for approximately 11 days before burning up in atmospheric re-entry, and since it will continue functioning and taking data into the demise stage of the mission, no post mission passivation will be performed. Therefore, SASSI2 is compliant with the requirement.

Requirement 4.4-3: Limiting the long-term risk to other spacecraft from planned breakups:

Compliance Statement:

There are no planned breakups, therefore SASSI2 meets this requirement.

Requirement 4.4-4: Limiting the short-term risk to other spacecraft from planned breakups:

Compliance Statement:

There are no planned breakups, therefore SASSI2 meets this requirement.

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

Assessment of spacecraft compliance with Requirements 4.5-1 and 4.5-2 (per DAS v2.1.1, and calculation methods provided in NASA-STD-8719.14, section 4.5.4):

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

For each spacecraft and launch vehicle orbital stage in or passing through LEO, the program or project shall demonstrate that, during the orbital lifetime of each spacecraft and orbital stage, the probability of accidental collision with space objects larger than 10 cm in diameter is less than 0.001 (Requirement 56506).

Compliance Statement: Per DAS v2.1.1, SASSI2 has a large object impact and debris generation probability less than 0.001. SASSI2 is compliant.

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

For each spacecraft, the program or project shall demonstrate that, during the mission of the spacecraft, the probability of accidental collision with orbital debris and meteoroids sufficient to prevent compliance with the applicable postmission disposal requirements is less than 0.001 (Requirement 56507).

Compliance Statement: Per DAS v2.1.1, SASSI2 has a small object impact and debris generation probability less than 0.001. SASSI2 is compliant.

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

Description of spacecraft disposal option selected: The satellite will naturally deorbit via atmospheric drag, and it will burn up on re-entry.

Plan for any spacecraft maneuvers required to accomplish postmission disposal: None.

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

Spacecraft mass: 3.87 kg

Cross-sectional area: .03 m^2

Area to mass ratio: .03949 m^2 / kg

Assessment of spacecraft compliance with Requirements 4.6-1 through 4.6-5 (per DAS v2.1.1 and NASA-STD-8719.14):

Requirement 4.6-1: Disposal for space structures passing through LEO: A spacecraft or orbital stage with perigee altitude below 2000 km shall be disposed of by one of three methods (Requirement 56557):

a. Atmospheric reentry option:
   - Leave the space structure in an orbit in which natural forces will lead to atmospheric reentry within 25 years after the completion of mission but no more than 30 years after launch, or
   - Maneuver the space structure into a controlled de-orbit trajectory as soon as practical after completion of mission.
b. Storage orbit option: Maneuver the space structure into an orbit with perigee altitude greater than 2000 km and apogee less than GEO – 500 km.
c. Direct retrieval: Retrieve the space structure and remove it from orbit within 10 years after completion of mission.

Compliance Statement:

SASSI2 employs method “a” of the above options. SASSI2 will re-enter the atmosphere after 11 days in orbit and will burn up on re-entry. The analysis assumes random tumbling behavior so as to ensure behavior is not mistaken as controlled re-entry. Using DAS v2.1.1, SASSI2 is shown as compliant.

Requirement 4.6-2: Disposal for space structures near GEO.

Compliance Statement: SASSI2 has an orbit in LEO, therefore this requirement is not applicable.

Requirement 4.6-3: Disposal for space structures between LEO and GEO.

Compliance Statement: SASSI2 has an orbit in LEO, therefore this requirement is not applicable.

Requirement 4.6-4: Reliability of Postmission Disposal Operations.

Compliance Statement: Since SASSI2 does not rely on deorbiting maneuvers and has a relatively short lifetime of 11 days, the proposed post mission disposal plan has high reliability.

10. <u>ODAR Section 7: Assessment of Spacecraft Reentry Hazards</u>

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 15 Joules:

a. For uncontrolled reentry, the risk of human casualty from surviving debris shall not exceed 0.0001 (1:10,000).

Compliance Statement:

DAS v2.1.1 reports that SASSI2 is compliant with the requirement. It predicts that two components reach the ground: the sapphire window and the pressure sensors. The sapphire window reaches the ground with a kinetic energy of 0.0 J and the pressure sensors reach the ground with a kinetic energy of 12 J. The anticipated casualty area is 0.0 m^2 and the chance of human casualty is 1:100,000,000. For a comprehensive list of all spacecraft components please refer to the reentry files generated by the DAS v2.1.1. The activity log presenting this information is in Appendix A.

