Hamilton-1

Orbital Debris Assessment Report (ODAR)

Revision A • 21 June 2017

Prepared for Kubos Corporation in compliance with NASA-STD-8719.14 by Southern Stars Group, LLC. This document contains no proprietary, ITAR, or export control restrictions.
NASA Debris Analysis Software (DAS) version 2.1.1 was used in preparing this report.

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Record of Revisions

Revision	Date	Affected Pages	Description of Change	Authors
A	21 June 2017	All	Initial Revision	Tim DeBenedictis

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Self-Assessment and OSMA Assessment of the ODAR

A self assessment is provided below, in accordance with the assessment format provided in Appendix A.2 of NASA-STD-8719.14. In the final ODAR document, this assessment will reflect any inputs received from OSMA as well.

Req. #	Launch Vehicle				Spacecraft			Comments
	Compliant	Not Compliant	Incomplete	Standard Non Compliant	Compliant	Not Compliant	Incomplete	
4.3-1.a			x		x			
4.3-1.b			x		x			
4.3-2			x		x			
4.4-1			x		x			
4.4-2			x		x			
4.4-3			x		x			
4.4-4			x		x			
4.5-1			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			
4.6-5			x		x			
4.7-1			x		x			
4.8-1			x		x			

Notes:

1. The primary payload belongs to ISRO. This is not a Kubos Corporation primary mission. All of the other portions of the launch stack are non-Kubos, and Hamilton-1 is not the lead.

Assessment Report Format

ODAR Technical Sections Format Requiremnents:

- This ODAR follows the format in NASA-STD-8719.14, Appendix A.1, and include the content indicated at a minimum in each section 2 through 8 below for the Hamilton-1 satellite. Sections 9 through 14 apply to the launch vehicle, and are not covered here.

ODAR Section 1: Program Management and Mission Overview

Hamilton-1 is a privately funded mission owned and operated Kubos Corporation, a Delaware corporation with its principal place of business at 608 E. Hickory St. #108, Denton, TX 76205.

Senior Manager:

- Marshall Culpepper, Kubos Corporation, marshall@kubos.co, (214) 500-6076.
  CEO and Co-Founder.

Key engineering personnel:

- Jesse Coffey, Kubos Corporation, jacoffey3@kubos.co, (415) 787-5223.
  Spacecraft Integration and Software Engineering.

- Jesse Hamner, Kubos Corporation, jesse@kubos.co, NEED PHONE NUMEBR.
  Radio Communication.

Foreign government or space agency participation:

- No foreign agency is participating in this mission. All personnel are United States citizens.

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

- Not Applicable.

Schedule of upcoming mission milestones:

1 October 2017	Integrated system testing begins.
1 December 2017	Integrated system testing complete.
1 February 2018	Spacecraft delivery to Launch Service Provider.
1 April 2018	Earliest possible launch.

Mission Overview

Hamilton-1, named for the Apollo-era software pioneer Margaret Hamilton, is a 1U CubeSat that will be launched as a secondary payload on an ISRO Polar Satellite Launch Vehicle (PSLV) into a near-circular sun-synchronous orbit at 600 km altitude. It will orbit for about 18 years, transmitting telemetry data for its 2-year operational lifetime.

Hamilton-1 will gradually experience orbital decay due to atmospheric drag. At EOM, spacecraft disposal will be accomplished by uncontrolled atmospheric re-entry.

Launch Vehicle and Launch Site:

- The launch vehicle is a Polar Satellite Launch Vehicle, scheduled for launch from the Satish Dhawan Space Center at Sriharikota, India.

Proposed Launch Date:

- No earlier than April 2018.

Mission Duration:

- 2 years in LEO operation, until atmospheric reentry via orbital decay.

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

- The PSLV will launch into a circular orbit. Once the final stage has burned out, the secondary payloads will be dispensed. After the secondary paylads are clear, the primary payload will separate.

- The destination orbit is entirely determined by the primary payload; Hamilton-1 is a secondary payload. Its orbital parameters are defined as follows:

  Apogee: 600 km
  Perigee: 600 km
  Inclination: 98 degrees

- Hamilton-1 has no propulsion system and therefore does not actively change orbits. There is no parking or transfer orbit.

- At this time, we know of no potential interaction or physical interference between Hamilton-1 and any other operational spacecraft.

