Prepared By Benjamin Spencer, Alex Lambert **Title** Systems Engineer, Sr. Systems Engineer	**CAGE CODE 6J8J8**	**Document Number** PE2-0028 **Revision** B
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TITLE: PE2-0028 Orbital Debris Assessment Report (ODAR)

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REVISION SUMMARY

REV NO.	RELEASE DATE	BRIEF DESCRIPTION/REASON FOR CHANGE	EFFECTIVE PAGES
A	03/21/2022	Initial draft for review	All
B	11/9/2022	Updated template, added vehicle dimensions, fixed incorrect aero-mass for Hinge X-Minus in DAS inputs, updated orbital altitude in plot, added station-keeping information, updated quantity of satellites in DAS output grammar	7-11, 14, 17-19, 31, 42

All future revisions to this document shall be approved by the controlling organization prior to release.

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ORBITAL DEBRIS SELF-ASSESSMENT: PONY EXPRESS 2 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			Probability is 0.0 < 0.001
4.4-2			X		X			Design to passivate 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 is 3.7642E-06 < 0.001
4.5-2			X		X			Probability is 0.0 < 0.01
4.6-1(a)			X		X			Predicted orbital lifetime <25 years after mission completion and <30 years after lauch.
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			N/A – No post-mission operations required
4.7-1			X		X			Risk of Human Casualty is 1:32100 < 1:10000 limit
4.8-1					X			No tethers used

1.0 PROGRAM MANAGEMENT AND MISSION OVERVIEW

1.1 Program Management

Parameter	Value
Mission Directorate	N/A
Program Executive	Shawn Hendricks (Tyvak)
Program/project Manager	Forrest Wanket (Tyvak)
Senior Scientist	N/A
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.

Parameter	Value
Launch	May 2023
End of Design Lifetime	May 2026

Table 1.2 – Summary of Mission Design and Development Milestones

1.2.2 Mission Overview

The goal of the Pony Express 2 mission is a technology demonstration between two 12U CubeSats in a low Earth orbit.

Parameter	Value
Launch vehicle and launch site	SpaceX Transporter 8, Cape Canaveral
Launch date	May 2023
Mission duration	2 years required, 3 year design life
Launch and deployment profile	The SpaceX launch vehicle will deliver the two spacecraft to an initial orbit of 525 km +/- 25 km circular orbit with a 97.5° +/- 0.1° inclination

Spacecraft Maneuvering Capability	After commissioning, the two spacecraft will conduct orbit correction maneuvers to get to a final orbit of 578km circular with 97.7-degree inclination within the first few months of the mission. For most of the mission, the two vehicles will be station-keeping at an altitude 578 +0/-5km, with inclination tolerance of 97.7 +/-0.1-degree.

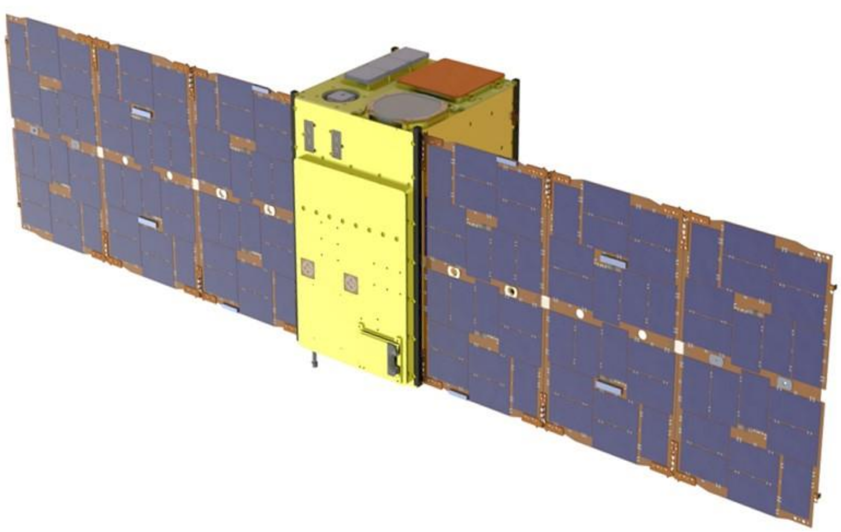
Table 1-2: Summary of Pony Express 2 Mission Parameters

