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TITLE: TYVAK-0085 Orbital Debris Assessment Report (ODAR) / End of Mission Plan (EOMP)			
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TYVAK PROPRIETARY

REVISION SUMMARY

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ORBITAL DEBRIS SELF-ASSESSMENT: TYVAK-0085 MISSION

Requirement	Launch Vehicle			Spacecraft			Comments	
	Compliant	Not Compliant	Incomplete	Standard Non Compliant	Compliant	Not Compliant	Incomplete	
4.3-1.a			X		X			No debris released in LEO
4.3-1.b			X		X			No debris released in LEO
4.3-2			X		X			No debris released in GEO
4.4-1			X		X			Less than 0.001 probability
4.4-2			X		X			Design to passivate propulsion, electrical power system, and reaction wheels
4.4-3			X		X			No planned breakups
4.4-4			X		X			No planned breakups
4.5-1			X		X			Probability 0.00000 (requirement < 0.001)
4.5-2			X		X			Probability 0.00000 (requirement < 0.01)
4.6-1(a)			X		X			Predicted orbital lifetime 15.18 years
4.6-1(b)			X		X			N/A – using atmospheric entry
4.6-1(c)			X		X			N/A – using atmospheric entry
4.6-2			X		X			N/A – Not GEO
4.6-3			X		X			N/A – Not between LEO and GEO
4.6-4			X		X			Expected probability < 0.001
4.7-1			X		X			No pieces survive reentry
4.8-1				X				No tethers used

TYVAK-0085 is currently manifested to fly as a secondary “rideshare” payload. Compliance with requirements levied by NASA-STD 9719.14A on the launch vehicle are not applicable to this document and the responsibility of the launch provider.

1.0 PROGRAM MANAGEMENT AND MISSION OVERVIEW

1.1 Program Management

Parameter	Value
Mission Directorate	N/A
Program Executive	Tom Yunck (GeoOptics) / Marco Villa (Tyvak)
Program/project Manager	Marco Villa (Tyvak)
Senior Scientist	Tom Yunck (GeoOptics)
Senior Management	N/A
Foreign government or space agency participation	N/A
Summary of NASA's responsibility under the governing agreement(s)	N/A

Table 1-1: Summary of Program Management Personnel

1.2 Mission Overview

1.2.1 Mission Design and Development Milestones

The schedule of mission design and development milestones is provided in Table 1.2.

Launch	January 12, 2018
--------	------------------

Table 1.2 – Summary of Mission Design and Development Milestones

1.2.2 Mission Overview

The goal of the TYVAK-0085 Mission is to perform GPS Radio Occultation (RO) measurement demonstration utilizing a single 6U CubeSat. The collection of RO data will be used to validate the TYVAK-0085 system and quality of data collected.

Parameter	Value
Launch vehicle and launch site	Sriharikota, India
Launch date	Q1 2018
Mission duration	2+ year
Launch and deployment profile	<p>The PSLV launch vehicle will launch the primary mission satellite. After which, it will deploy the TYVAK-0085 satellite into their final mission orbit (504km, circular, sun-synchronous orbit 97.56° inclination). There is no parking or transfer orbit.</p> <p>The TYVAK-0085 satellite will decay naturally for debris mitigation and will re-enter within 25 years after completion of mission.</p>

