Exhibit B – Orbital Debris Assessment Report ("ODAR")

SWARM Orbital Debris Assessment Report

SWARM TECHNOLOGIES MISSION PROFILE
PREPARED BY: SWARM TECHNOLOGIES INC
REVISION 1, Nov 18, 2018

ODAR Signature Approval

Program/ Project Manager	Sara Spangelo
Signature	
Date	Nov 18, 2018

ODAR Section 1: Program Management and Mission Overview

Program/ Project Manager	Sara Spangelo
Mission Description	This mission is a technology demo for two-way communications satellites and data relay.
Foreign Government Involvement	None
Project Milestones	The project milestones for the Swarm satellite aligns with the launch of the vehicles into orbit, including a delivery of the spacecraft one month prior to launch.
Proposed Launch Date:	February 15, 2019
Proposed Launch Vehicles	Electron Number of Satellites: 2 Altitude: 475 km Inclination: 45 degrees Period: 94 min
Proposed Launch Sites	Mahia Peninsula, New Zealand

Launch Vehicle Operator:	Rocket Lab
Mission Duration:	The operational lifetime of the hardware for each satellite is designed to be up to 10 years following deployment from the launch vehicle. The orbital lifetime for the satellites is expected to be between 2.67 and 3.21 years, depending on the vehicle's orbit and solar influence of the Earth's atmosphere, as described in Section 6.
Launch / Deployment Profile:	**Launch** The Swarm satellites will be injected directly into the target orbit outlined in the table above. **Checkout** For up to 1 month following deployment into orbit, the Swarm satellite will remain in checkout phase. During this phase, ground operators will verify correct operation of the satellite and its payloads, and prepare it for the operational phase. **Operations** The operational phase of the satellite begins following the successful deployment of the Swarm satellite from the launch vehicle and successful checkout. **Post-mission Disposal** Following the end of the operational phase, the satellites will remain on orbit in a non-transmitting mode while the orbit of the satellites passively decays until the satellites reenter the atmosphere and disintegrate. The satellites are nominally expected to reenter the atmosphere within 3.21 years following deployment from the launch vehicle, as detailed in Appendix B: Swarm Satellites Orbit Lifetime.
Selection of Orbit:	The selection of the chosen orbit was made due to available launch opportunities.
Potential Physical Interference with Other Orbiting Object:	As the satellites do not have any propulsion systems, their orbits will naturally decay following deployment from the launch vehicle. As detailed in Section 5, the probability of physical interference between the satellites and other space objects is sufficiently unlikely that the satellites comply with Requirement 4.5.

ODAR Section 2: Spacecraft Description

Physical Description:

Property	**Value**
Total Mass at Launch	1.175 kg (both satellites) [0.402 kg, 0.773 kg (individual satellite masses)]
Dry Mass at Launch	1.175 kg (both satellites) [0.402 kg, 0.773 kg (individual satellite masses)]
Form Factor	1U satellite, Qty 2
COG	<X1,Y1,Z1> = <0, 17.6, -14.7> mm relative to geometric center (both satellites)
Envelope (stowed)	100mm x 100mm x 113.5mm (each satellite)
Envelope (deployed)	100mm x 100mm x 113.5mm (each satellite) Deployed antennas are 1,142 mm tip to tip
Propulsion Systems	None
Fluid Systems	None
AOCS	Magnetorquer for active stabilization, GPS navigation
Range Safety/ Pyrotechnic Devices	None
Electrical Generation	Solar cells
Electrical Storage	Rechargeable lithium-ion battery. Qty 1: 18650 cell.
Radioactive Materials	None

ODAR Section 3: Assessment of Debris Released During Normal Operations

Objects larger than 1mm expected to be released during orbit:	**None**
Rationale for release of each object:	N/A
Time of release of each object:	N/A
Release velocity of each object:	N/A
Expected orbital parameters of each object:	N/A
Calculated orbital lifetime of each object:	N/A

Assessment of spacecraft compliance with Requirements 4.3-1 and 4.3-2:	
4.3-1, Mission-Related Debris Passing Through LEO:	COMPLIANT
4.3-2, Mission-Related Debris Passing Near GEO:	COMPLIANT

A DAS 2.1.2 log demonstrating the compliance to the above requirements is available in Appendix A – "DAS 2.1.2 Log".