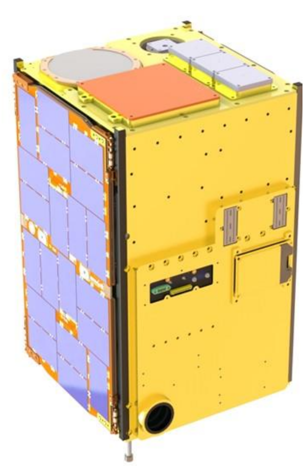
2.0 SPACECRAFT DESCRIPTION

2.1 Physical Description of Spacecraft

The two Pony Expresses 2 spacecraft are 12U CubeSats designed to demonstrate and improve the technology readiness level of various payloads and vehicle components. Two identical spacecraft will be in a low Earth orbit to perform the demonstration for a minimum of 2 years but with a design lifetime of 3 years.

The Pony Express 2 vehicle design uses subsystem modules built from printed circuit boards (PCB) or miniature enclosures secured to a primary structure consisting of panels and rails. The panel and railed open structure permit the vehicle to be built incrementally with access for integrating subsystem modules and securing interconnect harnessing. The subsystems are placed within the vehicle to optimize mass properties, radiation protection, thermal heat rejection, power handling, vehicle orientation, and cabling length. The deployable solar arrays attach to the primary structure and face towards the same direction. The vehicle is primarily constructed out of aluminum and PCB materials.