ODAR Section 2: Spacecraft Description

Hamilton-1 is a 1U CubeSat, 10x10x11 cm in size. It satellite contains a UHF/VFH radio transciever, microcontroller-based flight computer, fixed body-mounted solar panels, electrical power system with 18650 LiPo batteries, and a magnetorquer-based attitude determination and control system. Hamilton-1 carries no cameras or any other Earth-imaging subsystem. The only deployable component is the radio antenna; Hamilton-1 will not intentionally jettison or discard any materials on orbit.

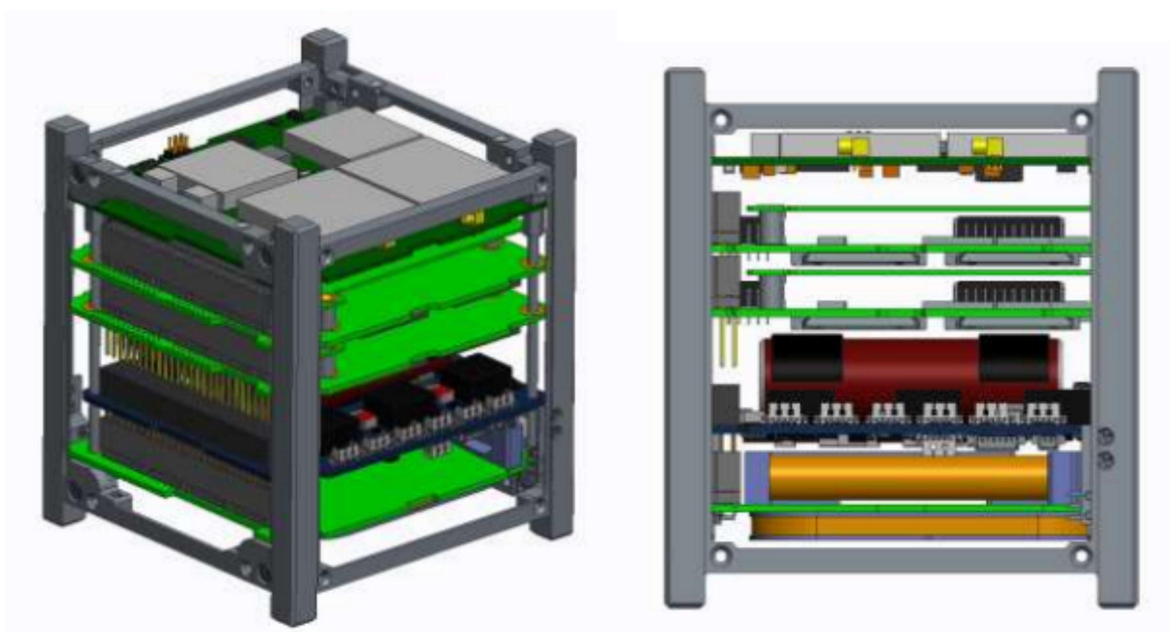

Figure 1. Orthographic (left) and isometric (right) views of Hamilton-1 spacecraft. Solar panels have been removed for clarity.

Total spacecraft mass at launch:

- 1.4 kg

Dry mass of spacecraft at launch:

- 1.4 kg

Propulsion systems:

- None.

On-board fluids:

- None.

Attitude control:

- Attitude will be accomplished through active magnetorquers.

Range safety or other pyrotechnic devices:

- None.

Electrical generation and storage system:

- Solar cells charging 2x Li-Ion batteries in 18650 form factor. The batteries have been pre-qualified by NASA for use in spaceflight applications.

Other sources of stored energy:

- None.

Radioactive materials:

- None.

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

No objects (>1 mm) are expected to be released from the spacecraft any time after launch. Therefore Hamilton-1 is COMPLIANT with requirements 4.3-1 and 4.3-2.

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 (per DAS v2.1.1)

- **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

There are no intentional breakups scheduled during on orbit operations. We are aware of no known potential causes of spacecraft breakup during deployment and mission operations.

Potential causes of spacecraft breakup during deployment and mission operations:

- There is no credible scenario that would result in spacecraft breakup during normal deployment and operations.

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

- The battery safety systems discussed in the FMEA (see requirement 4.4-1 below) describe the combined faults that must occur for any of nine independent, mutually exclusive failure modes that could lead to a battery venting. If the LiIon batteries fail, they are expected to vent gas rather than explode.

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

- There are no plans for any intentional spacecraft breakup by explosion, collision, nor by any other means.

