Flock 1b Orbital Debris Assessment Report (ODAR)

This report is presented in compliance with NASA-STD-8719.14, APPENDIX A.

Report Version: 12/18/2013

Document Data is Not Restricted.

This document contains no proprietary, ITAR, or export controlled information.

DAS Software Version Used In Analysis: v2.0.2

VERSION APPROVAL and/or FINAL APPROVAL*:

Chris Boshuizen
CTO

*Approval signatures indicate acceptance of the ODAR-defined risk.

Table of Contents

Self-assessment of the ODAR using the format in Appendix A.2 of NASA-STD-8719.14:

A self-assessment is provided below in accordance with the assessment format provided in Appendix A.2 of NASA-STD-8719.14.

Orbital Debris Self-Assessment Report Evaluation: Flock 1b Mission

Requirement #	Launch Vehicle				Spacecraft			Comments
	Compliant	Not Compliant	Incomplete	Standard Non Compliant	Compliant	Not Compliant	Incomplete	
4.3-1.a	☐	☐	☒	☐	☒	☐	☐	No Debris Released in LEO. See note 1.
4.3-1.b	☐	☐	☒	☐	☒	☐	☐	No Debris Released in LEO. See note 1.
4.3-2	☐	☐	☒	☐	☒	☐	☐	No Debris Released in GEO. See note 1.
4.4-1	☐	☐	☒	☐	☒	☐	☐	See note 1.
4.4-2	☐	☐	☒	☐	☒	☐	☐	See note 1.
4.4-3	☐	☐	☒	☐	☒	☐	☐	No planned breakups. See note 1.
4.4-4	☐	☐	☒	☐	☒	☐	☐	No planned breakups. See note 1.
4.5-1	☐	☐	☒	☐	☒	☐	☐	See note 1.
4.5-2					☒	☐	☐	No critical subsystems needed for EOM disposal
4.6-1(a)	☐	☐	☒	☐	☒	☐	☐	See note 1.
4.6-1(b)	☐	☐	☒	☐	☒	☐	☐	See note 1.
4.6-1(c)	☐	☐	☒	☐	☒	☐	☐	See note 1.
4.6-2	☐	☐	☒	☐	☒	☐	☐	See note 1.
4.6-3	☐	☐	☒	☐	☒	☐	☐	See note 1.
4.6-4	☐	☐	☒	☐	☒	☐	☐	See note 1.
4.6-5	☐	☐	☒	☐	☒	☐	☐	See note 1.
4.7-1	☐	☐	☒	☐	☒	☐	☐	See note 1.
4.8-1					☒	☐	☐	No tethers used.

Notes:

1. This launch has several spacecraft manifested and the Planet Labs spacecraft are not the primary mission.

Assessment Report Format:

ODAR Technical Sections Format Requirements:

As Planet Labs Inc. is a US company, this ODAR follows the format recommended in NASA-STD-8719.14, Appendix A.1 and includes the content indicated at a minimum in each section 2 through 8 below for the Flock 1b satellites. Sections 9 through 14 apply to the launch vehicle ODAR and are not covered here.

ODAR Section 1: Program Management and Mission Overview

Project Manager: Chris Boshuizen

Foreign government or space agency participation: The satellites will deploy from the Japanese Experimental Module aboard the International Space Station and will therefore involve representatives of the participating space agencies (NASA, the Russian Federal Space Agency, JAXA, ESA, and CSA). Transport to the space station will be aboard a Commercial Resupply Services (CRS) flight provided by Orbital Sciences on the Antares launch vehicle.

Schedule of upcoming mission milestones:

FRR:	February 2014
Launch:	May 2014

Mission Overview:
The "Flock 1b" constellation, comprising of 28 satellites, will be ejected from the International Space Station (ISS) to perform Earth observation imagery tasks. Initial altitude of the Flock 1b constellation depends on ISS altitude at time of ejection. The full range of 410 km ("high insertion case") to 380 km ("low insertion case") is considered.