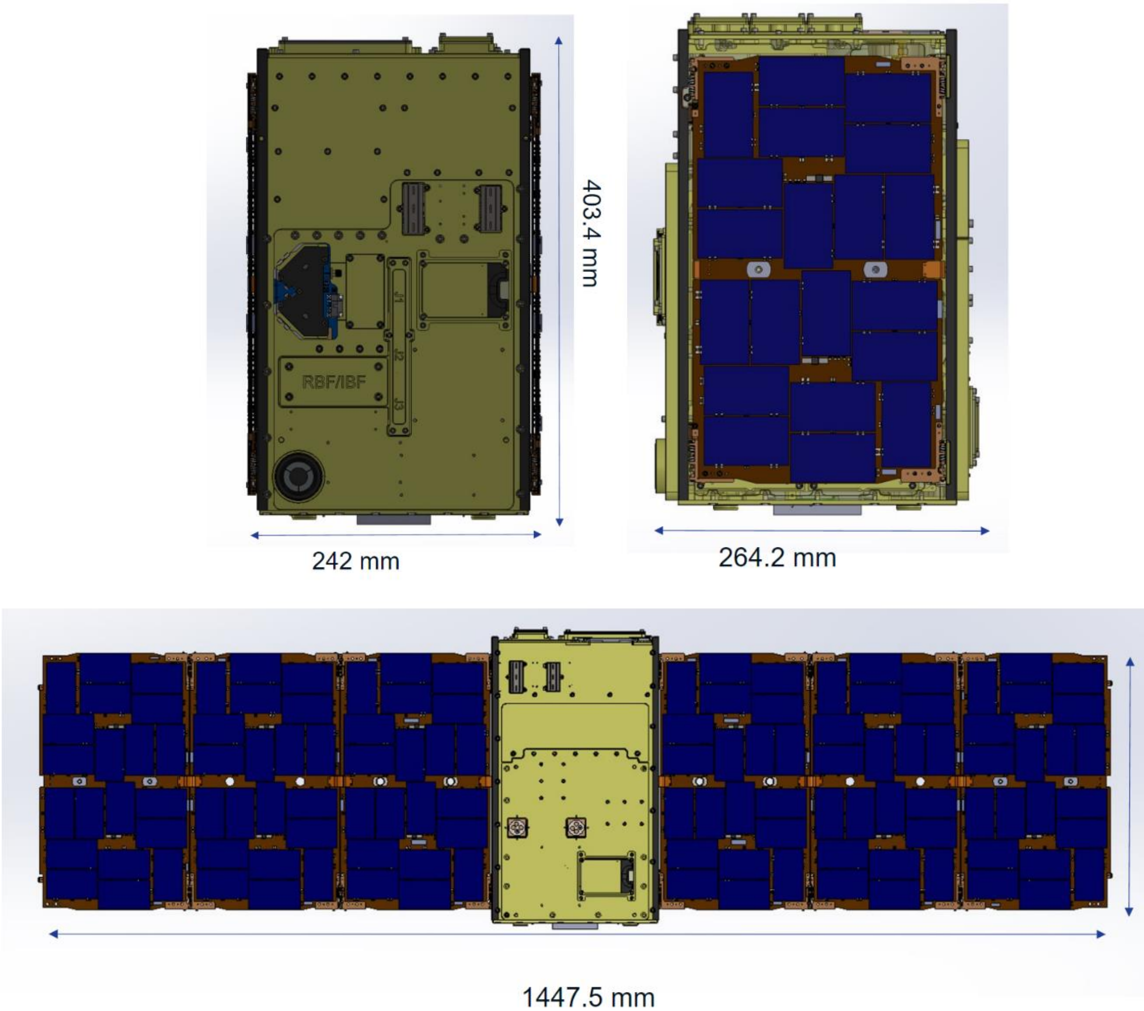


Figure 2-1: Spacecraft Vehicle Layout

Parameter	**Value**
Total spacecraft mass at launch, including all propellants and fluids	26.616 kg
Dry Mass of spacecraft at launch, excluding solid rocket motor propellants	26.326 kg
Identification, including mass and pressure, of all fluids	NONE
Fluids in Pressurized batteries	NONE. Battery 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

The propulsion system consists of one gridded ion thruster. This ion thruster used iodine, stored as a solid in an unpressurized tank, to generate thrust using electricity on the order of 0.3 to 1.1 mN.

2.1.2 Description of attitude control system

The attitude determination and control system consist of the flight computer, inertial measurement unit, reaction wheels, GPS receiver, sun sensors, magnetometers, and torque rods.

2.1.3 Description of normal attitude of the spacecraft

The nominal attitude of Pony Express 2 will ground tracking to support ground station passes, sun pointing to enable battery charging, and performing maneuvers to demonstrate and improve the TRL of various payload components.

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 two deployable solar array wings. Energy storage is accomplished using standard COTS Li-ion battery cells. The cells are recharged by the solar cells mounted on the deployable solar arrays. 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 ASESSMENT 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.

The propulsion system is launched with no stored energy. Propellant is the form of solid iodine stored in unpressurized tanks. During operation of the propulsion system, the tank does not become pressurized. There is no credible failure mode in the propulsion system that would result in a spacecraft breakup during normal operations.

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 reaction wheels will be passivated at end-of-mission 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.

The propulsion system does not have to be passivated at end-of-mission as any remaining iodine left in the system is stored as a solid and the tank is not pressurized. As the batteries will be passivated (discharged and disconnected from the solar panels and charging circuity), the propulsion system will be unable to be powered after end-of-mission.

4.5 Rationale 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 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:

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 because the cells are housed in a substantial aluminum bracket.

The reaction wheels will be passivated at end-of-mission through a series of commands to reduce wheel momentum to a minimum level and then to transition the vehicle to free drift mode.

The propulsion system does not have to be passivated at end-of-mission as any remaining iodine left in the system is stored as a solid and the tank is not pressurized. As the batteries will be passivated (discharged and disconnected from the solar panels and charging circuity), the propulsion system will be unable to be powered after end-of-mission.

