MESHBED SPACECRAFT

Orbital Debris Assessment Report (ODAR)

Initial Release

Date: February 20th, 2019

Adam Wong, Analytical Space Inc.
Government and Regulatory Affairs Lead

DOCUMENT CHANGE LOG:

1. Initial Release: July 11th, 2018
2. Corrections and Updates December 31, 2018
3. Corrections and Updates February 20th, 2019

ORBITAL DEBRIS ASSESSMENT REPORT

This document contains the orbital debris assessment report (ODAR) for Analytical Space, Inc. (ASI)'s experimental spacecraft Meshbed.

Table 1 includes a summary of the results in the following sections.

ODAR Requirement for Meshbed	Compliant or N/A	Not Compliant	Incomplete
4.3.1-a	x		
4.3.1-b	x		
4.3.2	x		
4.4-1	x		
4.4-2	x		
4.4-3	x		
4.4-4	x		
4.5-1	x		
4.5-2	x		
4.6-1(a)	x		
4.6-2	x		
4.6-3	x		
4.6-4	x		
4.7-1	x		
4.8-1	x		

ODAR SECTION 1: PROGRAM MANAGEMENT AND MISSION OVERVIEW

Project Manager: Adam Wong

Foreign Government / Space Agency Participation: None

Schedule of Upcoming Mission Milestones:
Hand-off for integration: April 1, 2019
Launch: June 1, 2019

Mission Overview:

The Meshbed experimental spacecraft will be launched in Q2 2019 (NET June 1, 2019) aboard an ISRO PSLV rocket. The spacecraft will be deployed at an approximate altitude of 505 km at an inclination of 97.4798 degrees. The mission will demonstrate an experimental phased array antenna system.

ODAR Summary:
1. No orbital debris to be released as part of normal operations
2. No credible scenarios for spacecraft breakup
3. Collision probability is compliant with NASA ODAR requirements 4.5-1 and 4.5-2 as calculated by DAS v2.1.1
4. Estimated nominal decay lifetime due to atmospheric drag is significantly less than 25 years and therefore compliant with ODAR requirement 4.6
5. Reentry debris casualty risk is compliant with NASA ODAR 4.7-1 as calculated by DAS v2.1.1

Launch Vehicle and Launch Site: ISRO PSLV - Sriharikota, India

Projected Launch Date: Q2 2019 (NET June 1, 2019)

Mission Duration:
1. Primary nominal operations: 6 months after deployment
2. Post-operations orbital lifetime: ~41 months after deployment

Launch and Deployment Profile:

Spacecraft, as scheduled, will launch on a ISRO PSLV rocket NET June 1, 2019. Spaceflight Industries will integrate Meshbed as a secondary payload.

Table 3.1: Summary of Meshbed Launch Information

Target Launch Date	June 1, 2019
Launch Vehicle	ISRO PSLV
Secondary Payload Aggregator	Spaceflight Industries
Meshbed Launch Configuration	3U
Perigee Altitude	505 km
Apogee Altitude	505 km
Inclination	97.4798 degrees
Period	94.716 min

ODAR SECTION 2: SPACECRAFT DESCRIPTION

Total satellite mass at launch, including all propellants and fluids: ~4.5 kg

Dry mass of satellite at launch, excluding solid rocket motor propellants: ~4.5 kg

Description of all propulsion systems: None

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: None

Fluids in pressurized batteries: None

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

Attitude determination and control system includes one reaction wheel, five magnetic torquer panels, a 3-axis magnetometer, a 3-axis inertial measurement unit, a GPS receiver, and six coarse sun sensors. Nominally, the spacecraft will fly with its solar panels in a sun-point configuration.

Description of any range safety or other pyrotechnic devices: None

Description of the electrical generation and storage system:

A COTS battery assembly of 8 lithium ion cells will provide 20 watts on average with a peak of approximately 65 watts. The battery assembly will be charged at time of integration and three deployable solar arrays will recharge the assembly on-orbit. Power management and distribution electronics onboard the spacecraft control the charge of the battery and flow of power to other spacecraft elements.

Identification of any other sources of stored energy not noted above: None

Identification of any radioactive material on board: None

ODAR SECTION 3: ASSESSMENT OF SPACECRAFT DEBRIS – NOMINAL OPERATIONS

Identification of any object > 1mm expected to be released from spacecraft after launch: 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 of each object after release: N/A

Calculated orbital lifetime of each object, including time spent in Low Earth Orbit: N/A

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

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

ODAR SECTION 4: ASSESSMENT OF SPACECRAFT INTENTIONAL BREAKUPS AND POTENTIAL FOR EXPLOSION

Potential causes of spacecraft breakup during deployment and mission operations:

There are no credible causes of spacecraft breakup during nominal deployment and mission operations

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

The spacecraft has no propellants or pressurized vessels.

