**Before the**
**FEDERAL COMMUNICATIONS COMMISSION**
**Washington, D.C. 20554**

| | | |
|---|---|---|
| In the Matter of | ) | |
| | ) | |
| BlackSky Global LLC | ) | |
| | ) | File No. |
| Application for Authority to Deploy and Operate an NGSO Earth Exploration Satellite Service Constellation System | ) | |

# APPLICATION NARRATIVE

## I. Introduction and Overview

BlackSky Global LLC ("BlackSky"), by its attorneys and pursuant to Section 25.113(g) of the Commission's rules, requests authority to deploy and operate a non-geostationary satellite orbit ("NGSO")-like Earth Exploration Satellite Service ("EESS") constellation ("BlackSky's Constellation"). As further described in this narrative to BlackSky's application ("Application"), BlackSky's Constellation will support and enhance BlackSky's global information platform providing a wide range of customers, including U.S. government agencies, with an affordable means of gathering information in real-time.

The present Application reflects BlackSky's near-term plan for four (4) satellites in orbit. BlackSky's plans, however, include the expansion of the Constellation to up to sixty (60) satellites, with additional inclinations to allow ubiquitous and frequent earth observation.

The Constellation will operate in the following frequency bands:

| | | |
|---|---|---|
| Primary Payload Downlink: | (X-band) | 8025-8400 MHz |
| Secondary TT&C Downlink: | (UHF) | 401-402 MHz |
| Primary TT&C Uplink | (S-band) | 2025-2100 MHz[1] |
| Secondary TT&C Uplink: | (UHF) | 449.75–450.25 MHz |
| GPS Receiver (receive-only) | (L-band) | 1575.42 MHz |

Details describing the orbital parameters are listed in Section 2 below.

## II. BlackSky Is Breaking New Ground for Global Information Gathering, Making Available Real-Time Data on an Affordable Basis

BlackSky is part of the Spaceflight Industries group of companies, founded in 1999, and headquartered in Seattle, Washington, with offices in Herndon, Virginia. With approximately 150 employees, BlackSky and its affiliate, Spaceflight, Inc. ("Spaceflight") operates in two synergistic lines of business: Spaceflight has revolutionized access to space, allowing its customers to buy "seats," not rockets, for capacity to space and other space based services. Among other accomplishments, Spaceflight was awarded the first (and to date only) General Services Administration contract for commercial launch services.

BlackSky has built and operates an analytics infrastructure that allows its customers to observe and understand in real time events and activities occurring

[1] These frequencies and UHF frequencies 449.75–450.25 MHz will be the subject of a separate earth station application.

around the world. BlackSky's multi-sensor global intelligence platform effectively creates for its customers a source for all relevant information fully integrated into one affordable package. The platform employs BlackSky's advanced analytics to integrate data derived from multiple third party geospatial sources (*e.g.*, visible imagery, radar imagery, and tracking data—including both on-demand imaging and persistent surveillance) coupled with BlackSky's activity monitoring (*e.g.*, the monitoring of social media, news feeds, and other data sources). The integrated and user-directed product allows BlackSky's customers to monitor and derive insights into relevant world events. Such insights include, for example, greater awareness and understanding of activity at a refugee camp, a pipeline or other key element in a supply chain, a border crossing or other sensitive locations, all in real time.

Through the development of BlackSky's Constellation, BlackSky plans to improve the services that it provides to its users in two ways: allowing BlackSky more immediately to direct and coordinate the focus of its observations on a particular area, not just once, but several times a day; and making the provision of such data far more affordable to its customers. By reducing the cost to build, launch, and orbit a high-resolution imaging satellite by two orders of magnitude, from hundreds of millions to <$10M, BlackSky will be able to reduce the cost of imagery from what is today, roughly $2500/image to a goal of $90/image. Imagery will be available for ordering on the web, with 90 minutes to delivery.

BlackSky will build its Constellation on lessons learned through its experimental program. BlackSky's first experimental satellite (Pathfinder-1)[2] allowed BlackSky to prove the concept that such a comparatively inexpensive satellite—built with standard hardware, software, and systems, yet possessing such important features as propulsion and tracking and control capabilities—can provide quality imagery and content, and will be able to do so at a fraction of today's prices. While the testing was largely successful, it also revealed shortcomings that BlackSky hopes to remedy with its Global satellite series. BlackSky notes in this regard that has a pending experimental license for the first satellite in the BlackSky's Constellation, Global-1.[3] BlackSky intends to use Global-1 initially for demonstration and testing, with a focus on that satellite's subsystems and what BlackSky believes will be improved the imaging capability of this second-generation prototype satellite. BlackSky is hopeful the testing will be successful, and is seeking a commercial authorization for Global-1, as part of the Constellation for which commercial authority is sought herein, once the test phase is over.