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: 3.7642E-06 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: 0.00000 COMPLIANT

6.0 ASSESSMENT OF SPACECRAFT POSTMISSION DISPOSAL PLANS AND PROCEDURES

6.1 **Description of spacecraft disposal option selected**

The spacecraft will de-orbit naturally by atmospheric re-entry, but the propulsion system can be used to increase the pace of orbital altitude decay.

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

None.

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

Spacecraft Mass: 26.326 kg (dry mass)

Cross-sectional Area: 0.3186 m^2 (random tumbling cross-sectional area)

Area to mass ratio: 0.3186 m^2 / 26.326 kg = 0.01211 m^2/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 580 km. This is to provide worst-case margin against nominal 578km mission altitude. The worst-case orbital lifetime is predicted to be less than 25 years after mission complete and less than 30 years after launch assuming a mission complete date 3 years after launch. COMPLIANT

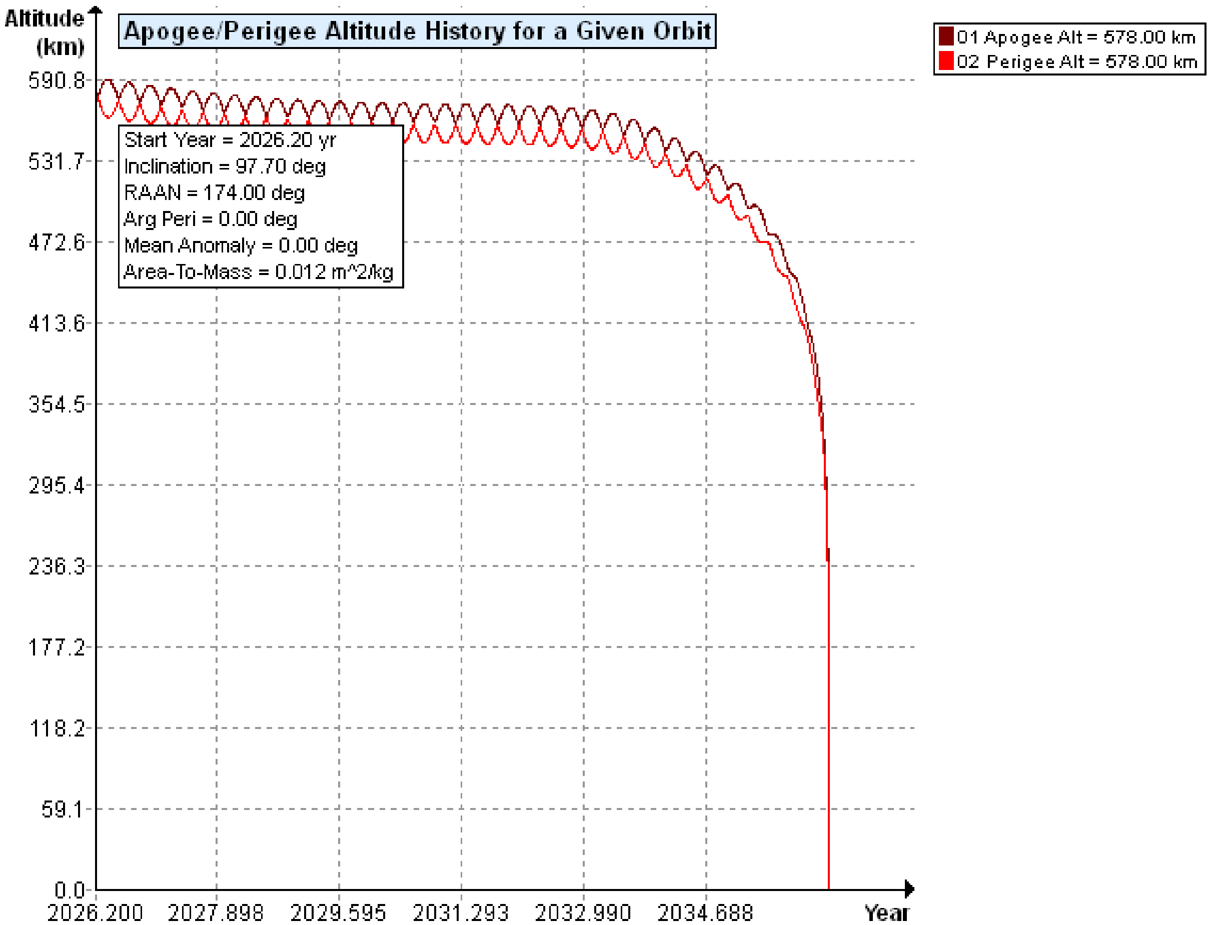


Figure 6-1: Orbit Lifetime

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

Compliance statement:

Not applicable. Pony Express 2 mission orbit is LEO.

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

Compliance statement:

Not applicable. Pony Express 2 mission orbit is LEO.

Requirement 4.6-4. *Reliability of Post-mission Disposal Operations*

Compliance statement:

Not applicable. The spacecraft 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 reaction wheels will be passivated at end-of-mission 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 reaction wheels. The power service to the reaction wheels will also be deactivated so that no inadvertent switch to another attitude control mode can actuate the reaction wheels.

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.

The propulsion system does not have to be passivated at end-of-mission as any remaining iodine left in the system is stored as a solid and the tank is not pressurized. As the batteries will be passivated (discharged and disconnected from the solar panels and charging circuity), the propulsion system will be unable to be powered after end-of-mission.