Table 1-2: Summary of Mission Parameters

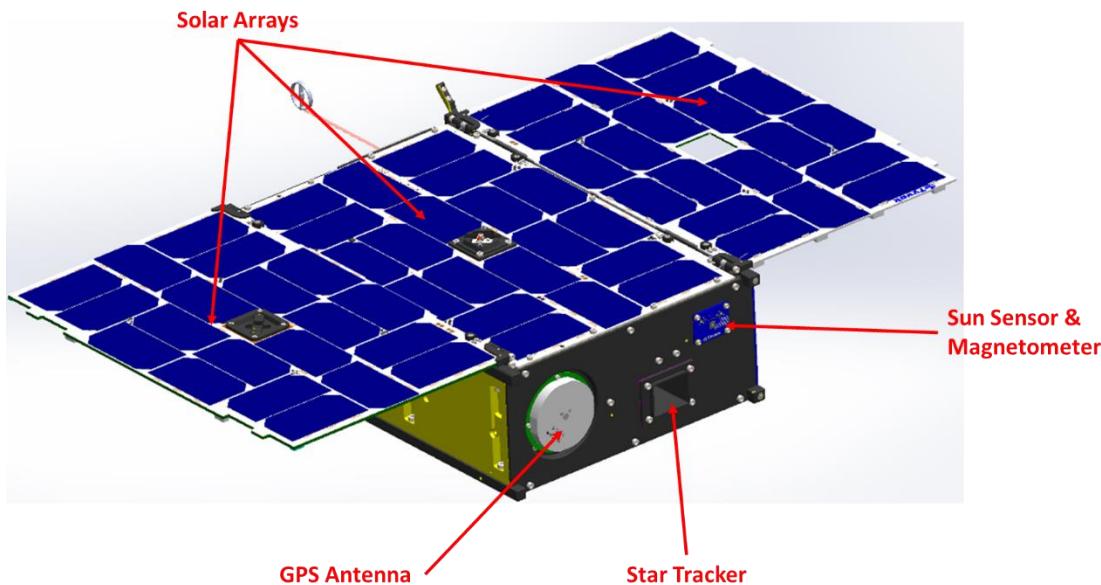
2.0 SPACECRAFT DESCRIPTION

2.1 Physical Description of Spacecraft

The TYVAK-0085 vehicles have been designed to support a 2+ year mission in LEO, and it is compatible with the P-POD launch environments and designed to the requirements in the CubeSat Design Specification (CDS). The TYVAK-0085 vehicle is a 6U CubeSat with the vehicle being 30cm x 20cm x 10cm with a mass of 10.226 kg.

The TYVAK-0085 vehicle design uses subsystem modules built from printed circuit boards (PCB) or miniature enclosures mounted to the open frame primary structure. The open structure permits the vehicle to be built incrementally with open access for securing interconnects. The subsystems are placed within the vehicle to optimize mass properties, radiation protection, thermal heat rejection, power handling, vehicle orientation, and cabling length. The body mounted side panels attach directly to the primary structure and are used for thermal management and can be easily removed to get access to the interior of the vehicle. The vehicle is primarily constructed out of aluminum and PCB materials.

The TYVAK-0085 payload utilizes a GPS array antenna mounted to the Minus-Y panel to receive GPS RO signals. The signals are then captured by the CION Payload board which outputs the data files to the TYVAK-0085 CDH for storage and later transmission to the ground via X-Band of UHF transmission.