ODAR Section 4: Assessment of Spacecraft Intentional Breakups and Potential for Explosions

Potential causes for spacecraft breakup (there is only one plausible causes for breakup of the satellites):

- Energy released from onboard Lithium-ion battery from the unlikely event of overcharging or shorts

Summary of failure modes and effects analysis of all credible failure modes which may lead to an accidental explosion:
The battery aboard the satellite is a 12.5 Whr Lithium-Ion battery, which represents the only credible failure mode during which stored energy is released. The main failure modes associated with Lithium Ion batteries result from overcharging, over-discharging, internal shorts, and external shorts.

The battery onboard Swarm satellites complies with all controls / process requirements identified in JSC-20793 Section 5.4.3 to mitigate chance of any accidental venting / explosion caused by the above failure modes.

Detailed Plan for any designed spacecraft breakup, including explosions and intentional collisions:
There is no planned breakup of the satellites on-orbit.

List of components passivated at EOM:
At end of mission, all radio transmissions and beacons will be disabled. Spacecraft transmissions are only initiated by ground command and self terminate. All RF transmissions from the satellite can be disabled via command from the ground.

Rationale for all items required to be passivated that cannot be due to design:
N/A

Assessment of spacecraft compliance with Requirements 4.4-1 through 4.4-4:	
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	**COMPLIANT**

4.4-2, Design for passivation after completion of mission operations while in orbit about Earth or the Moon	**COMPLIANT**
4.4-3, Limiting the long-term risk to other space systems from planned breakups: There are no planned breakups of any of the satellites.	**COMPLIANT**
4.4-4, Limiting the short-term risk to other space systems from planned breakups There are no planned breakups of any of the satellites.	**COMPLIANT**

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

Probability for Collision with Objects >10cm:
The probability of a collision of any of the satellites with an orbiting object larger than 10cm in diameter was sufficiently small that the simulation performed using DAS 2.1.2 software returned a probability value of 0.

Assessment of spacecraft compliance with Requirement 4.5-1 and 4.5-2:	
4.5-1, Probability of Collision with Large Objects:	**COMPLIANT**
4.5-2, Probability of Damage from Small Objects:	**COMPLIANT**

A DAS 2.1.2 log demonstrating the compliance to the above requirements is available in Appendix A – “DAS 2.1.2 Log”.

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

Description of Disposal Option Selected:
Following its deployment, the satellite’s orbit will naturally decay until it reenters the atmosphere. Table 1 describes the mission scenarios for which lifetime analysis of Swarm satellites was considered, and the effective area-to-mass ratio of the satellite in each scenario. The ratio was calculated using the external dimensions of the satellite and deployed arrays. The satellites will be deployed from the P-POD with a spring and will separate from one another with separation springs in the feet.

Drag area from deployed antennas (4 antennas, 521 mm long turnstile antennas) was neglected; as such, the effective area-to-mass calculated below is a conservative case.

Table 1 - Area-to-Mass Ratio of Swarm Satellites in Various Mission Scenarios

Scenario	Description	Effective Area-to-Mass (m^2/kg)
Operational, Nominal	● Satellite maintains +Z axis nadir ● Satellite maintains position around Z axis as planned for mission operations	0.0249 (for 0.402 kg satellite) 0.0129 (for 0.773 kg satellite)
ADCS Nonfunctional	● Satellite tumbles randomly	0.0249 (for 0.402 kg satellite) 0.0129 (for 0.773 kg satellite)

Table 2 shows the simulated orbital dwell time for a Swarm satellite for the range of possible orbits, in each of the identified mission scenarios. In all mission scenarios and orbits, the dwell time of the satellite was simulated using DAS 2.1.2 software to be less than 10 years.