7.0 ASSESSMENT OF SPACECRAFT REENTERY 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 v3.1.1 reports that Pony Express 2 is COMPLIANT with the requirement. The vehicle is primarily composed of Aluminum and PCB (Fiberglass) material. Only the largest of the antennas, the largest PCBA, and two small stainless-steel solar panel hold down cup mechanisms are expected to survive reentry and produce debris. Total Debris Casualty Area for these parts are 0.45 m^2, 0.54 m^2, and 0.4 m^2 with kinetic energy equal to 29.94 J, 7.83 J, 11.55 J, and 4.95 J respectively. The predicted Total Debris Casualty Area of Pony Express 2 is 3.73 m^2 and the risk of Human Casualty is 1:20,700 below the required 1:10,000 limit. Appendix B contains the DAS 3.1.1 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 Pony Express 2.

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 spacecraft 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 spacecraft 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 4.7-1 DAS 2.0.2 LOG

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Thermal Mass = 0.067000
Diameter/Width = 0.058000
Length = 0.102000
Height = 0.045000

name = BASE CUP X PLUS
quantity = 1
parent = 17
materialID = 54
type = Box
Aero Mass = 0.020000
Thermal Mass = 0.020000
Diameter/Width = 0.038000
Length = 0.038000
Height = 0.005000

name = BODY PANEL Y PLUS
quantity = 1
parent = 1
materialID = 9
type = Box
Aero Mass = 2.626200
Thermal Mass = 0.673000
Diameter/Width = 0.226000
Length = 0.383000
Height = 0.008200

name = SENSOR MODULE
quantity = 1
parent = 24
materialID = 8
type = Box

Aero Mass = 0.081000
Thermal Mass = 0.081000
Diameter/Width = 0.066400
Length = 0.078400
Height = 0.024740

name = MOUNT REACTION WHEEL
quantity = 4
parent = 24
materialID = 9
type = Box
Aero Mass = 0.078000
Thermal Mass = 0.078000
Diameter/Width = 0.056700
Length = 0.088470
Height = 0.020000

name = REACTION WHEEL NANO MKII
quantity = 4
parent = 24
materialID = 9
type = Box
Aero Mass = 0.218000
Thermal Mass = 0.218000
Diameter/Width = 0.060000
Length = 0.060000
Height = 0.060000

name = ACCESS PANEL Y PLUS
quantity = 1
parent = 24
materialID = 9
type = Box
Aero Mass = 0.492000
Thermal Mass = 0.492000
Diameter/Width = 0.200000
Length = 0.231000
Height = 0.010000