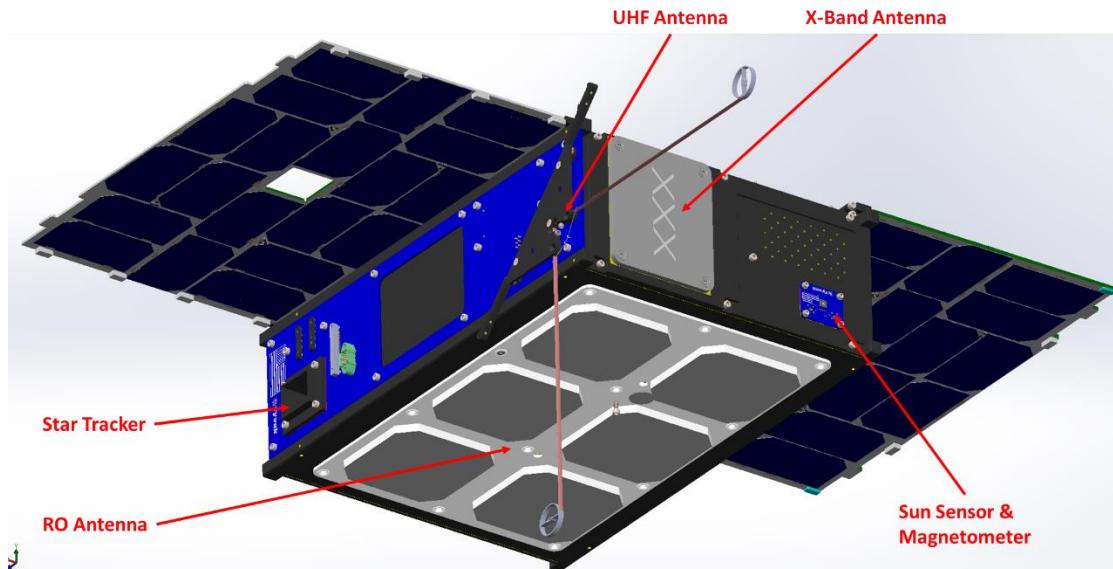


Figure 2-1: TYVAK-0085 Vehicle Layout

Parameter	Value
Total satellite mass at launch, including all propellants and fluids	10.226 kg
Dry Mass of satellite at launch, excluding solid rocket motor propellants	10.226 kg
Identification, including mass and pressure, of all fluids	NONE. TYVAK-0085 has no propulsion
Fluids in Pressurized batteries	NONE. TYVAK-0085 uses unpressurized standard COTS Li-ion battery cells
Identification of any other sources of stored energy	NONE
Identification of any radioactive materials on board	NONE

Table 2-1: Summary of Spacecraft Parameters

2.1.1 Description of Propulsion Systems

None.

2.1.2 Description of attitude control system

The TYVAK-0085 attitude determination and control system consists of a processor, Inertial Reference Module (IRM), nano-Reaction Wheel Array (nRWA), GPS receiver, Sun sensors, magnetometers, and integrated torque coils. Primary attitude knowledge is provided by the IRM which hosts two star sensors and the inertial measurement unit (IMU). Primary attitude control is provided by the nRWA which consists of an orthogonal set of three wheels. Momentum management and vehicle detumble are provided by a set of three torque coils.

2.1.3 Description of normal attitude of the spacecraft with respect to the velocity vector

The nominal attitude of the TYVAK-0085 vehicles is an LVLH orientation with the long axis (z-axis) facing Nadir towards the Earth and the Y-axis aligned with the velocity vector. The vehicle

will rotate about the x-axis for pointing the boresight of the vehicle GPS array at the Earth limb during RO collections and will slew for sun-pointing periodically.

2.1.4 Description of any range safety or other pyrotechnic devices

None.

2.1.5 Description of the electrical generation and storage system

Energy generation is accomplished using the primary Plus-Y solar panels. Energy storage is accomplished using standard COTS Li-ion battery cells in a 3S2P (3 in series, 2 parallel) configuration. TYVAK-0085 utilizes two parallel 3S2P packs to increase the overall capacity of the vehicle. The cells are recharged by the solar cells mounted on the deployable and body panels. The power management and distribution is provided by the electrical power system and battery protection circuitry.

3.0 ASSESSMENT OF SPACECRAFT DEBRIS RELEASED DURING NORMAL OPERATIONS

No intentional release of any object > 1mm is expected.

Parameter	Value
Identification of any object (>1mm) expected to be released from the spacecraft at any time after launch	None
Rationale/necessity for release of 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	N/A
Compliance 4.3-1 Mission related debris passing through GEO	COMPLIANT
Compliance 4.3-2 Mission related debris passing through LEO	COMPLIANT

Table 3-1: Summary of Spacecraft Debris Released During Normal Operations

4.0 ASSESSMENT OF SPACECRAFT POTENTIAL FOR EXPLOSIONS AND INTENTIONAL BREAKUPS

4.1 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.

4.2 Summary of failure modes and effects analysis of all credible failure modes

In-mission failure of a battery cell protection circuit could lead to a short circuit resulting in overheating and a very remote possibility of battery cell explosion. The battery safety systems discussed in the FMEA (Appendix A, see requirement 4.4-1) describe the combined faults that must occur for any of seven (7) independent, mutually exclusive failure modes to lead to explosion.

Over-pressure due to temperature control failure or crushing of the propulsion tank could lead to vent or burst of the propulsion tank. The propulsion safety systems discussed in the FMEA (Appendix A, see requirement 4.4-1) describe the combined faults that must occurs for any of the three (3) independent, mutually exclusive failure modes to lead to tank failure.

4.3 Detailed plan for any designed spacecraft breakup

There are no planned breakups.

4.4 List of components which shall be passivated at End of Mission (EOM)

The nRWA will be passivated at EOM through a series of commands to reduce wheel momentum to a minimum level and then to transition the vehicle to free drift mode.

The batteries will be passivated by discharging the cells to a minimum state and then disconnecting them from the solar panels and charging circuitry.