ODAR Summary: No debris released in normal operations; no credible scenario for breakups; the collision probability with other objects is compliant with NASA standards; and the estimated nominal decay lifetime due to atmospheric drag is under 25 years following operations.

Launch vehicle and launch site: Antares, Wallops

Mission duration: High insertion case: 9.6 months, Low insertion case: 4.8 months until reentry via atmospheric orbital decay. Predicted lifetime: 7.2 months.

Constellation size: 28 satellites, all having the same design.

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

After being delivered to the ISS by the Antares launcher, the satellites will be stored on the ISS for approximately one month and released over a period of 2 weeks through the aft-located JAXA module. The Flock 1b satellites will deploy to, and decay naturally from, a circular orbit whose altitude depends on the ISS station-keeping boost schedule, so the entire altitude range is considered.

***High Insertion Case*:** **Apogee:** 410 km **Perigee:** 410 km

***Low Insertion Case*:** **Apogee:** 380 km **Perigee:** 380 km

Inclination: 51.6 degrees

The DAS analysis results reported in this document are based on a 400 km mean insertion case. The Flock 1b satellites have no propulsion and therefore do not actively change their orbit. There is no parking or transfer orbit.

ODAR Section 2: Spacecraft Description

This ODAR will state compliance to most requirements by only considering one satellite at a time. This approach is viable due to the fact that all the satellites in the constellation have the same design and orbital parameters.

Physical description of the spacecraft:

All the Flock 1b satellites are variants the 3U CubeSat specification, with a launch mass of 4.5 kg. Basic physical dimensions are 100mm x 100mm x 340mm, with two 260mm x 300mm deployable solar arrays.

The satellite load bearing structure is comprised of three 100mm x 100mm skeleton plates, with L rails along each 300mm corner edge. The solar arrays are spring-loaded and deployed by command.

Power storage is provided by Lithium-Ion cells. The batteries will be recharged by solar cells mounted on the body of the satellite and on the two deployable solar panels.

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

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

Description of all propulsion systems (cold gas, mono-propellant, bi-propellant, electric, nuclear): None.

Identification, including mass and pressure, of all fluids (liquids and gases) planned to be on board and a description of the fluid loading plan or strategies, excluding fluids in sealed heat pipes: None

Fluids in Pressurized Batteries: None. The Flock 1b satellites use unpressurized standard COTS Lithium-Ion battery cells. Each battery has a height of 65mm, a diameter of 14mm and a weight of 26 grams.

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

Attitude is controlled by magnetorquers and reaction wheels. The nominal attitude is the long axis nadir-aligned with the solar panels constrained to the orbit plane normal (known as “Nadir Pointing”, see Figure 1-A). Two additional attitude states can be used to perform differential drag maneuvers for collision avoidance and orbital spacing: long axis velocity-aligned and the solar panels zenith constrained (known as “Low Drag”, see Figure 1-B), and long axis nadir-aligned and the solar panels constrained to the orbital plane perpendicular (known as “High Drag”, see Figure 1-C).

