SPACEX

Space Exploration Technologies

Exhibit 3

Information Regarding Orbital Debris Assessment

Applicant: **Space Exploration Technologies Corp.**

Orbital Debris Mitigation

SpaceX's launch and space experience provides the knowledge base for implementing an aggressive and effective space-debris mitigation plan. The company's current and planned space-based activities underscore its unparalleled commitment to safe space. SpaceX has had extensive experience in safe-flight design and operation through many missions of both the Falcon 9 launch vehicle and the Dragon spacecraft carrying out missions to the International Space Station ("ISS"). The company is highly experienced with cutting-edge debris mitigation practices and has deep ties with the domestic and international institutions tasked with ensuring the continued safety of space operations. SpaceX has a long-standing collaborative working relationship with the Joint Space Operations Center ("JSpOC"), a multinational focal point for management of space traffic, debris, and other space coordination functions associated with the U.S. Department of Defense. It also has existing relationships with both NASA and the Air Force Center for Space Situational Awareness in the support of its space-based activities, and will continue to utilize these experiences and relationships as resources while developing the SpaceX System and spacecraft.

SpaceX will largely be using recommendations set forth in both NASA Technical Standard 8719.14A and AIR FORCE INSTRUCTION 91-217, typically choosing the more restrictive of the two and, where deemed applicable, choosing a more restrictive value than either reference due to the scope of the project. SpaceX intends to incorporate the material objectives set forth in this application into the technical specifications established for design and operation of the SpaceX System. SpaceX will internally review orbit debris mitigation as part of the preliminary design review and critical design review for the spacecraft, and incorporate these objectives, as appropriate, into its operational plans. Because this mitigation statement is necessarily forward looking, the process of designing, building, and testing may result in minor changes to the parameters discussed herein. In addition, SpaceX will continue to stay current with the Space Situational Awareness community and technology and, if appropriate, SpaceX will modify this mitigation statement to continue its leadership in this area.

Spacecraft Hardware Design

SpaceX has assessed and limited the amount of debris released in a planned manner during normal operations, and does not intend to release debris during the planned course of operations of the satellite constellation.

SpaceX will also consider the possibility of its system becoming a source of debris by collisions with small debris or meteoroids that could either create jetsam or cause loss of control of the spacecraft and prevent post-mission disposal. As such, SpaceX will take steps to address this possibility by incorporating redundancy, shielding, separation of components, and other physical characteristics into the satellites' design. For example, the on-board command receivers, telemetry transmitters, and the bus control electronics will be fully redundant and appropriately shielded to minimize the probability of the spacecraft becoming flotsam due to a collision. SpaceX will continue to review these aspects of on-orbit operations throughout the spacecraft manufacturing process and will make such adjustments and improvements as appropriate to assure that its spacecraft will not become a source of debris during operations or become derelict in space due to a collision.

Minimizing Accidental Explosions

SpaceX will seek an overall spacecraft design that limits the probability of accidental explosion. The key areas reviewed for this purpose will include leakage of propellant as well as battery pressure vessels. The basic propulsion design (including the placement of propellant inside a central cylinder which provides a shielding from the bus walls), propulsion subsystem component construction, preflight verification through both proof testing and analysis, and quality standards will be designed to ensure a very low risk of propellant leakage that can result in an energetic discharge of the inert propellant. During the mission, batteries and various critical areas of the propulsion subsystem will be instrumented with fault detection, isolation, and recovery (similar or in many cases identical to flight-proven methods utilized onboard the SpaceX Dragon capsule for its missions to ISS) to continually monitor and preclude conditions that could result in the remote possibility of energetic discharge and subsequent generation of debris. Through this process, SpaceX will assess and limit the possibility of accidental explosions during mission operations and assure that all stored energy at the end of the satellite's operation will be removed.

Safe Flight Profiles

SpaceX takes seriously the responsibility of deploying large numbers of satellites into space, and intends to exceed best practices to ensure the safety of space. It will assess and limit the probability of its system becoming a source of debris by collisions with large debris or other operational space stations through detailed and conscientious mission planning. It will maintain the accuracy of its orbital parameters at a level that will allow operations with sufficient spacing to minimize the risk of conjunction with adjacent satellites in the constellation and other constellations. SpaceX has and will continue to work closely with JSpOC to ensure the service provided for conjunction assessment to SpaceX and all operators is robust, reliable, and secure. Significant coordination must be performed with other satellite operators in nearby orbits to safely ascend and descend through constellations and to ensure any altitude perturbations do not result in unnecessarily close approaches. SpaceX is willing to engage with any operators of nearby constellations to ensure safe and coordinated space operations.