4.5 Rational for all items which are required to be passivated, but cannot be due to their design

None.

4.6 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 COMPLIANT

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:

The batteries will be passivated by discharging the cells to a minimum state and then disconnecting them from the solar panels and charging circuit. In the unlikely event that a battery cell does explosively rupture, the small size, mass, and potential energy of these batteries is such that while the spacecraft could be expected to vent gases, most debris from the battery rupture would be contained within the vehicle due to lack of penetration energy and also because the cells are housed in a substantial aluminum bracket.

The nRWA will be passivated at EOM through a series of commands to reduce wheel momentum to a minimum level and then to transition the vehicle to free drift mode.

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.

5.0 ASSESSMENT OF SPACECRAFT POTENTIAL FOR ON-ORBIT COLLISIONS

5.1 Assessment of spacecraft compliance with Requirements 4.5-1 and 4.5-2:

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: (Large Object Impact and Debris Generation Probability)

Required Probability: 0.001

Expected probability: 0.000001 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).

Compliance statement: (Small Object Impact and Debris Generation Probability)

Required Probability: 0.01

Expected probability: 0.000000 COMPLIANT

6.0 ASSESSMENT OF SPACECRAFT POSTMISSION DISPOSAL PLANS AND PROCEDURES

6.1 Description of spacecraft disposal option selected

The satellite will de-orbit naturally by atmospheric re-entry. The propulsion system is not used for re-entry.

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

None.

6.3 Calculation of area-to-mass ratio after postmission disposal:

Spacecraft Mass: ~10.226 kg (dry mass)

Cross-sectional Area: 0.117516 m²

Area to mass ratio: (0.117516 m²)/(10.226kg) = 0.01149 m²/kg

6.4 Assessment of spacecraft compliance with Requirements 4.6-1 through 4.6-5:

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.

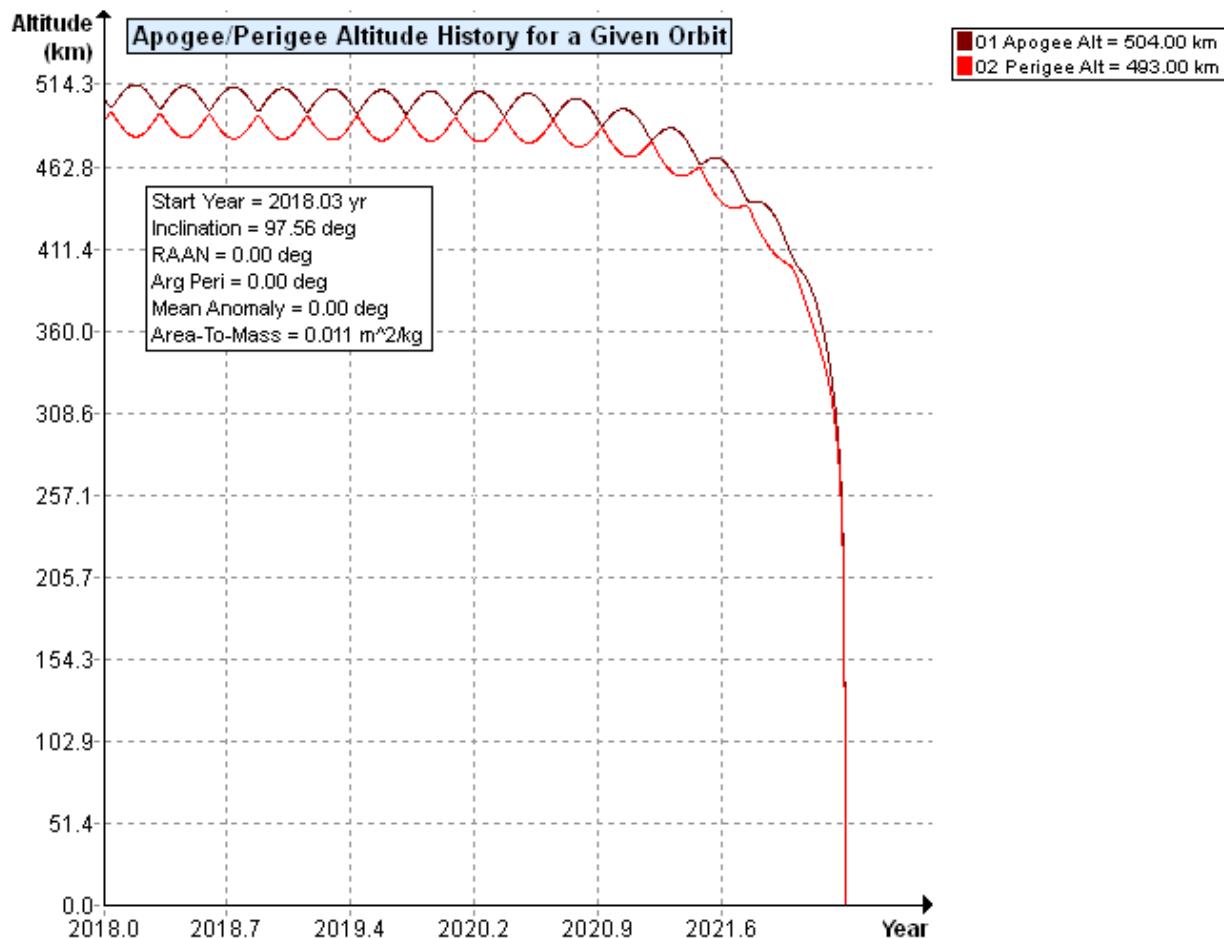
c. Direct retrieval:

- Retrieve the space structure and remove it from orbit within 10 years after completion of mission
-

Compliance statement:

The orbit used for disposal of structure analysis is 504 km. The orbital lifetime is predicted to be 4.131 years; COMPLIANT

Figure 6-1: TYVAK-0085 Deorbit Lifetime



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

Compliance statement:

Not applicable. TYVAK-0085 mission orbit is a LEO.

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

Compliance statement:

Not applicable. TYVAK-0085 mission orbit is a LEO.

Requirement 4.6-4. Reliability of Postmission Disposal Operations

Compliance statement:

Not applicable. The satellite will reenter passively without the need for post mission disposal operations within the allowable timeframe.

6.5 Detailed plan for passivating (depleting all energy sources) of the spacecraft:

The nRWA will be passivated at EOM through a series of commands to reduce wheel momentum to a minimum level and then to transition the vehicle to free drift mode. The free drift mode does not utilize any attitude control actuators, specifically the nRWA. The power service to the nRWA will also be deactivated so that no inadvertent switch to another attitude control mode can actuate the nRWA.

The batteries will be passivated by permanently disconnecting solar array power from the battery module and discharging the cells to a minimum state under load of the spacecraft bus.

7.0 ASSESSMENT OF SPACECRAFT REENTRY HAZARDS

7.1 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).

Compliance statement:

DAS v2.0.2 reports that TYVAK-0085 is COMPLIANT with the requirement. The vehicle is primarily composed of Aluminum and PCB (Fiberglass) material and none of the components is expected to survive re-entry. The predicted Total Debris Casualty Area is 0.00. Appendix D located in the back of this report contains the DAS 2.0.2 modeling input and results.

Requirement 4.7-1., b) *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).*

Compliance statement:

Not applicable. No controlled reentry planned.

Requirement 4.7-1., c) *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).*

Compliance statement:

Not applicable. No controlled reentry planned.

8.0 ASSESSMENT FOR TETHER MISSIONS

Not applicable. There are no tethers in the TYVAK-0085 mission.

APPENDIX A – FMEA DETAILS AND SUPPORTING RATIONALE

Battery Explosion Failure:

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. The battery is housed within a substantial aluminum bracket.

Probability: Very Low. It is believed to be less than 0.1% given that multiple independent (not common mode) faults must occur for each failure mode to cause the ultimate effect (explosion).

Failure mode 1: Battery Internal short circuit.

Mitigation 1: Qualification and acceptance tests include vibration, thermal cycling, and vacuum tests followed by maximum system rate-limited charge and discharge to prove that no internal short circuit sensitivity exists.

Mitigation 2: Over/under voltage cell protection circuitry guards against stress conditions that can cause the development of internal shorts.

Combined faults required for realized failure: Environmental testing **AND** functional charge/discharge tests must both be ineffective in discovery of infant mortality failure rate (IMFR) related faults **OR** protection circuitry malfunctions and fails to protect cells from stress conditions.