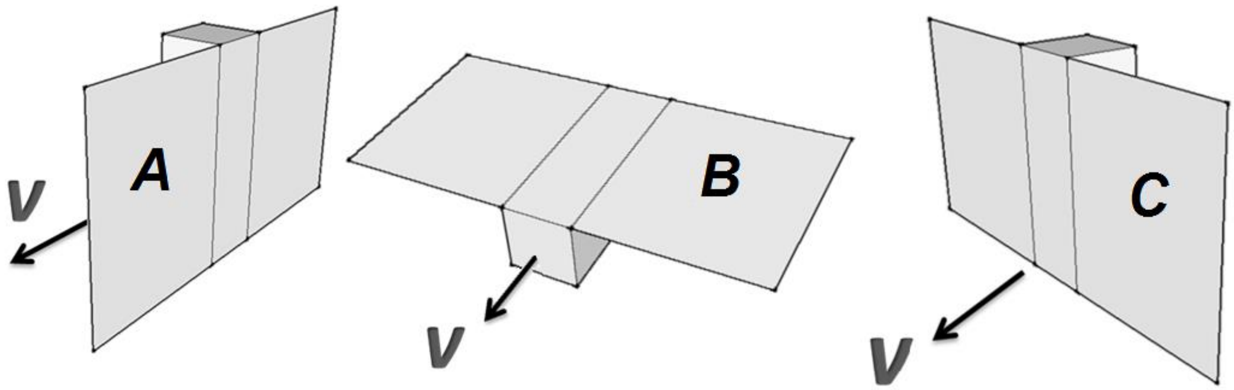

Figure 1: Attitude modes for Flock 1b. A –nadir pointing, B – low drag, C – high drag.

Description of any range safety or other pyrotechnic devices: No pyrotechnic devices are used.

Description of the electrical generation and storage system: Standard COTS Lithium-Ion battery cells are charged before payload integration and provide electrical energy during the mission. The cells are recharged by solar cells mounted on the deployable arrays. The battery cell protection circuit manages the charging cycle.

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

Identification of any radioactive materials on board: None**.**

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

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

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 v2.0.2)

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.

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:

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 (see requirement 4.4-1 below) describe the combined faults that must occur for any of seven (7) independent, mutually exclusive failure modes to lead to explosion. The deployment of the solar arrays will feature a simple spring and stopper system, released by command. The probability of a detachment during deployment is negligible.

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

There are no planned breakups.

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

None. The 12 batteries on each satellite will not be passivated at End of Mission due to the low risk and low impact of explosive rupturing. The maximum total energy stored in each battery is 12kJ.

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

The satellites' battery charge circuits include overcharge protection and a parallel design 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.

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.

Supporting Rationale and FMEA details:

Battery explosion:

Effect: All failure modes below might theoretically 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 the selected COTS 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 a much less than 0.1% probability 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 like likelihood and impact 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: 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 failure must all occur to enable this failure mode.

Failure Mode 4: Inoperable vents.
Mitigation 5: Battery vents are not inhibited by the battery holder design or the spacecraft.
Combined effects required for realized failure: The final assembler fails to install proper venting.

Failure Mode 5: 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 6: 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 failure modes in environmental tests must occur to result in this failure mode.

Failure Mode 7: 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** over-current monitoring and control must all 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:
COMPLIANT. As stated above, the battery charge circuits include overcharge protection and a parallel design 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

Assessment of spacecraft compliance with Requirements 4.5-1 and 4.5-2 (per DAS v2.0.2, 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:

Collision Probability: 0.000000; 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:
Collision Probability: 0.000237; COMPLIANT.

Identification of all systems or components required to accomplish any postmission disposal operation, including passivation and maneuvering:
To actively place the satellite in the final "maximum drag" configuration requires the flight computer and ADCS subsystems to be working. However, this configuration is the dynamically stable state for satellite, so even in the event of system failure this attitude will eventually be achieved.

Collision risk between Flock 1b and ISS:

All the satellites are released in the Aft-Nadir direction (45º) with a separation speed of 1.2 m/s. This initial separation speed, together with the fact that the Flock 1b satellites comply with the ISS requirements of a ballistic number greater than 100 kg/m^2, results in all satellites decaying faster than (and be below) the ISS. This is the same ejection scheme as the Flock 1 constellation.

Collision risk amongst Flock 1b satellites:

The risk of collision amongst the 28 satellites of the constellation is negligible; small differences in orbital parameters caused by deployment sequencing will quickly spread the satellites over the orbital plane. In addition, each satellite has the ability to perform collision avoidance maneuvers using differential drag techniques. This is the same orbital spreading scheme as the Flock 1 constellation.