Detailed plan for any designed spacecraft breakup: None planned

List of components that shall be passivated at End of Mission (EOM):

No component passivation is planned. The spacecraft's eight lithium-ion cells will not be passivated at the end of the mission due to the low risk.

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

Onboard battery management and overcharge protection in the battery assembly makes any risk of a cell failure low and if it does fail, no material would discharge outside of the satellite's aluminum structure.

Assessment of spacecraft compliance with ODAR requirements 4.1-4.4:

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

- Required Probability: .0001 – COMPLIANT

Supporting Rationale:

- Failure Mode 1: Internal cell short circuit
    - Mitigation: Qualification and acceptance dynamic, thermal, and vacuum testing, followed by qualification charge / discharge
- Failure Mode 2: Increase in cell temperature resulting in venting
    - Mitigation: Over test of cells as well as an overall assembly test resulted in no failures
- Failure Mode 3: Excessive discharge rate or short circuit due to technical device failure
    - Mitigation: 1) Short circuit protection and 2) design of assembly to ensure no possible contact with other conductive paths in proximity to battery
- Failure Mode 4: Battery cell vent path failure
    - Mitigation: Failure mode mitigated by design with a vent path for each cell
- Failure Mode 5: Crushing
    - Mitigation: Failure mode prevented by design. No moving parts near the battery assembly
- Failure Mode 6: Excess battery cell temperature due to orbital environment

    - Mitigation: Spacecraft thermal design prevents failure mode and testing in both vacuum and non-vacuum conditions

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

- Compliance Statement: As noted, above passivation of the battery system is not planned. Meshbed's battery system, given its small size, mass, and potential energy, debris from any battery rupture would be expected to be contained within the aluminum structure.

4.4-3: Limiting the long-term risk to other space systems from planned breakups:

- Compliance Statement: Requirement not applicable, no planned breakups

4.4-4: Limiting the short-term risk to other space systems from planned breakups:

- Compliance Statement: Requirement not applicable, no planned breakups

ODAR SECTION 5: ASSESSMENT OF SPACECRAFT POTENTIAL FOR ON-ORBIT COLLISIONS

Assessment of spacecraft compliance with ODAR requirements 4.5-1 and 4.5-2:

- 4.5-1: Limiting debris generated by collisions with large objects when operating in Earth Orbit (per DAS v2.1.1):
    - COMPLIANT; Collision Probability <0.00001
- 4.5-2: Limiting debris generated by collisions with small objects when operating in Earth or Lunar Orbit:
    - Compliance statement: Not applicable as the planned disposal method is via atmospheric reentry that does not require a specific orientation or drag state.

ODAR SECTION 6: ASSESSMENT OF SPACECRAFT POST-MISSION DISPOSAL PLANS AND PROCEDURES

Description of spacecraft disposal option selected:

Per NASA-STD 8719.4, Meshbed will be disposed of via atmospheric reentry. Its low deployment altitude means the spacecraft will de-orbit naturally well within the timeframe specified in 4.6-1(a)

Plan for any spacecraft maneuvers required to accomplish post-mission disposal:

No special maneuvers or operations required for post-mission disposal. Spacecraft will deorbit naturally.

Calculation of area-to-mass ratio after post-mission disposal:

- Spacecraft mass: ~4.5 kg
- Cross-sectional area: 0.08 m^2 (average)
- Area to mass ratio: 0.017 m^2/kg (average)

Assessment of spacecraft compliance with ODAR requirements 4.6-1 to 4.6-4:

- 4.6-1(a): Disposal for space structures in or passing through LEO:
  - COMPLIANT per DAS v2.1.1; Expected de-orbit with a ~56 month on-orbit lifetime
- 4.6-2: Disposal for space structure near GEO
  - Not applicable
- 4.6-3: Disposal for space structures between LEO and GEO
  - Not applicable
- 4.6-4: Reliability of post-mission disposal operations
  - The spacecraft will reenter passively without post mission disposal operations within the acceptable time frame

ODAR SECTION 7: ASSESSMENT OF SPACECRAFT REENTRY HAZARDS

Assessment of spacecraft compliance with ODAR requirement 4.7-1:

- 4.7-1(a): Limit the risk of human casualty from surviving debris for an uncontrolled reentry to no greater than 1 in 10000
  - COMPLIANT per DAS v2.1.1; all components demise before reaching earth surface; there are no surviving debris, so there is no risk from surviving debris.
- 4.7-1(b): Not applicable, only for controlled reentry
- 4.7-1(c): Not applicable, only for controlled reentry

ODAR SECTION 8: ASSESSMENT FOR TETHER MISSIONS

Section not applicable, no tethers aboard Meshbed.