11. <u>ODAR Section 8: Assessment for Tether Mission</u>

Assessment of spacecraft compliance with Requirement 4.8-1:

(Requirement 4.8-1) - Mitigate the collision hazards of space tethers in Earth or Lunar orbits: Intact tether systems in Earth and lunar orbit shall meet the requirements limiting the generation of orbital debris from on-orbit collisions (Requirements 4.5-1 and 4.5-2) and the requirements governing postmission disposal (Requirements 4.6-1 through 4.6-4) to the limits specified in those paragraphs. Due to the potential of tether systems being severed by orbital debris or meteoroids, all possible remnants of a severed tether system shall be compliant with the requirements for the collision, debris, and disposal of space structures.

Compliance Statement:

SASSI2 has no tethers, therefore this requirement is not applicable.

END of ODAR for SASSI2

A. Appendix A: Reentry Hazard Data Log from DAS v2.1.1

```
08 29 2018; 15:17:29PM     Activity Log Started
08 29 2018; 15:19:10PM     *********Processing Requirement 4.7-1
     Return Status :  Passed

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

name = SASSI
quantity = 1
parent = 0
materialID = 5
type = Box
Aero Mass = 3.950000
Thermal Mass = 3.950000
Diameter/Width = 0.100000
Length = 0.340000
Height = 0.100000

name = Ballast 1
quantity = 1
parent = 1
materialID = 62
type = Box
Aero Mass = 0.415040
Thermal Mass = 0.415040
Diameter/Width = 0.040000
Length = 0.045000
Height = 0.030000

name = Ballast 2
quantity = 2
parent = 1
materialID = 62
type = Box
Aero Mass = 0.415000
Thermal Mass = 0.415000
Diameter/Width = 0.030000
Length = 0.060000
Height = 0.030000

name = Ballast 3
quantity = 1
parent = 1
materialID = 62
type = Box
Aero Mass = 0.227430
Thermal Mass = 0.227430
Diameter/Width = 0.030000
Length = 0.040000
Height = 0.025000
```

```
name = Ballast Attachment Bracket
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.064700
Thermal Mass = 0.064700
Diameter/Width = 0.043000
Length = 0.093638
Height = 0.024000

name = Front Radio Mount
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.047000
Thermal Mass = 0.047000
Diameter/Width = 0.043000
Length = 0.093638
Height = 0.009500

name = Rear Radio Mount
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.010800
Thermal Mass = 0.010800
Diameter/Width = 0.010000
Length = 0.093638
Height = 0.009500

name = Front Spectrometer Mount
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.011400
Thermal Mass = 0.011400
Diameter/Width = 0.010000
Length = 0.093638
Height = 0.009500

name = Spectrometer
quantity = 1
parent = 1
materialID = 5
type = Box
Aero Mass = 0.265000
Thermal Mass = 0.265000
```

```
Diameter/Width = 0.063500
Length = 0.088900
Height = 0.031900

name = Rear Spectrometer Mount
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.010980
Thermal Mass = 0.010980
Diameter/Width = 0.010000
Length = 0.093638
Height = 0.009500

name = Lens
quantity = 1
parent = 1
materialID = 62
type = Box
Aero Mass = 0.008869
Thermal Mass = 0.008869
Diameter/Width = 0.013000
Length = 0.015000
Height = 0.008000

name = Window
quantity = 1
parent = 1
materialID = -1
type = Box
Aero Mass = 0.001500
Thermal Mass = 0.001500
Diameter/Width = 0.003000
Length = 0.250000
Height = 0.001000

name = Lens Mount
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.009000
Thermal Mass = 0.009000
Diameter/Width = 0.020000
Length = 0.020000
Height = 0.010627

name = Fiber Optic Cable