ODAR Section 6: Assessment of Spacecraft Post-mission Disposal Plans and Procedures

6.1 Description of spacecraft disposal option selected: Each satellite will de-orbit naturally by atmospheric re-entry. At the end of Flock 1b's operational life (i.e. at EOM) the attitude control system of each satellite will stop counteracting the aerodynamic disturbance torques and will rotate the satellite into the maximum drag configuration. This will result in each satellite gradually assuming a dynamically stable configuration. To determine this stable orientation, an in-house developed aerodynamic simulation based on free-molecular flow with a simplified particle/surface interaction model (NASA SP-8058 eq 2-2) was used to compute force and moment coefficients for the spacecraft in all attitudes. In the event that satellite functionality ceases before the EOM maneuver is completed, the gravity gradient and aerodynamics torques will naturally force the satellite to the dynamically stable, maximum drag configuration.

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

The stable maximum drag configuration enables aerodynamic reentry. To accelerate the orbital decay, the satellite will be placed in this maximum drag configuration at the end of operations.

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

Spacecraft Mass: 4.5kg

Cross-sectional Area:	Nadir pointing configuration:	0.039 m^2 (drag area)
	Low Drag configuration:	0.013 m^2 (drag area)
	High Drag configuration:	0.19 m^2 (drag area)
Area to mass ratio:	Nadir pointing configuration:	0.00867 m^2/kg
	Low Drag configuration:	0.00289 m^2/kg
	High Drag configuration:	0.04222 m^2/kg

6.4 Assessment of spacecraft compliance with Requirements 4.6-1 through 4.6-4 (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 reentry of each satellite in Flock 1b is COMPLIANT using method "a".

High Insertion Case

BOL "High" Orbit	410 × 410 km
EOM Orbit	200 × 200 km
Predicted Lifetime	9.6 months
Post-ops Life	< 1 week

Low Insertion Case

BOL "Low" Orbit	380 × 380 km
EOM Orbit	200 × 200 km
Predicted Lifetime	4.8 months
Post-ops Life	< 1 week

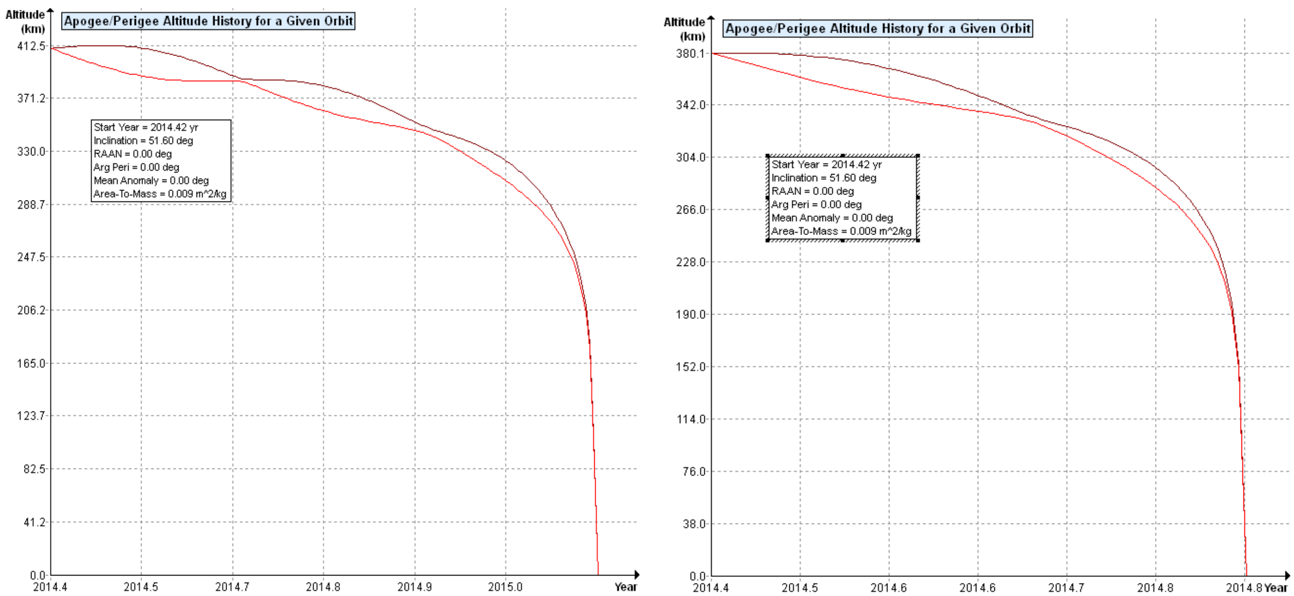

Figure 2: Flock 1b orbit history –High insertion Case (left image) and Low Insertion Case (right image)