Table 2 – Orbit Dwell Time for Swarm Satellite in Each Planned Orbit and Mission Scenario

		Orbital Lifetime (years)
Case		**Nominal**
Launch		**November 2019 Rocket Lab (2 x 1U Satellites)**
Orbit		**475 km x 475 km (45 deg)**
Scenario	**Effective Area-to-Mass (m^2/kg)**	
Operational, Nominal (for 0.402 kg satellite)	0.0249	2.67 (for 0.402 kg satellite)
ADCS Nonfunctional (for 0.402 kg satellite)	0.0249	2.67 (for 0.402 kg satellite)
Operational, Nominal (for 0.773 kg satellite)	0.0129	3.21 (for 0.773 kg satellite)
ADCS Nonfunctional (for 0.773 kg satellite)	0.0129	3.21 (for 0.773 kg satellite)

Identification of Systems Required for Post-mission Disposal: None

Plan for Spacecraft Maneuvers required for Post-mission Disposal: N/A

Calculation of final Area-to-Mass Ratio if Atmospheric Reentry Not Selected: N/A

Assessment of Spacecraft Compliance with Requirements 4.6-1 through 4.6-4:	
4.6-1, Disposal for space structures passing through LEO All of the satellites will reenter the atmosphere within 25 years of mission completion and 30 years of launch.	**COMPLIANT**
4.6-2, Disposal for space structures passing through GEO:	**N/A**
4.6-3, Disposal for space structures between LEO and GEO:	**N/A**
4.6-4, Reliability of post-mission disposal operations:	**COMPLIANT**

ODAR Section 7: Assessment of Spacecraft Reentry Hazards

Detailed description of spacecraft components by size, mass, material, shape, and original location on the space vehicle:
A system-level mass breakdown and primary materials list included in the generic satellite bus is available in the table below:

Subsystem	Materials	Quantity	Mass (grams)	Shape	Size (mm)
Solar Panels	Copper, Glass	2	1	Box	79 x 50 x 0.3
Main Board PCB	FR4	2	28.0	Box	98 x 98 x 1.6
Primary Structure	Al 6061	1	295.5 (for 0.402 kg satellite) 666.5 (for 0.773 kg satellite)	Box	100 x 100 x 100
Battery	Li-Ion	1	48.5	Cylinder	18 (r) x 67 (l)

Summary of objects expected to survive an uncontrolled reentry (using DAS 2.1.2 software): None
Calculation of probability of human casualty for expected reentry year and inclination: 0%

Assessment of spacecraft compliance with Requirement 4.7-1:	

4.7-1, Casualty Risk from Reentry Debris:	**COMPLIANT**

A DAS 2.1.2 log demonstrating the compliance to Requirement 4.7-1 is available in Appendix A – "DAS 2.1.2 Log".

ODAR Section 7A: Assessment of Spacecraft Hazardous Materials

Summary of Hazardous Materials Contained on Spacecraft: None

ODAR Section 8: Assessment for Tether Missions

Type of tether: N/A
Description of tether system: N/A
Determination of minimum size of object that will cause the tether to be severed: N/A
Tether mission plan, including duration and post-mission disposal: N/A
Probability of tether colliding with large space objects: N/A
Probability of tether being severed during mission or after post-mission disposal: N/A
Maximum orbital lifetime of a severed tether fragment: N/A

Assessment of compliance with Requirement 4.8-1:	
4.8-1, Collision Hazards of Space Tethers:	**N/A**

ODAR Section 9: Orbital Tracking Methodology

The satellite is a standard 1U CubeSat in size (10 cm x 10 cm x 10 cm), and can be tracked by normal means with the Space Surveillance network.

Further, the satellite has an onboard GPS receiver, and the GPS location of the satellite is transmitted every time that the satellite is interrogated from the ground. We will have the ability to silence all RF transmission of the satellite by command from the ground. Our GPS data, and computed TLEs, will be provided to CSpOC, and any other entity that wishes to receive the live telemetry. The GPS device will provide telemetry for the hardware lifetime of the satellite, which exceeds the anticipated orbital lifetime of the satellite.