name = LDRR
quantity = 1
parent = 24
materialID = 9
type = Box
Aero Mass = 0.183000
Thermal Mass = 0.183000
Diameter/Width = 0.069000
Length = 0.085400
Height = 0.027000

name = RWA COMBINER BOARD
quantity = 2
parent = 24
materialID = 23
type = Box

Aero Mass = 0.006600
Thermal Mass = 0.006600
Diameter/Width = 0.050000
Length = 0.080000
Height = 0.002000

name = BODY PANEL Y MINUS
quantity = 1
parent = 1
materialID = 9
type = Box
Aero Mass = 2.306406
Thermal Mass = 1.041600
Diameter/Width = 0.226000
Length = 0.383000
Height = 0.020500

name = SENSOR MODULE Y MINUS
quantity = 1
parent = 31
materialID = 9
type = Box
Aero Mass = 0.081000
Thermal Mass = 0.081000
Diameter/Width = 0.066400
Length = 0.076400
Height = 0.024700

name = TORQUE ROD Y-MINUS
quantity = 2
parent = 31
materialID = 54
type = Cylinder
Aero Mass = 0.118508
Thermal Mass = 0.118508
Diameter/Width = 0.018500
Length = 0.075000

name = IMU Y MINUS
quantity = 2
parent = 31
materialID = 9
type = Box
Aero Mass = 0.360300
Thermal Mass = 0.360300
Diameter/Width = 0.056900
Length = 0.069600
Height = 0.052320

name = UHF HARNESS COVER
quantity = 1
parent = 31
materialID = 9
type = Box
Aero Mass = 0.014400

Thermal Mass = 0.014400
Diameter/Width = 0.062000
Length = 0.320000
Height = 0.010400

name = UHF ANTENNA
quantity = 1
parent = 31
materialID = 23
type = Box
Aero Mass = 0.046700
Thermal Mass = 0.046700
Diameter/Width = 0.056500
Length = 0.088000
Height = 0.010000

name = STATE LATCH EXPANDER
quantity = 1
parent = 31
materialID = 9
type = Box
Aero Mass = 0.132270
Thermal Mass = 0.132270
Diameter/Width = 0.070500
Length = 0.082500
Height = 0.021000

name = Y MINUS COVERS
quantity = 2
parent = 31
materialID = 9
type = Box
Aero Mass = 0.016410
Thermal Mass = 0.016410
Diameter/Width = 0.041700
Length = 0.090000
Height = 0.009000

name = DIVIDER PLATE
quantity = 1
parent = 1
materialID = 9
type = Box
Aero Mass = 3.470800
Thermal Mass = 0.881000
Diameter/Width = 0.196444
Length = 0.225100
Height = 0.014000

name = 12V SLICE BATTERY MODULE
quantity = 1
parent = 39
materialID = 9
type = Box
Aero Mass = 2.029000

Thermal Mass = 2.029000
Diameter/Width = 0.087150
Length = 0.159000
Height = 0.073400

name = GPS MODULE ASSEMBLY
quantity = 2
parent = 39
materialID = 9
type = Box
Aero Mass = 0.064000
Thermal Mass = 0.064000
Diameter/Width = 0.043200
Length = 0.076120
Height = 0.014900

name = NANO LOAD CONTROLLER
quantity = 2
parent = 39
materialID = 9
type = Box
Aero Mass = 0.013200
Thermal Mass = 0.013200
Diameter/Width = 0.036500
Length = 0.066000
Height = 0.013550

name = PIB
quantity = 1
parent = 39
materialID = 23
type = Box
Aero Mass = 0.005000
Thermal Mass = 0.005000
Diameter/Width = 0.115000
Length = 0.126000
Height = 0.002000

name = SCR-106
quantity = 1
parent = 39
materialID = 8
type = Box
Aero Mass = 0.250000
Thermal Mass = 0.250000
Diameter/Width = 0.082000
Length = 0.088100
Height = 0.018000

name = NANOTX
quantity = 1
parent = 39
materialID = 8
type = Box
Aero Mass = 0.038400