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

- hamilton-1 contains no components which are passivated at EOM. The spacecraft will be destroyed by atmospheric reentry. There is no plan to passivate the batteries, but even in the event of mechanical damage or short-circuit they will not explode.

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 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:

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: Extremely Low. It is believed to be 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: Qualification and acceptance shock, vibration, thermal cycling, and vacuum tests followed by maximum system rate-limited charge and discharge to prove that no internal short circuit sensitivity exists.

Combined faults required for realized failure: Environmental testing **AND** functional charge/discharge tests must both be ineffective in discovery of the failure mode.

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

Mitigation 2: Cells were tested in lab for high load discharge rates in a variety of flight like configurations to determine if the feasibility of an out of control thermal rise in the cell. Cells were also tested in a hot environment to test the upper limit of the cells capability. No failures were seen.

*Combined faults required for realized failure: S*pacecraft thermal design must be incorrect **AND** external over current detection and disconnect function must fail to enable this failure mode.

Failure Mode 3: Overcharging and excessive charge rate.

Mitigation 3: The satellite bus battery charging circuit design eliminates the possibility of the batteries being overcharged if circuits function nominally. This circuit has been proto- qualification tested for survival in shock, vibration, and thermal-vacuum environments. The charge circuit disconnects the incoming current when battery voltage indicates normal full charge at 8.4 V. If this circuit fails to operate, continuing charge can cause gas generation. The batteries include overpressure release vents that allow gas to escape, virtually eliminating any explosion hazard.

Combined faults required for realized failure:

1. **For overcharging:** The charge control circuit must fail to function **AND** the PTC device must fail (or temperatures generated must be insufficient to cause the PTC device to modulate) **AND** the overpressure relief device must be inadequate to vent generated gasses at acceptable rates to avoid explosion.

2. **For excessive charge rate:** The maximum charging rate from a single solar panel when in AM 1.5G conditions (in space, perpendicular to the sun) is 124 mA. The maximum charge rate our battery can accept is 3 A. The battery itself has one string of 2 cells connected in series. Due to solar panel current limits and their direction-facing arrangement on the satellite, there is no physical means of exceeding charging rate limits, even if the single string from the battery was accepting charge. The overpressure relief vent keeps the battery cells from rupturing, and is thus limited to worst-case effects of overcharging.

Failure Mode 4: Excessive discharge rate or short circuit due to external device failure or terminal contact with conductors not at battery voltage levels (due to abrasion or inadequate proximity separation).

Mitigation 4: This failure mode is negated by a) qualification tested short circuit protection on each external circuit, b) design of battery packs and insulators such that no contact with nearby board traces is possible without being caused by some other mechanical failure, c) obviation of such other mechanical failures by proto-qualification and acceptance environmental tests (shock, vibration, thermal cycling, and thermal-vacuum tests).

Combined faults required for realized failure: An external load must fail/short-circuit **AND** external over-current detection and disconnect function must all occur to enable this failure mode.

Failure Mode 5: Inoperable vents.

Mitigation 5: Battery vents are not inhibited by the battery holder design or the spacecraft.

Combined effects required for realized failure: The manufacturer fails to install proper venting.

Failure Mode 6: Crushing.

Mitigation 6: This mode is negated by spacecraft design. There are no moving parts in the proximity of the batteries.

Combined faults required for realized failure: A catastrophic failure must occur in an external system **AND** the failure must cause a collision sufficient to crush the batteries leading to an internal short circuit **AND** the satellite must be in a naturally sustained orbit at the time the crushing occurs.

Failure Mode 7: Low level current leakage or short-circuit through battery pack case or due to moisture-based degradation of insulators.

Mitigation 7: These modes are negated by a) battery holder/case design made of non-conductive plastic, and b) operation in vacuum such that no moisture can affect insulators.

Combined faults required for realized failure: Abrasion or piercing failure of circuit board coating or wire insulators **AND** dislocation of battery packs **AND** failure of battery terminal insulators **AND** failure to detect such failures in environmental tests must occur to result in this failure mode.

Failure Mode 8: 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** the PTC device must fail **AND** over-current monitoring and control must all fail for this failure mode to occur.

Failure Mode 9: Polarity reversal due to over-discharge caused by continuous load during periods of negative power generation vs. consumption.