DAS ACTIVITY LOG

02 19 2019; 16:32:07PM Activity Log Started

02 19 2019; 16:32:07PM Opened Project
C:\Users\ASI\AppData\Local\NASA\DAS2.1.1\MESHBED_Q3PSLV\

02 19 2019; 16:32:39PM Science and Engineering - Orbit Lifetime/Dwell Time

INPUT
Start Year = 2019.000000 (yr)
Perigee Altitude = 505.000000 (km)
Apogee Altitude = 505.000000 (km)
Inclination = 97.430000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Area-To-Mass Ratio = 0.017000 (m^2/kg)

OUTPUT
Orbital Lifetime from Startyr = 3.400411 (yr)
Time Spent in LEO during Lifetime = 3.400411 (yr)
Last year of Propagation = 2022 (yr)
Returned Error Message: Object reentered

02 19 2019; 16:32:50 PM Processing Requirement 4.3-1: Return Status : Not Run
==========
No Project Data Available
==========
========== End of Requirement 4.3-1 ==========
02 19 2019; 16:32:53 PM Processing Requirement 4.3-2: Return Status : Passed
==========
No Project Data Available
==========
========== End of Requirement 4.3-2 ==========
02 19 2019; 16:32:55 PM Requirement 4.4-3: Compliant
========== End of Requirement 4.4-3 ==========
02 19 2019; 16:37:42 PM Processing Requirement 4.5-1: Return Status : Passed
==========
Run Data
==========
INPUT
Space Structure Name = Meshbed

Space Structure Type = Payload
Perigee Altitude = 505.000000 (km)
Apogee Altitude = 505.000000 (km)
Inclination = 97.430000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Final Area-To-Mass Ratio = 0.017000 (m^2/kg)
Start Year = 2019.000000 (yr)
Initial Mass = 4.500000 (kg)
Final Mass = 4.500000 (kg)
Duration = 3.000000 (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 ==========
02 19 2019; 16:59:17PM Requirement 4.5-2: Compliant
02 19 2019; 16:59:19PM Processing Requirement 4.6 Return Status : Passed
==========
Project Data
==========
INPUT
Space Structure Name = Meshbed
Space Structure Type = Payload

Perigee Altitude = 505.000000 (km)
Apogee Altitude = 505.000000 (km)
Inclination = 97.430000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)

Area-To-Mass Ratio = 0.017000 (m^2/kg)
Start Year = 2019.000000 (yr)
Initial Mass = 4.500000 (kg)
Final Mass = 4.500000 (kg)
Duration = 3.000000 (yr)
Station Kept = False
Abandoned = True
PMD Perigee Altitude = 439.815133 (km)
PMD Apogee Altitude = 439.815133 (km)
PMD Inclination = 97.461875 (deg)
PMD RAAN = 6.192420 (deg)
PMD Argument of Perigee = 4.207323 (deg)
PMD Mean Anomaly = 0.000000 (deg)

OUTPUT
Suggested Perigee Altitude = 439.815133 (km)
Suggested Apogee Altitude = 439.815133 (km)
Returned Error Message = Passes LEO reentry orbit criteria.

Released Year = 2022 (yr)
Requirement = 61
Compliance Status = Pass
==========
========== End of Requirement 4.6 ==========
02 19 2019; 16:59:40PM *********Processing Requirement 4.7-1
Return Status : Passed
**********INPUT****
Item Number = 1

name = Meshbed
quantity = 1
parent = 0
materialID = 8
type = Box
Aero Mass = 4.500000
Thermal Mass = 4.500000
Diameter/Width = 0.100000
Length = 0.340000
Height = 0.100000

name = Solar Array
quantity = 3
parent = 1

materialID = 23
type = Box
Aero Mass = 0.200000
Thermal Mass = 0.200000
Diameter/Width = 0.100000
Length = 0.600000
Height = 0.002000

name = Chassis
quantity = 1
parent = 1
materialID = 5
type = Box
Aero Mass = 1.700000
Thermal Mass = 1.700000
Diameter/Width = 0.100000
Length = 0.340000
Height = 0.100000

name = Batteries
quantity = 1
parent = 1
materialID = 27
type = Box
Aero Mass = 0.500000
Thermal Mass = 0.500000
Diameter/Width = 0.100000
Length = 0.100000
Height = 0.050000

name = Electronics
quantity = 1
parent = 1
materialID = 23
type = Box
Aero Mass = 0.500000
Thermal Mass = 0.500000
Diameter/Width = 0.100000
Length = 0.100000
Height = 0.050000

name = Antenna
quantity = 1

parent = 1
materialID = 8
type = Box
Aero Mass = 1.200000
Thermal Mass = 1.200000
Diameter/Width = 0.100000
Length = 0.200000
Height = 0.080000

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

name = Meshbed
Demise Altitude = 77.994843
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
****
name = Solar Array
Demise Altitude = 77.325096
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
****
name = Chassis
Demise Altitude = 72.366119
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
****
name = Batteries
Demise Altitude = 76.652092
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
****
name = Electronics
Demise Altitude = 74.033684
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
****
name = Antenna
Demise Altitude = 71.996216
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
****
========== End of Requirement 4.7-1 ==========