Thermal Mass = 0.038400
Diameter/Width = 0.031750
Length = 0.086360
Height = 0.007620

name = GPS MODULE BRACKETS
quantity = 1
parent = 39
materialID = 9
type = Box
Aero Mass = 0.113000
Thermal Mass = 0.113000
Diameter/Width = 0.062000
Length = 0.161500
Height = 0.006000

name = X MINUS BODY PANEL
quantity = 1
parent = 1
materialID = 9
type = Box
Aero Mass = 2.519490
Thermal Mass = 1.173690
Diameter/Width = 0.209110
Length = 0.374900
Height = 0.011150

name = FLIGHT COMPUTER ASSY
quantity = 1
parent = 47
materialID = 9
type = Box
Aero Mass = 1.318800
Thermal Mass = 0.367000
Diameter/Width = 0.090000
Length = 0.137000
Height = 0.030000

name = BACKPLANE
quantity = 1
parent = 48
materialID = 23
type = Box
Aero Mass = 0.140000
Thermal Mass = 0.140000
Diameter/Width = 0.192000
Length = 0.193000
Height = 0.003000

name = WATCHDOG
quantity = 1
parent = 48
materialID = 9
type = Box
Aero Mass = 0.135800

Thermal Mass = 0.135800
Diameter/Width = 0.058500
Length = 0.112000
Height = 0.028000

name = FLIGHT COMPUTER
quantity = 2
parent = 48
materialID = 9
type = Box
Aero Mass = 0.338000
Thermal Mass = 0.338000
Diameter/Width = 0.084000
Length = 0.131000
Height = 0.023000

name = X MINUS ACCESS PANEL
quantity = 1
parent = 47
materialID = 9
type = Box
Aero Mass = 0.027000
Thermal Mass = 0.027000
Diameter/Width = 0.039000
Length = 0.121720
Height = 0.004500

name = SOLAR PANEL ASSY
quantity = 6
parent = 1
materialID = 23
type = Box
Aero Mass = 0.308000
Thermal Mass = 0.142000
Diameter/Width = 0.202500
Length = 0.347500
Height = 0.002400

name = SOLAR CELLS
quantity = 120
parent = 53
materialID = 24
type = Box
Aero Mass = 0.007000
Thermal Mass = 0.007000
Diameter/Width = 0.037200
Length = 0.076100
Height = 0.000800

name = PANEL HINGES
quantity = 12
parent = 53
materialID = 19
type = Box
Aero Mass = 0.013000

Thermal Mass = 0.013000
Diameter/Width = 0.036000
Length = 0.050000
Height = 0.004600

name = HARNESSES
quantity = 50
parent = 1
materialID = 19
type = Cylinder
Aero Mass = 0.040000
Thermal Mass = 0.040000
Diameter/Width = 0.008000
Length = 0.250000

name = FASTENERS
quantity = 1000
parent = 1
materialID = 57
type = Cylinder
Aero Mass = 0.000440
Thermal Mass = 0.000440
Diameter/Width = 0.003000
Length = 0.008000

name = STAKING
quantity = 1
parent = 1
materialID = 76
type = Sphere
Aero Mass = 0.500000
Thermal Mass = 0.500000
Diameter/Width = 0.150000

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

name = PE2_FLT1
Demise Altitude = 77.996185
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = BODY PANEL Z MINUS
Demise Altitude = 76.508171
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = PATCH ANTENNA S
Demise Altitude = 73.739357
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****

name = PATCH ANTENNA X
Demise Altitude = 0.000000
Debris Casualty Area = 0.453490
Impact Kinetic Energy = 7.831854