Mitigation 9: In nominal operations, the spacecraft EPS design negates this mode because the processor will stop when voltage drops too low, below 7 V. This disables ALL connected loads, creating a guaranteed power-positive charging scenario. The spacecraft will not restart or connect any loads until battery voltage is above the acceptable threshold. At this point, only the safemode processor and radio receiver are enabled and charging the battery. Once the battery reaches 90% of the peak voltage (around 7.5 V), it will switch to nominal mode and will be able to receive ground commands for continuing mission functions.

Combined faults required for realized failure: The microcontroller must stop executing code **AND** significant loads must be commanded/stuck "on" **AND** power margin analysis must be wrong **AND** the charge control circuit must fail for this failure mode to occur.

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 postmission disposal or control to a level which can not cause an explosion or deflagration large enough to release orbital debris or break up the spacecraft (Requirement 56450).

- **Compliance statement:**

  Hamilton-1's battery charge circuits include overcharge protection and to limit the risk of battery failure. 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.

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

- **Compliance statement:**

  This requirement is not applicable. There are no planned breakups.

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

- **Compliance statement:**

  This requirement is not applicable. There are no planned breakups.

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

We computed the probability of spacecraft collision with space objects larger than 10 cm in diameter during the orbital lifetime of the spacecraft (assumptions: 600 km altitude, 98° inclination, 0.011 m^2 area), using the DAS 2.1.1 sofware, as 0.000.

We did not compute the probability of collision with small objects. We expect that, over time, the spacecraft may encouter collisions with micrometeoroids, paint flecks, etc. which may cause pitting or scarring to the structure. However, the spacecraft contains no "critical surfaces", such as exposed PCBs, for which damage could interefere with postmission disposal. The spacecraft will passively re-enter Earth's atmosphere after TBD years, regardless of the cumulative impact of small object colliions.

Assessment of spacecraft compliance with Requirements 4.5-1 and 4.5-2 (per DAS v2.0, 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).

  Large Object Impact and Debris Generation Probability: 0.000; COMPLIANT.

- ***Requirement 4.5-2. Limiting debris generated by collisions with small objects when operating in Earth 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 0.01 (Requirement 56507).

  Small Object Impact and Debris Generation Probability: NOT APPLICABLE.

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

This section describes the post-mission disposal of the Hamilton-1 spacecraft.

6.1 Description of spacecraft disposal option selected:

- Disposal of Hamilton-1 will be accomplished by natural orbital decay and uncontrolled atmospheric reentry.

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

- No spacecraft maneuvers are required to accomplish post-mission disposal.

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

Spacecraft Mass: 1.4 kg
Cross-sectional Area: 0.011 m^2 (For the configuration in Figure 1).
Area to mass ratio: 0.011/1.4 = 0.0079 m^2/kg

6.4 Assessment of spacecraft compliance with Requirements 4.6-1 through 4.6-5 (per DAS v 2.0 .2 and NASA-STD-8719.14 section):

Requirement 4.6-1. Disposal for space structures passing through LEO: A spacecraft or orbital stage with a 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.

- **Analysis:** The Hamilton-1 satellite reentry is COMPLIANT using Method "a." Hamilton-1 will re-enter approximately 18 years after orbit insertion with altitude history as shown in Figure 2 (analysis assumes a gravity-gradient orientation).