Appendix A: DAS 2.1.2 Log

11 18 2018; 20:06:33PM Activity Log Started
11 18 2018; 20:14:01PM Mission Editor Changes Applied
11 18 2018; 20:14:08PM Processing Requirement 4.3-1: Return Status : Not Run

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

========== End of Requirement 4.3-1 ==========
11 18 2018; 20:14:10PM Processing Requirement 4.3-2: Return Status : Passed

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

========== End of Requirement 4.3-2 ==========
11 18 2018; 20:14:12PM Requirement 4.4-3: Compliant

========== End of Requirement 4.4-3 ==========
11 18 2018; 20:20:11PM Processing Requirement 4.5-1: Return Status : Passed

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

INPUT

Space Structure Name = SPACEBEE-8
Space Structure Type = Payload
Perigee Altitude = 475.000000 (km)
Apogee Altitude = 475.000000 (km)
Inclination = 45.000000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Final Area-To-Mass Ratio = 0.024900 (m^2/kg)
Start Year = 2019.000000 (yr)
Initial Mass = 0.402000 (kg)
Final Mass = 0.402000 (kg)
Duration = 2.700000 (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

==========

INPUT

Space Structure Name = SPACEBEE-9
Space Structure Type = Payload
Perigee Altitude = 475.000000 (km)
Apogee Altitude = 475.000000 (km)
Inclination = 45.000000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Final Area-To-Mass Ratio = 0.012900 (m^2/kg)
Start Year = 2019.000000 (yr)
Initial Mass = 0.773000 (kg)
Final Mass = 0.773000 (kg)
Duration = 3.200000 (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 ==========
11 18 2018; 20:23:34PM Requirement 4.5-2: Compliant
11 18 2018; 20:23:36PM Processing Requirement 4.6 Return Status : Passed

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

INPUT

Space Structure Name = SPACEBEE-8
Space Structure Type = Payload

Perigee Altitude = 475.000000 (km)
Apogee Altitude = 475.000000 (km)
Inclination = 45.000000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Area-To-Mass Ratio = 0.024900 (m^2/kg)
Start Year = 2019.000000 (yr)
Initial Mass = 0.402000 (kg)
Final Mass = 0.402000 (kg)
Duration = 2.700000 (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 = 475.000000 (km)
Suggested Apogee Altitude = 475.000000 (km)
Returned Error Message = Reentry during mission (no PMD req.).

Released Year = 2021 (yr)
Requirement = 61
Compliance Status = Pass

==========

INPUT

Space Structure Name = SPACEBEE-9
Space Structure Type = Payload

Perigee Altitude = 475.000000 (km)
Apogee Altitude = 475.000000 (km)

Inclination = 45.000000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Area-To-Mass Ratio = 0.012900 (m^2/kg)
Start Year = 2019.000000 (yr)
Initial Mass = 0.773000 (kg)
Final Mass = 0.773000 (kg)
Duration = 3.200000 (yr)
Station Kept = False
Abandoned = True
PMD Perigee Altitude = 245.165599 (km)
PMD Apogee Altitude = 252.890125 (km)
PMD Inclination = 44.976953 (deg)
PMD RAAN = 350.140636 (deg)
PMD Argument of Perigee = 66.990779 (deg)
PMD Mean Anomaly = 0.000000 (deg)

OUTPUT

Suggested Perigee Altitude = 245.165599 (km)
Suggested Apogee Altitude = 252.890125 (km)
Returned Error Message = Passes LEO reentry orbit criteria.