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: The maximum drag configuration is the aerodynamically stable state, meaning that even under massive subsystem failure we would eventually assume this orientation.

ODAR Section 7: Assessment of Spacecraft Reentry Hazards

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 v2.0.2 reports that all Flock 1b satellites are compliant with the requirement. Total human casualty probability is reported by the DAS software as:

> **0.000000** for the Flock 1b satellites.

This is expected to represent the absolute maximum casualty risk, as calculated with DAS's limited modeling capability.

> Requirements 4.7-1b, and 4.7-1c below are non-applicable requirements because the satellites do 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 8: Assessment for Tether Missions

Not applicable. There are no tethers in the Flock 1b mission.

APPENDIX: Analysis log output (per DAS v2.0.2):

```
12 16 2013; 18:01:33PM     DAS Application Started
12 16 2013; 18:01:33PM     Opened Project C:\Program Files (x86)\NASA\DAS 2.0\project\
12 16 2013; 18:01:45PM     Processing Requirement 4.3-1:     Return Status :  Not Run

=====================
No Project Data Available
=====================

=============== End of Requirement 4.3-1 ===============
12 16 2013; 18:01:47PM     Processing Requirement 4.3-2: Return Status : Passed

=====================
No Project Data Available
=====================

=============== End of Requirement 4.3-2 ===============
12 16 2013; 18:01:49PM     Requirement 4.4-3:  Compliant

=============== End of Requirement 4.4-3 ===============
12 16 2013; 18:01:59PM     Processing Requirement 4.5-1:     Return Status :  Passed

==============
Run Data
==============

**INPUT**

       Space Structure Name = Flock1b
       Space Structure Type = Payload
       Perigee Altitude = 400.000000 (km)
       Apogee Altitude = 400.000000 (km)
       Inclination = 51.600000 (deg)
       RAAN = 0.000000 (deg)
       Argument of Perigee = 0.000000 (deg)
       Mean Anomaly = 0.000000 (deg)
       Final Area-To-Mass Ratio = 0.008667 (m^2/kg)
       Start Year = 2014.416000 (yr)
       Initial Mass = 4.500000 (kg)
       Final Mass = 4.500000 (kg)
       Duration = 2.000000 (yr)
       Station-Kept = False
       Abandoned = True
       PMD Perigee Altitude = -1.000000 (km)
       PMD Apogee Altitude = -1.000000 (km)
       PMD Inclination = 0.000000 (deg)
       PMD RAAN = 0.000000 (deg)
       PMD Argument of Perigee = 0.000000 (deg)
       PMD Mean Anomaly = 0.000000 (deg)

**OUTPUT**

       Collision Probability = 0.000000
       Returned Error Message: Normal Processing
       Date Range Error Message: Normal Date Range
```

```
      Status = Pass

==============

=============== End of Requirement 4.5-1 ===============
12 16 2013; 18:06:15PM     Requirement 4.5-2:  Compliant

==================================================
Spacecraft = Flock1b
Critical Surface = Aluminium
==================================================

**INPUT**

      Apogee Altitude = 400.000000 (km)
      Perigee Altitude = 400.000000 (km)
      Orbital Inclination = 51.600000 (deg)
      RAAN = 0.000000 (deg)
      Argument of Perigee = 0.000000 (deg)
      Mean Anomaly = 0.000000 (deg)
      Final Area-To-Mass = 0.008667 (m^2/kg)
      Initial Mass = 4.500000 (kg)
      Final Mass = 4.500000 (kg)
      Station Kept = No
      Start Year = 2014.416000 (yr)
      Duration = 2.000000 (yr)
      Orientation = Fixed Oriented
      CS Areal Density = 0.216000 (g/cm^2)
      CS Surface Area = 0.039000 (m^2)