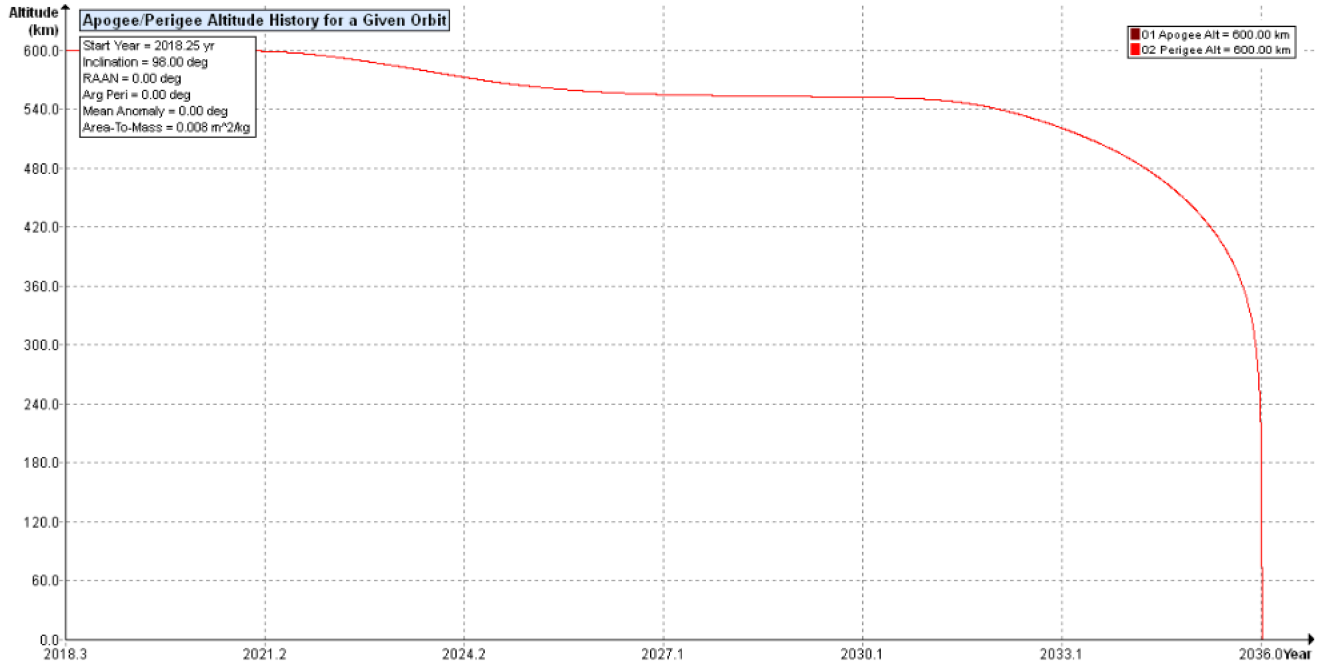

Figure 2. Hamilton-1 orbit history after deployment and orbit insertion at T=2018.25

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

- **Analysis:** Not applicable.

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

- **Analysis:** Not applicable.

Requirement 4.6-4. Reliability of Postmission Disposal Operations

- **Analysis:** Hamilton-1 does not rely on any maneuvers or de-orbiting device to ensure post mission disposal within the allowed 25-year timeframe. The satellite will reenter passively approximately TBD years after launch, as shown in Figure 2, above.

ODAR Section 7: Assessment of Spacecraft Reentry Hazards

A detailed description of spacecraft components includes small Li-ion batteries; a thin aluminum framework; cameras and other circuitry; solar cells. All components will vaporize.

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) (Requirement 56626).

- **Summary Analysis Results:** DAS v2.1.1 reports that Hamilton-1 is COMPLIANT with the requirement. No components are predicted by NASA DAS software to survive re-entry. The probability of human casualty due to uncontrolled reentry is 0.000000.

Analysis (per DAS v2.1.1):

```
06 23 2017; 13:25:37PM       Activity Log Started
06 23 2017; 13:25:37PM       Opened Project C:\Users\timmyd\Desktop\DAS - Hamilton-1\
06 23 2017; 13:28:01PM       Processing Requirement 4.6    Return Status :  Passed

==============
Project Data
==============

**INPUT**

      Space Structure Name = Hamilton-1
      Space Structure Type = Payload

      Perigee Altitude = 600.000000 (km)
      Apogee Altitude = 600.000000 (km)
      Inclination = 98.000000 (deg)
      RAAN = 0.000000 (deg)
      Argument of Perigee = 0.000000 (deg)
      Mean Anomaly = 0.000000 (deg)
      Area-To-Mass Ratio = 0.007900 (m^2/kg)
      Start Year = 2018.250000 (yr)
      Initial Mass = 1.300000 (kg)
      Final Mass = 1.300000 (kg)
      Duration = 2.000000 (yr)
      Station Kept = False
      Abandoned = True
      PMD Perigee Altitude = 599.525766 (km)
      PMD Apogee Altitude = 599.525766 (km)
      PMD Inclination = 97.991694 (deg)
      PMD RAAN = 16.133891 (deg)
      PMD Argument of Perigee = 41.191275 (deg)
      PMD Mean Anomaly = 0.000000 (deg)

**OUTPUT**

      Suggested Perigee Altitude = 599.525766 (km)
      Suggested Apogee Altitude = 599.525766 (km)
      Returned Error Message = Passes LEO reentry orbit criteria.

      Released Year = 2036 (yr)
      Requirement = 61
      Compliance Status = Pass

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