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

==========

========== End of Requirement 4.6 ==========
11 18 2018; 20:23:50PM *********Processing Requirement 4.7-1
Return Status : Passed

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

name = SPACEBEE-8
quantity = 1
parent = 0
materialID = 5
type = Box
Aero Mass = 0.402000
Thermal Mass = 0.402000
Diameter/Width = 0.100000
Length = 0.100000
Height = 0.100000

name = Solar Panel

quantity = 2
parent = 1
materialID = 24
type = Box
Aero Mass = 0.001000
Thermal Mass = 0.001000
Diameter/Width = 0.050000
Length = 0.079000
Height = 0.000300

name = Main Board PCB
quantity = 2
parent = 1
materialID = 23
type = Box
Aero Mass = 0.028000
Thermal Mass = 0.028000
Diameter/Width = 0.098000
Length = 0.098000
Height = 0.001600

name = Battery Pack
quantity = 1
parent = 1
materialID = 5
type = Cylinder
Aero Mass = 0.048500
Thermal Mass = 0.048500
Diameter/Width = 0.039000
Length = 0.067000

name = Primary Structure
quantity = 1
parent = 1
materialID = 5
type = Box
Aero Mass = 0.295500
Thermal Mass = 0.295500
Diameter/Width = 0.100000
Length = 0.100000
Height = 0.100000

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

name = SPACEBEE-8
Demise Altitude = 77.989319
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Solar Panel
Demise Altitude = 77.967941
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Main Board PCB
Demise Altitude = 76.856377
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Battery Pack
Demise Altitude = 73.772690
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Primary Structure
Demise Altitude = 70.953552
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****

**********INPUT****
Item Number = 2

name = SPACEBEE-9
quantity = 1
parent = 0
materialID = 5
type = Box
Aero Mass = 0.773000
Thermal Mass = 0.773000
Diameter/Width = 0.100000
Length = 0.100000
Height = 0.100000

name = Solar Panel 2
quantity = 2
parent = 1
materialID = 24
type = Box
Aero Mass = 0.001000
Thermal Mass = 0.001000
Diameter/Width = 0.050000

Length = 0.079000
Height = 0.000300

name = Main Board PCB 2
quantity = 2
parent = 1
materialID = 23
type = Box
Aero Mass = 0.028000
Thermal Mass = 0.028000
Diameter/Width = 0.098000
Length = 0.098000
Height = 0.001600

name = Battery Pack 2
quantity = 1
parent = 1
materialID = 5
type = Cylinder
Aero Mass = 0.048500
Thermal Mass = 0.048500
Diameter/Width = 0.039000
Length = 0.067000

name = Primary Structure 2
quantity = 1
parent = 1
materialID = 5
type = Box
Aero Mass = 0.666500
Thermal Mass = 0.666500
Diameter/Width = 0.100000
Length = 0.100000
Height = 0.100000

**********OUTPUT****
Item Number = 2

name = SPACEBEE-9
Demise Altitude = 77.997307
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Solar Panel 2
Demise Altitude = 77.979416
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Main Board PCB 2
Demise Altitude = 77.244904
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Battery Pack 2
Demise Altitude = 75.018684
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Primary Structure 2
Demise Altitude = 67.996552
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****

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

Appendix B: Swarm Satellites Orbit Lifetime

11 18 2018; 19:31:46PM Activity Log Started
11 18 2018; 19:32:35PM Science and Engineering - Orbit Lifetime/Dwell Time

INPUT

Start Year = 2019.000000 (yr)
Perigee Altitude = 475.000000 (km)
Apogee Altitude = 475.000000 (km)
Inclination = 45.000000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Area-To-Mass Ratio = 0.024900 (m^2/kg)

OUTPUT

Orbital Lifetime from Startyr = 2.672142 (yr)
Time Spent in LEO during Lifetime = 2.672142 (yr)
Last year of Propagation = 2021 (yr)
Returned Error Message: Object reentered
11 18 2018; 19:33:09PM Science and Engineering - Orbit Lifetime/Dwell Time

INPUT

Start Year = 2019.000000 (yr)
Perigee Altitude = 475.000000 (km)
Apogee Altitude = 475.000000 (km)
Inclination = 45.000000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Area-To-Mass Ratio = 0.012900 (m^2/kg)

OUTPUT

Orbital Lifetime from Startyr = 3.214237 (yr)
Time Spent in LEO during Lifetime = 3.214237 (yr)
Last year of Propagation = 2022 (yr)
Returned Error Message: Object reentered