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

Mitigation 3: Each cell includes an internal positive temperature coefficient (PTC) variable resistance device that reduces discharge current as cell temperature increases to prevent thermal runaway.

Mitigation 4: External under-voltage lockout circuitry disconnects battery when battery discharge voltage droop crosses a predefined threshold.

Combined faults required for realized failure: Spacecraft thermal design must be incorrect **AND** internal **AND** external over current detection and protection must fail for this failure mode to occur.

Failure Mode 3: Overcharging and excessive charge rate.

Mitigation 5: The satellite bus battery charging circuit design eliminates the possibility of the batteries being overcharged if circuits function nominally. This circuit will be extensively bench-tested and be proto-qualified for survival in vibration, and thermal-vacuum environments. The charge circuit disconnects the incoming current when cell voltage indicates normal full charge at 4.2V and limits charge current within battery specification. If this circuit fails to operate, continuing or excessive charge current 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 limit charge voltage **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 charge control circuitry must fail to limit charge current **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.

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 6: This failure mode is negated by a) proto-qualification tested short circuit protection on each external circuit, b) design of battery packs and insulators such that no contact with nearby board traces or structure 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: The PTC must fail **AND** an external load must fail/short-circuit **AND** external over-current detection and disconnect function must fail to enable this failure mode.

Failure Mode 5: Inoperable vents.

Mitigation 7: Battery vents are not inhibited by the battery holder design or the spacecraft.

Combined effects required for realized failure: The spacecraft design inhibits cell venting, or cell venting clearance is sensitive to environmental stress.

Failure Mode 6: Crushing.

Mitigation 8: This mode is negated by spacecraft design. There are no moving parts in the proximity of the batteries. Qualification and acceptance tests including vibration, thermal cycling, and vacuum tests will demonstrate cell venting clearance insensitivity to environmental stress.

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: Excess temperatures due to orbital environment and high discharge combined.

Mitigation 9: The spacecraft thermal design will negate this possibility. Thermal rise will be 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 8: Polarity Reversal Due to Over-Discharge

Mitigation 10: The spacecraft battery chemistry (Li-ion) is not susceptible to polarity reversal due to over-discharge.

Combined faults required for realized failure: Spacecraft battery module assembled with incorrect cell chemistry **AND** failure of cell protection circuitry

APPENDIX B - REQUIREMENT 4.5-1 DAS 2.0.1 LOG

09 26 2018; 14:24:12PM Processing Requirement 4.5-1: Return Status : Passed

Run Data

INPUT

```
Space Structure Name = TYVAK-0085
Space Structure Type = Payload
Perigee Altitude = 493.000000 (km)
Apogee Altitude = 504.000000 (km)
Inclination = 97.560000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Final Area-To-Mass Ratio = 0.011490 (m^2/kg)
Start Year = 2018.000000 (yr)
Initial Mass = 10.226000 (kg)
Final Mass = 10.226000 (kg)
Duration = 25.000000 (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 = 0.000001
Returned Error Message: Normal Processing
Date Range Error Message: Normal Date Range
Status = Pass
```

End of Requirement 4.5-1

APPENDIX C - REQUIREMENT 4.6 DAS 2.0.1 LOG

09 26 2018; 14:29:43PM Processing Requirement 4.6 Return Status : Passed

=====

Project Data

=====

INPUT

Space Structure Name = TYVAK-0085
Space Structure Type = Payload

Perigee Altitude = 493.000000 (km)
Apogee Altitude = 504.000000 (km)
Inclination = 97.560000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Area-To-Mass Ratio = 0.011490 (m^2/kg)
Start Year = 2018.000000 (yr)
Initial Mass = 10.226000 (kg)
Final Mass = 10.226000 (kg)
Duration = 25.000000 (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

Suggested Perigee Altitude = 493.000000 (km)
Suggested Apogee Altitude = 504.000000 (km)
Returned Error Message = Reentry during mission (no PMD req.).