****
name = BODY PANEL Z PLUS
Demise Altitude = 74.438652
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = MKII NANO ST
Demise Altitude = 71.748039
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = 55MM BAFFLE ZPLUS
Demise Altitude = 67.786011
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = ST BRACKET ZPLUS
Demise Altitude = 70.482635
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = BASE CUP ZPLUS
Demise Altitude = 0.000000
Debris Casualty Area = 0.395117
Impact Kinetic Energy = 4.948890

****
name = GPS PATCH ANTENNA
Demise Altitude = 70.894806
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = BRACKET PROP INTERFACE
Demise Altitude = 72.564232
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = BRAKET PROP Z PANEL
Demise Altitude = 74.438652
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = BRACKET Y ST MOUNT

Demise Altitude = 73.470726
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = NPT30
Demise Altitude = 66.938591
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = RANGING ANTENNA COVER ZPLUS
Demise Altitude = 73.055679
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = PE2 PAYLOAD
Demise Altitude = 52.350208
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = BODY PANEL X PLUS
Demise Altitude = 73.394478
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = MPPT
Demise Altitude = 65.780151
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = TORQUE ROD X PLUS
Demise Altitude = 60.232979
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = STAR TRACKER ASSY X PLUS
Demise Altitude = 70.268578
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = ST 55MM BAFFLE X PLUS
Demise Altitude = 65.809341
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = ST BRACKET X PLUS
Demise Altitude = 68.821106

Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = BASE CUP X PLUS
Demise Altitude = 0.000000
Debris Casualty Area = 0.395117
Impact Kinetic Energy = 4.948596

****
name = BODY PANEL Y PLUS
Demise Altitude = 75.291283
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = SENSOR MODULE
Demise Altitude = 72.714104
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = MOUNT REACTION WHEEL
Demise Altitude = 73.003967
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = REACTION WHEEL NANO MKII
Demise Altitude = 69.986923
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = ACCESS PANEL Y PLUS
Demise Altitude = 70.943436
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = LDRR
Demise Altitude = 70.656601
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = RWA COMBINER BOARD
Demise Altitude = 75.060036
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = BODY PANEL Y MINUS
Demise Altitude = 73.975922
Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****
name = SENSOR MODULE Y MINUS
Demise Altitude = 71.353630
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = TORQUE ROD Y-MINUS
Demise Altitude = 61.796818
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = IMU Y MINUS
Demise Altitude = 65.476738
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = UHF HARNESS COVER
Demise Altitude = 73.774300
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = UHF ANTENNA
Demise Altitude = 72.698601
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = STATE LATCH EXPANDER
Demise Altitude = 69.889175
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Y MINUS COVERS
Demise Altitude = 73.261063
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = DIVIDER PLATE
Demise Altitude = 72.303078
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = 12V SLICE BATTERY MODULE
Demise Altitude = 58.091557
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = GPS MODULE ASSEMBLY
Demise Altitude = 70.064110
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = NANO LOAD CONTROLLER
Demise Altitude = 71.714066
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = PIB
Demise Altitude = 72.256462
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = SCR-106
Demise Altitude = 65.964561
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = NANOTX
Demise Altitude = 70.471626
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = GPS MODULE BRACKETS
Demise Altitude = 70.094048
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = X MINUS BODY PANEL
Demise Altitude = 72.992401
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = FLIGHT COMPUTER ASSY
Demise Altitude = 68.083290
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = BACKPLANE
Demise Altitude = 0.000000
Debris Casualty Area = 0.543430
Impact Kinetic Energy = 11.546056

****
name = WATCHDOG
Demise Altitude = 64.998672
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = FLIGHT COMPUTER
Demise Altitude = 61.498692
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = X MINUS ACCESS PANEL
Demise Altitude = 71.912376
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = SOLAR PANEL ASSY
Demise Altitude = 77.442612
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = SOLAR CELLS
Demise Altitude = 77.276253
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = PANEL HINGES
Demise Altitude = 76.344681
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = HARNESSES
Demise Altitude = 76.746880
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = FASTENERS
Demise Altitude = 76.756905
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = STAKING
Demise Altitude = 76.501274
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****

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