quantity = 1
parent = 1
materialID = 23
```

```
type = Cylinder
Aero Mass = 0.050000
Thermal Mass = 0.050000
Diameter/Width = 0.030000
Length = 0.200000

name = Radio
quantity = 1
parent = 1
materialID = 23
type = Box
Aero Mass = 0.149000
Thermal Mass = 0.149000
Diameter/Width = 0.061000
Length = 0.118700
Height = 0.013387

name = Radio Support Board
quantity = 1
parent = 1
materialID = 23
type = Box
Aero Mass = 0.006310
Thermal Mass = 0.006310
Diameter/Width = 0.075400
Length = 0.559500
Height = 0.001570

name = Antenna
quantity = 1
parent = 1
materialID = 3
type = Box
Aero Mass = 0.068890
Thermal Mass = 0.068890
Diameter/Width = 0.048430
Length = 0.048430
Height = 0.020000

name = Helicoil
quantity = 100
parent = 1
materialID = 58
type = Cylinder
Aero Mass = 0.000050
Thermal Mass = 0.000050
Diameter/Width = 0.003000
Length = 0.003000

name = Pressure Sensor
quantity = 3
parent = 1
```

```
materialID = 62
type = Box
Aero Mass = 0.030200
Thermal Mass = 0.030200
Diameter/Width = 0.030000
Length = 0.050000
Height = 0.003000

name = Heat Flux Sensor
quantity = 1
parent = 1
materialID = 23
type = Box
Aero Mass = 0.000400
Thermal Mass = 0.000400
Diameter/Width = 0.035100
Length = 0.285000
Height = 0.000300

name = Solar Panel Plate
quantity = 4
parent = 1
materialID = 8
type = Flat Plate
Aero Mass = 0.027432
Thermal Mass = 0.027432
Diameter/Width = 0.080000
Length = 0.127000

name = Solar Panel Cell
quantity = 27
parent = 1
materialID = -2
type = Flat Plate
Aero Mass = 0.002595
Thermal Mass = 0.002595
Diameter/Width = 0.040000
Length = 0.080000

name = Magnetometer
quantity = 4
parent = 1
materialID = 23
type = Box
Aero Mass = 0.002468
Thermal Mass = 0.002468
Diameter/Width = 0.030000
Length = 0.050000
Height = 0.001000

name = Gyroscope
quantity = 4
```

```
parent = 1
materialID = 23
type = Box
Aero Mass = 0.002468
Thermal Mass = 0.002468
Diameter/Width = 0.030000
Length = 0.050000
Height = 0.001000

name = Torque Coils
quantity = 6
parent = 1
materialID = 23
type = Box
Aero Mass = 0.025092
Thermal Mass = 0.025092
Diameter/Width = 0.076200
Length = 0.090000
Height = 0.003500

name = Flex Cable
quantity = 4
parent = 1
materialID = 50
type = Flat Plate
Aero Mass = 0.006080
Thermal Mass = 0.006080
Diameter/Width = 0.035000
Length = 0.355000

name = Top Plate
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.086170
Thermal Mass = 0.086170
Diameter/Width = 0.096930
Length = 0.097000
Height = 0.022430

name = Bottom Plate
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.116570
Thermal Mass = 0.116570
Diameter/Width = 0.096910
Length = 0.096940
Height = 0.031120
```

```
name = Left Tab Rail
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.072010
Thermal Mass = 0.072010
Diameter/Width = 0.017570
Length = 0.355000
Height = 0.011390

name = Right Tab Rail
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.072190
Thermal Mass = 0.072190
Diameter/Width = 0.017600
Length = 0.355000
Height = 0.011060

name = Left Rail
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.053620
Thermal Mass = 0.053620
Diameter/Width = 0.011110
Length = 0.355000
Height = 0.011040

name = Right Rail
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.051860
Thermal Mass = 0.051860
Diameter/Width = 0.011210
Length = 0.355000
Height = 0.011050

name = Power Board
quantity = 1
parent = 1
materialID = 23
type = Box
Aero Mass = 0.060000
Thermal Mass = 0.060000
Diameter/Width = 0.100000
```