Released Year = 2022 (yr)
Requirement = 61
Compliance Status = Pass

=====

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

APPENDIX D - REQUIREMENT 4.7-1 DAS 2.0.1 LOG

09 26 2018; 14:34:17PM *****Processing Requirement 4.7-1

Return Status : Passed

*****INPUT****

Item Number = 1

name = TYVAK-0085
quantity = 1
parent = 0
materialID = 9
type = Box
Aero Mass = 10.226000
Thermal Mass = 10.226000
Diameter/Width = 0.366000
Length = 0.678000
Height = 0.100000

name = PX Panel
quantity = 1
parent = 1
materialID = 9
type = Box
Aero Mass = 0.362000
Thermal Mass = 0.362000
Diameter/Width = 0.082000
Length = 0.335000
Height = 0.010000

name = MX Panel
quantity = 1
parent = 1
materialID = 9
type = Box
Aero Mass = 0.700000
Thermal Mass = 0.700000
Diameter/Width = 0.082000

Length = 0.335000

Height = 0.011500

name = PZ Panel

quantity = 1

parent = 1

materialID = 9

type = Box

Aero Mass = 0.272000

Thermal Mass = 0.272000

Diameter/Width = 0.100000

Length = 0.209000

Height = 0.020000

name = MZ Panel

quantity = 1

parent = 1

materialID = 9

type = Box

Aero Mass = 0.248000

Thermal Mass = 0.248000

Diameter/Width = 0.082000

Length = 0.205000

Height = 0.020000

name = PY Panel

quantity = 1

parent = 1

materialID = 9

type = Box

Aero Mass = 1.800000

Thermal Mass = 1.800000

Diameter/Width = 0.226000

Length = 0.330000

Height = 0.011500

name = MY Panel

quantity = 1

parent = 1

materialID = 9

```
type = Box
Aero Mass = 2.100000
Thermal Mass = 2.100000
Diameter/Width = 0.226000
Length = 0.330000
Height = 0.011500
```

```
name = IRM
quantity = 1
parent = 1
materialID = 23
type = Box
Aero Mass = 0.225000
Thermal Mass = 0.125000
Diameter/Width = 0.100000
Length = 0.100000
Height = 0.050000
```

```
name = IMU
quantity = 1
parent = 8
materialID = 9
type = Box
Aero Mass = 0.018000
Thermal Mass = 0.018000
Diameter/Width = 0.024500
Length = 0.038000
Height = 0.011100
```

```
name = Star Camera
quantity = 2
parent = 8
materialID = 9
type = Cylinder
Aero Mass = 0.041000
Thermal Mass = 0.041000
Diameter/Width = 0.030000
Length = 0.047000
```

```
name = RWA_Motor_Flywheel
```

```
quantity = 3
parent = 1
materialID = 9
type = Cylinder
Aero Mass = 0.040000
Thermal Mass = 0.020000
Diameter/Width = 0.040000
Length = 0.013000
```

```
name = RWA_Motor
quantity = 3
parent = 11
materialID = 9
type = Cylinder
Aero Mass = 0.010000
Thermal Mass = 0.010000
Diameter/Width = 0.040000
Length = 0.013000
```

```
name = RWA_Brackets
quantity = 3
parent = 11
materialID = 9
type = Box
Aero Mass = 0.010000
Thermal Mass = 0.010000
Diameter/Width = 0.040000
Length = 0.040000
Height = 0.013000
```

```
name = Battery Module_1
quantity = 2
parent = 1
materialID = 9
type = Box
Aero Mass = 0.493000
Thermal Mass = 0.352000
Diameter/Width = 0.042000
Length = 0.086000
Height = 0.042000
```

```
name = Batteries
quantity = 6
parent = 14
materialID = 54
type = Cylinder
Aero Mass = 0.047000
Thermal Mass = 0.047000
Diameter/Width = 0.018000
Length = 0.065000
```

```
name = POD Antenna
quantity = 1
parent = 1
materialID = 9
type = Cylinder
Aero Mass = 0.075000
Thermal Mass = 0.075000
Diameter/Width = 0.060000
Length = 0.030000
```

```
name = CION Payload
quantity = 1
parent = 1
materialID = 23
type = Box
Aero Mass = 0.700000
Thermal Mass = 0.100000
Diameter/Width = 0.200000
Length = 0.300000
Height = 0.005000
```

```
name = CION Cover
quantity = 1
parent = 17
materialID = 9
type = Box
Aero Mass = 0.600000
Thermal Mass = 0.600000
Diameter/Width = 0.200000
```