```
=============== End of Requirement 4.6 ===============
06 23 2017; 13:28:01PM       *********Processing Requirement 4.7-1
      Return Status :  Passed

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

name = Hamilton-1
quantity = 1
parent = 0
materialID = 5
type = Box
Aero Mass = 1.300000
Thermal Mass = 1.300000
Diameter/Width = 0.100000
Length = 0.110000
Height = 0.100000

name = Structure
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 1.285000
Thermal Mass = 0.215000
Diameter/Width = 0.100000
Length = 0.110000
Height = 0.100000

name = Radio
quantity = 1
parent = 2
materialID = 8
type = Flat Plate
Aero Mass = 0.080000
Thermal Mass = 0.080000
Diameter/Width = 0.090000
Length = 0.090000

name = Antenna
quantity = 1
parent = 2
materialID = 8
type = Flat Plate
Aero Mass = 0.075000
Thermal Mass = 0.075000
Diameter/Width = 0.090000
Length = 0.090000

name = Flight Computer
quantity = 1
parent = 2
materialID = 23
type = Flat Plate
Aero Mass = 0.110000
Thermal Mass = 0.110000
Diameter/Width = 0.090000
Length = 0.090000

name = Power System
quantity = 1
parent = 2
materialID = 8
type = Box
Aero Mass = 0.215000
Thermal Mass = 0.215000
Diameter/Width = 0.090000
Length = 0.090000
Height = 0.010000

name = Solar Panels
quantity = 6
parent = 2
```

```
materialID = 23
type = Flat Plate
Aero Mass = 0.055000
Thermal Mass = 0.055000
Diameter/Width = 0.100000
Length = 0.110000

name = ADCS
quantity = 1
parent = 2
materialID = 8
type = Box
Aero Mass = 0.205000
Thermal Mass = 0.205000
Diameter/Width = 0.090000
Length = 0.090000
Height = 0.010000

name = IGIS
quantity = 1
parent = 2
materialID = 23
type = Flat Plate
Aero Mass = 0.055000
Thermal Mass = 0.055000
Diameter/Width = 0.090000
Length = 0.090000

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

name = Hamilton-1
Demise Altitude = 77.997437
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Structure
Demise Altitude = 76.150085
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Radio
Demise Altitude = 73.868958
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Antenna
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Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Flight Computer
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Impact Kinetic Energy = 0.000000

*************************************
name = Power System
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Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Solar Panels
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Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = ADCS
```

```
Demise Altitude = 71.147537
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = IGIS
Demise Altitude = 75.089996
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

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

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

Requirements 4.7-1b and 4.7-1c below are non-applicable requirements because Hamilton-1 does not use controlled reentry.

4.7-1, b) **NOT APPLICABLE.** For controlled reentry, the selected trajectory shall ensure that no surviving debris impact with a kinetic energy greater than 15 joules is closer than 370 km from foreign landmasses, or is within 50 km from the continental U.S., territories of the U.S., and the permanent ice pack of Antarctica (Requirement 56627).

4.7-1 c) **NOT APPLICABLE.** For controlled reentries, the product of the probability of failure of the reentry burn (from Requirement 4.6-4.b) and the risk of human casualty assuming uncontrolled reentry shall not exceed 0.0001 (1:10,000) (Requirement 56628).

ODAR Section 7A: Assessment of Spacecraft Hazardous Materials

Not Applicable. There are no hazardous materials contained on the spacecraft.

ODAR Section 8: Assessment for Tether Missions

No tether will be used; this section is not applicable.

END of ODAR for Hamilton-1

Appendix A: Acronyms

Al	Aluminum
cm	centimeter
COTS	Commercial Off-The-Shelf
CSD	Cannisterized Satellite Dispenser
DAS	Debris Assessment Software
EOM	End Of Mission
GEO	Geosynchronous Earth Orbit
ISIPOD	ISIS CubeSat Deployer
ISRO	Indian Space Research Organization
ITAR	International Traffic In Arms Regulations
kg	kilogram
km	kilometer
LEO	Low Earth Orbit
Li-Ion	Lithium Ion
m^2	meters squared
Ml	Milliliter
mm	Millimeter
N/A	Not Applicable
ODAR	Orbital Debris Assessment Report
OSMA	Office of Safety and Mission Assurance
P-POD	Poly Picosatellite Orbital Deployer
Ti	Titanium
yr	year