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Length = 0.150000
Height = 0.003000

name = C&DH Carrier
quantity = 1
parent = 1
materialID = 23
type = Box
Aero Mass = 0.041350
Thermal Mass = 0.041350
Diameter/Width = 0.100000
Length = 0.100000
Height = 0.003000

name = C&DH Daughter
quantity = 1
parent = 1
materialID = 23
type = Box
Aero Mass = 0.010120
Thermal Mass = 0.010120
Diameter/Width = 0.040000
Length = 0.070000
Height = 0.002000

name = Harness
quantity = 7
parent = 1
materialID = 9
type = Box
Aero Mass = 0.003880
Thermal Mass = 0.003880
Diameter/Width = 0.016500
Length = 0.045000
Height = 0.004000

name = Breakout Board
quantity = 1
parent = 1
materialID = 23
type = Box
Aero Mass = 0.004860
Thermal Mass = 0.004860
Diameter/Width = 0.020000
Length = 0.052000
Height = 0.005000

name = Hex Standoffs
quantity = 26
parent = 1
materialID = 58
type = Cylinder
```

```
Aero Mass = 0.001110
Thermal Mass = 0.001110
Diameter/Width = 0.004450
Length = 0.014880

name = Rail Screws
quantity = 56
parent = 1
materialID = 58
type = Cylinder
Aero Mass = 0.000480
Thermal Mass = 0.000480
Diameter/Width = 0.005880
Length = 0.007980

name = Battery Support Plate
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.034180
Thermal Mass = 0.034180
Diameter/Width = 0.085950
Length = 0.086040
Height = 0.003130

name = Battery Pack Board
quantity = 1
parent = 1
materialID = 23
type = Box
Aero Mass = 0.031320
Thermal Mass = 0.031320
Diameter/Width = 0.090000
Length = 0.095000
Height = 0.002000

name = Batteries
quantity = 4
parent = 1
materialID = 9
type = Cylinder
Aero Mass = 0.048771
Thermal Mass = 0.048771
Diameter/Width = 0.020000
Length = 0.065026

name = Middle Plate
quantity = 1
parent = 1
materialID = 8
type = Box
```

```
Aero Mass = 0.063280
Thermal Mass = 0.063280
Diameter/Width = 0.085270
Length = 0.093630
Height = 0.013520

name = Payload Interface Board
quantity = 1
parent = 1
materialID = 23
type = Box
Aero Mass = 0.025343
Thermal Mass = 0.025343
Diameter/Width = 0.080000
Length = 0.095000
Height = 0.002000

name = Purdue Payload Board
quantity = 1
parent = 1
materialID = 23
type = Box
Aero Mass = 0.022252
Thermal Mass = 0.022252
Diameter/Width = 0.060000
Length = 0.085000
Height = 0.002500

name = Purdue Breakout
quantity = 3
parent = 1
materialID = 23
type = Box
Aero Mass = 0.039590
Thermal Mass = 0.039590
Diameter/Width = 0.040000
Length = 0.060000
Height = 0.010000

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

name = SASSI
Demise Altitude = 77.995262
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Ballast 1
Demise Altitude = 57.428894
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
```

```
*************************************
name = Ballast 2
Demise Altitude = 61.611660
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Ballast 3
Demise Altitude = 62.370861
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Ballast Attachment Bracket
Demise Altitude = 76.277023
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Front Radio Mount
Demise Altitude = 76.336334
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Rear Radio Mount
Demise Altitude = 77.229340
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Front Spectrometer Mount
Demise Altitude = 77.186081
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Spectrometer
Demise Altitude = 72.274559
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Rear Spectrometer Mount
Demise Altitude = 77.207909
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Lens
Demise Altitude = 70.435532
```

```
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Window
Demise Altitude = 0.000000
Debris Casualty Area = 0.387333
Impact Kinetic Energy = 0.066989

*************************************
name = Lens Mount
Demise Altitude = 76.180092
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Fiber Optic Cable
Demise Altitude = 77.211418
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Radio
Demise Altitude = 75.792686
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Radio Support Board
Demise Altitude = 77.968399
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Antenna
Demise Altitude = 74.610283
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Helicoil
Demise Altitude = 77.714470
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Pressure Sensor
Demise Altitude = 0.000000
Debris Casualty Area = 1.185877
Impact Kinetic Energy = 12.296156

*************************************
```

```
name = Heat Flux Sensor
Demise Altitude = 77.995262
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Solar Panel Plate
Demise Altitude = 77.393547
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Solar Panel Cell
Demise Altitude = 77.981239
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Magnetometer
Demise Altitude = 77.830574
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Gyroscope
Demise Altitude = 77.830574
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Torque Coils
Demise Altitude = 77.477608
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Flex Cable
Demise Altitude = 77.967522
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Top Plate
Demise Altitude = 76.297112
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Bottom Plate
Demise Altitude = 75.896919
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
```

```
***********************************
name = Left Tab Rail
Demise Altitude = 76.906494
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

***********************************
name = Right Tab Rail
Demise Altitude = 76.884956
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

***********************************
name = Left Rail
Demise Altitude = 77.076195
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

***********************************
name = Right Rail
Demise Altitude = 77.105431
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

***********************************
name = Power Board
Demise Altitude = 77.345406
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

***********************************
name = C&DH Carrier
Demise Altitude = 77.324341
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

***********************************
name = C&DH Daughter
Demise Altitude = 77.594635
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

***********************************
name = Harness
Demise Altitude = 77.469986
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

***********************************
name = Breakout Board
Demise Altitude = 77.634903
```

```
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Hex Standoffs
Demise Altitude = 76.615791
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Rail Screws
Demise Altitude = 77.214966
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Battery Support Plate
Demise Altitude = 76.970840
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Battery Pack Board
Demise Altitude = 77.422516
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Batteries
Demise Altitude = 75.035118
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Middle Plate
Demise Altitude = 76.490639
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Payload Interface Board
Demise Altitude = 77.505943
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Purdue Payload Board
Demise Altitude = 77.434029
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
```

```
name = Purdue Breakout
Demise Altitude = 76.555283
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

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

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