Length = 0.300000

Height = 0.005000

name = KL_BPF

quantity = 1

parent = 1

materialID = 9

type = Box

Aero Mass = 0.010000

Thermal Mass = 0.010000

Diameter/Width = 0.015000

Length = 0.030000

Height = 0.010000

name = Miteq_LNA

quantity = 1

parent = 1

materialID = 9

type = Box

Aero Mass = 0.010000

Thermal Mass = 0.010000

Diameter/Width = 0.015000

Length = 0.030000

Height = 0.010000

name = Backplane

quantity = 1

parent = 1

materialID = 23

type = Box

Aero Mass = 0.200000

Thermal Mass = 0.200000

Diameter/Width = 0.200000

Length = 0.300000

Height = 0.004000

name = UHF_assembly

quantity = 1

parent = 1

materialID = 23

```
type = Box
Aero Mass = 0.070000
Thermal Mass = 0.040000
Diameter/Width = 0.050000
Length = 0.100000
Height = 0.050000
```

```
name = UHF_radio
quantity = 1
parent = 22
materialID = 9
type = Box
Aero Mass = 0.030000
Thermal Mass = 0.030000
Diameter/Width = 0.036000
Length = 0.083000
Height = 0.007000
```

```
name = OEM628
quantity = 1
parent = 1
materialID = 23
type = Box
Aero Mass = 0.537000
Thermal Mass = 0.037000
Diameter/Width = 0.060000
Length = 0.100000
Height = 0.009000
```

```
name = GPS Housing
quantity = 1
parent = 24
materialID = 9
type = Box
Aero Mass = 0.500000
Thermal Mass = 0.500000
Diameter/Width = 0.060000
Length = 0.150000
Height = 0.030000
```

*****OUTPUT*****

Item Number = 1

```
name = TYVAK-0085
Demise Altitude = 77.999543
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
```

```
name = PX Panel
Demise Altitude = 74.253027
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
```

```
name = MX Panel
Demise Altitude = 71.191738
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
```

```
name = PZ Panel
Demise Altitude = 74.929558
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
```

```
name = MZ Panel
Demise Altitude = 74.869714
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
```

```
name = PY Panel
Demise Altitude = 68.447316
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
```

```
name = MY Panel
```

Demise Altitude = 67.023792
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

name = IRM
Demise Altitude = 76.521191
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

name = IMU
Demise Altitude = 74.379300
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

name = Star Camera
Demise Altitude = 73.346589
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

name = RWA_Motor_Flywheel
Demise Altitude = 75.771191
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

name = RWA_Motor
Demise Altitude = 74.585988
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

name = RWA_Brackets
Demise Altitude = 74.927160
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

```
*****  
name = Battery Module_1  
Demise Altitude = 70.537644  
Debris Casualty Area = 0.000000  
Impact Kinetic Energy = 0.000000
```

```
*****  
name = Batteries  
Demise Altitude = 65.407839  
Debris Casualty Area = 0.000000  
Impact Kinetic Energy = 0.000000
```

```
*****  
name = POD Antenna  
Demise Altitude = 74.320652  
Debris Casualty Area = 0.000000  
Impact Kinetic Energy = 0.000000
```

```
*****  
name = CION Payload  
Demise Altitude = 77.563715  
Debris Casualty Area = 0.000000  
Impact Kinetic Energy = 0.000000
```

```
*****  
name = CION Cover  
Demise Altitude = 73.338964  
Debris Casualty Area = 0.000000  
Impact Kinetic Energy = 0.000000
```

```
*****  
name = KL_BPF  
Demise Altitude = 76.137347  
Debris Casualty Area = 0.000000  
Impact Kinetic Energy = 0.000000
```

```
*****  
name = Miteq_LNA  
Demise Altitude = 76.137347  
Debris Casualty Area = 0.000000
```

Impact Kinetic Energy = 0.000000

name = Backplane
Demise Altitude = 76.976152
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

name = UHF_assembly
Demise Altitude = 77.428566
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

name = UHF_radio
Demise Altitude = 75.732074
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

name = OEM628
Demise Altitude = 77.179410
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

name = GPS Housing
Demise Altitude = 69.849331
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

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