      Vector = (1.000000 (u), 0.000000 (v), 0.000000 (w))
      CS Pressurized = No
      Outer Wall 1   Density: 0.216000 (g/cm^2)  Separation: 0.500000 (cm)

**OUTPUT**

      Probabilty of Penitration = 0.000237
      Returned Error Message: Normal Processing
      Date Range Error Message: Normal Date Range


12 16 2013; 18:06:53PM     Processing Requirement 4.6 Return Status :  Passed

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

**INPUT**

      Space Structure Name = Flock1b
      Space Structure Type = Payload

      Perigee Altitude = 400.000000 (km)
      Apogee Altitude = 400.000000 (km)
      Inclination = 51.600000 (deg)
      RAAN = 0.000000 (deg)
      Argument of Perigee = 0.000000 (deg)
      Mean Anomaly = 0.000000 (deg)
      Area-To-Mass Ratio = 0.008667 (m^2/kg)
      Start Year = 2014.416000 (yr)
```

```
        Initial Mass = 4.500000 (kg)
        Final Mass = 4.500000 (kg)
        Duration = 2.000000 (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 = 400.000000 (km)
        Suggested Apogee Altitude = 400.000000 (km)
        Returned Error Message = Reentry during mission (no PMD req.).

        Released Year = 2015 (yr)
        Requirement = 61
        Compliance Status = Pass

==============

=============== End of Requirement 4.6 ===============
12 16 2013; 18:07:09PM     *********Processing Requirement 4.7-1
        Return Status :  Passed

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

name = Flock1b
quantity = 1
parent = 0
materialID = 5
type = Box
Aero Mass = 4.500000
Thermal Mass = 4.500000
Diameter/Width = 0.100000
Length = 0.340000
Height = 0.100000

name = Camera
quantity = 1
parent = 1
materialID = 5
type = Box
Aero Mass = 0.370000
Thermal Mass = 0.370000
Diameter/Width = 0.060000
Length = 0.080000
Height = 0.060000

name = Batteries
quantity = 12
parent = 1
materialID = 46
type = Cylinder
Aero Mass = 0.026000
```

```
Thermal Mass = 0.026000
Diameter/Width = 0.014000
Length = 0.065000

name = Structure
quantity = 1
parent = 1
materialID = 5
type = Box
Aero Mass = 1.280000
Thermal Mass = 1.280000
Diameter/Width = 0.100000
Length = 0.340000
Height = 0.100000

name = Solar Arrays
quantity = 8
parent = 1
materialID = 24
type = Flat Plate
Aero Mass = 0.050000
Thermal Mass = 0.050000
Diameter/Width = 0.080000
Length = 0.300000

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

name = Optical Tube
quantity = 1
parent = 1
materialID = 5
type = Cylinder
Aero Mass = 1.700000
Thermal Mass = 1.700000
Diameter/Width = 0.091000
Length = 0.200000

name = Radiators
quantity = 2
parent = 1
materialID = 5
type = Flat Plate
Aero Mass = 0.100000
Thermal Mass = 0.100000
Diameter/Width = 0.100000
Length = 0.300000

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

```
name = Flock1b
Demise Altitude = 77.993738
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Camera
Demise Altitude = 71.891253
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Batteries
Demise Altitude = 71.923699
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Structure
Demise Altitude = 73.169214
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Solar Arrays
Demise Altitude = 77.821027
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Avionics
Demise Altitude = 77.313676
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Optical Tube
Demise Altitude = 66.521417
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Radiators
Demise Altitude = 77.033871
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

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

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

END of ODAR for Flock 1b