SpaceX has reviewed the list of licensed systems and systems that are under consideration by the Commission for the orbital planes it has requested. In addition, in order to address non-U.S. licensed systems, SpaceX has reviewed the list of NGSO satellite networks for which a request for coordination has been published by the ITU. As a consequence of this review, it has been determined that no other system is currently licensed by the Commission for, is currently operating in, or has submitted a request for coordination to the ITU with respect to the same nominal orbital planes sought by SpaceX.

Post-Mission Disposal

Each Microsat satellite is designed for a six month useful lifetime. SpaceX intends to dispose of these satellites through atmospheric reentry at end of life. As suggested by the Commission,[1] SpaceX intends to comply with Section 4.6 and 4.7 of NASA Technical Standard 8719.14A with respect to this reentry process. In particular, SpaceX anticipates that its satellites will demise in the Earth's atmosphere just over one year after completion of their mission – much sooner than the

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1 *Mitigation of Orbital Debris*, 19 FCC Rcd. 11567, ¶ 88 (2004).

international standard of twenty-five years. After the mission is complete, the spacecraft will be moved to a 1,075 km circular orbit, then gradually lower perigee until the propellant is exhausted, achieving a perigee no greater than 300 km. After all propellant is consumed, the spacecraft will be reoriented to maximize the vehicle's total cross-sectional area, a configuration also stable in the direction of aerodynamic drag. Finally, the spacecraft will begin to passivate itself by de-spinning reaction wheels and drawing batteries down to a safe level and powering down. Over the following months, the denser atmosphere will gradually lower the satellite's perigee until its eventual atmospheric demise.

SpaceX has conducted an assessment using NASA's Debris Assessment Software ("DAS"). That analysis indicates a total spacecraft Risk of Human Casualty rate of 1:31,400 – satisfying the requirement established by NASA of no greater than 1:10,000 risk. This analysis will be conducted regularly throughout the spacecraft design life cycle to ensure continued compliance. The results of the analysis done to date is included on the following pages.

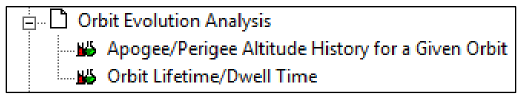
Orbital Lifetime Calculation

Satellite Body Dimensions		
Length	4.0	m
Width	1.8	m
Height	1.2	m
Solar Array Dimensions		
Length	6.0	m
Width	2.0	m
Area	12.0	m^2
Quantity	2	
Overall Vehicle Area		
Max Vehicle Area	28.3	m^2
Min Vehicle Area	2.6	m^2
Average Vehicle Area	15.45	m^2
Vehicle Mass		
Mass	386	kg
Area-to-Mass (A/M) Ratios		
Max A/M	0.0733	m^2/kg
Min A/M	0.0067	m^2/kg
Average A/M	0.0400	m^2/kg
Orbit		
Perigee Altitude	300	km
Apogee Altitude	1075	km
Inclination	97	deg

Orbital Lifetime		
(Calculated using NASA DAS)		
Nominal Operations	0.5	years
Nominal Disposal	1.1	years

Re-Entry Timeline Estimates / Orbit Dwell Time

NASA’s DAS provides tools to estimate spacecraft post-mission dwell time prior to atmospheric re-entry:

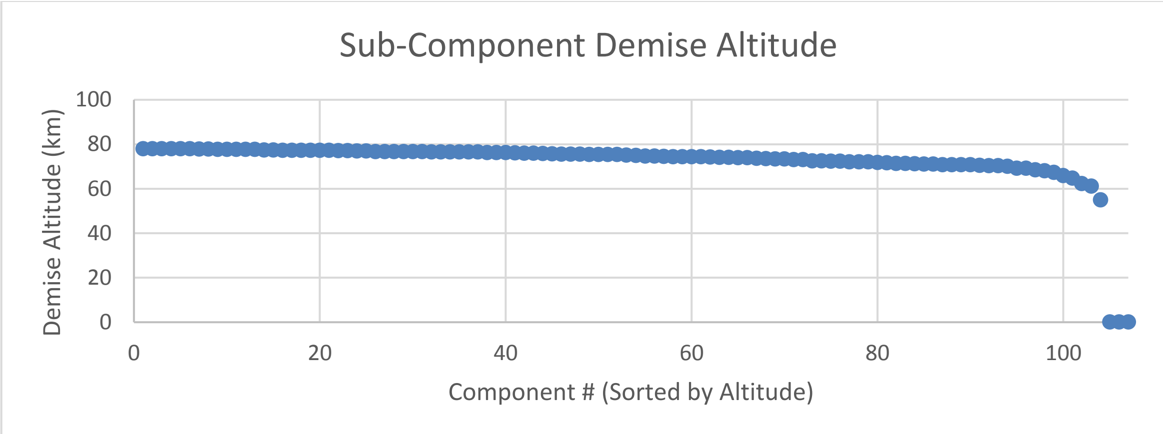


Re-entry timelines are also provided for several disposal perigees in proximity of the target. The 300 km target does not account for a fuel margin stack-up reserved for other uses. In the vast majority of cases, any remaining margin would allow satellites to push their perigee even lower past 300 km. Nonetheless, satellites will hold some fuel in reserve for conjunction avoidance during the de-orbit phase. Re-entry estimates for the year 2019:

Disposal Perigee	Time to Re-entry
200 km	26 days
250 km	102 days
> 300 km <	1.1 years
350 km	2.87 years
400 km	3.56 years

Atmospheric Demise

The spacecraft’s small mass and predominantly aluminum construction make atmospheric demise a likely scenario upon re-entry. To verify this, SpaceX also utilized NASA’s DAS. The satellite was broken down into approximately 100 major components, each defined with its own shape, material, mass and dimensions. Components were modeled in a nested fashion; a child component would not be exposed to the environment until its parent burned up. This enabled conservative re-entry survivability analysis of common problematic components, such as spherical fuel tanks contained within an enclosed spacecraft bus. DAS models the release of all root components 78 km above the surface; the demise altitudes of all modeled components is shown in the figure below:



Several objects were identified as components of interest. This reflected objects which had a distinct mass, quantity, or shape factor which made them of particular concern during re-entry analysis. Those components and their corresponding demise altitudes are given in the table below:

Component	Demise (km)
First Bus Panel	76.6
Reaction Wheels	74.6
Batteries	72.5
Propellant Tank	71.8
Last Bus Panel	71.7

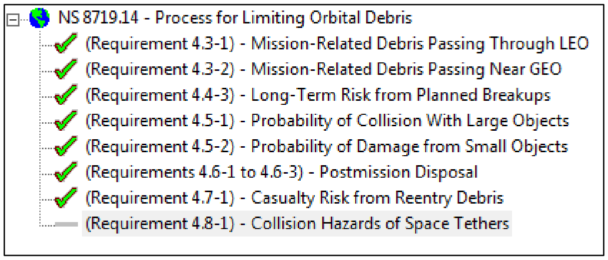
Although a major effort was made to avoid the use of components resistant to disintegration, some scenarios were unavoidable. DAS analysis indicates that three components may have a chance of reaching the Earth's surface; these components are listed in the table below. Of the three, only one contributes substantially to the total Debris Casualty Area ("DCA") calculation.

Component	Qty.	Material	Mass (kg)	Total DCA (m^2)	Energy (J)
Comms. Component	5	Silicon Carbide	1.50	2.79	961
Rotor Bearing	5	Stainless Steel	0.07	2.45	8
Strut Fitting	12	Titanium	0.03	4.92	6

The DCA model does not consider components characterized by a ground impact energy of less than 15 joules. The only components above this level with a chance of re-entry survivability are a set of silicon carbide communications components. The high survivability of the silicon carbide communications components stems from the material properties, primarily its very high melting point of 2,730 °C. The five components are the main contributors to the satellite's total DCA of 2.79 m^2. Yet even with these components, the total spacecraft Risk of Human Casualty is 1:31,400, satisfying the requirement of 1:10,000 established by NASA.

DAS Accordance

As shown in the screen shot below, the DAS assessment concludes that SpaceX's anticipated de-orbit plan satisfies all applicable requirements under NASA-STD-8719.14.[2]



[2] Requirement 4.8-1, related to Collision Hazards of Space Tethers, does not apply to SpaceX's satellites.