Among the many applications for BlackSky's Constellation is a collaborative effort with the United Nations Institute for Training and Research ("UNITAR"). Planned activities include joint work on research and innovative applications of satellite imagery, to include humanitarian relief, climate change

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[2] See 0831-EX-PL-2014, Call Sign WH2XPS
[3] See 0864-EX-CN-2017 filed on November 13, 2017

adaptation, disaster risk reduction, cultural heritage and environmental monitoring and sustainable development.

## III. Information Required Under Section 25.114(d) of the Commission's Rules

### A. Overall Description of Facilities and Operations[4]

#### 1. BlackSky's Constellation

This application is for authorization to operate the first commercial phase of the BlackSky Constellation. This phase includes four (4) microsatellites currently in development, including Global-1. Each satellite has a mass of approximately 55 kg, and take both still and video images at a resolution (GSD) of 1.0 m[5].

Each of the satellites will operate with its own propulsion system and includes GPS capability, enabling BlackSky to track the satellites, perform station-keeping, and undertake collision avoiding maneuvers, as needed.

The primary payload downlink for the Global satellites operates in the X-band. The Global satellites also have a beacon, which, when enabled, will transmit a single telemetry packet periodically through the entire orbit. This is used to aid in the initial acquisition of the satellite and will be disabled during normal operations. This beacon is transmitted in the satellites' UHF Transmit frequency, only (401.5 MHz).

[4] The required description of BlackSky's services is set forth in Section II above.
[5] This is performance at 450km, NADIR. Actual performance varies as a function of altitude.

The ground segment will be comprised of a network of geographically diverse ground stations. Initially, this will include two (2) earth stations, one (1) of which will operate in the United States, for which a separate application for commercial operation will be submitted to the Commission. Basic operating parameters for the two (2) earth stations are shown in Exhibit A hereto. The ground stations communicate with each of the satellites as they pass over their locations. No inter-satellite communications are planned for this generation of satellites.

BlackSky's satellites will be launched on several different launch vehicles and will operate in different orbits highlighted in the table below. This diversity, to be increased as BlackSky's Constellation is eventually grown to its presently planned sixty (60) satellites, will allow BlackSky to view locations multiple times a day, giving its customers a greatly increased understanding of activities at locations of interest.

**2. Orbital Information**

The next four BlackSky satellites will launch into various orbits, with the first two operating in Sun Synchronous orbits and the latter two in mid-inclination orbits. The planned orbit parameters for the four (4) satellites are described in the table below:

| Satellite Name | Altitude | Inclination | Period | LTDN/LTAN | Launch Provider and Launch Vehicle | Timeframe |
|---|---|---|---|---|---|---|
| Global 1 | 550 km circular[6] | 97.6° (SSO) | 96.0 min | 0930 LTDN | Antrix/ISRO Polar Satellite Launch Vehicle | NET May 31, 2018 |
| Global 2 | 585 km circular | 97.7° (SSO) | 96.7 min | 1030 LTAN | Space Exploration Technologies Corp. Falcon 9 | NET July 26, 2018 |
| Global 3 | 460 km circular | 45° | 94.2 min | Not applicable | Antrix/ISRO Polar Satellite Launch Vehicle | NET October 2018 |
| Global 4 | 475 km circular | 45° | 94.5 min | Not applicable | Rocket Lab/Electron Launch Vehicle | NET November 2018 |

BlackSky notes that the above orbits represent the orbits at which operations are planned to commence. Over time, even taking into account the use of the propulsion systems on board each satellite, physical laws mean that these orbits may naturally descend somewhat. BlackSky has addressed this potential in its worst case PFD analysis that is discussed below.

As shown in the above table, the Global-1 satellite is currently scheduled to launch no earlier than May 31, 2018. As discussed above, it is intended to commence

[6] This is the anticipated insertion altitude for Global-1, which is launching as a secondary payload,. That insertion altitude has not yet been finalized by the launch provider and it is possible that the insertion altitude will be 500 km circular. BlackSky will notify the Commission when the launch provider has made a final decision in this regard.

operation on an experimental basis, authority for which has been requested in a separate application that has been pending with the Commission for several months. Planned conversion to commercial operation will depend on the outcome of that testing. Global-2 is currently scheduled for launch no earlier than July 26, 2018; Global-3 is currently scheduled for launch no earlier than October 2018, and Global-4 is currently scheduled for launch no earlier than November 2018. BlackSky's Constellation will operate in the following frequency bands:

| | | |
|---|---|---|
| Primary Payload Downlink: | (X-band) | 8025-8400 MHz - |
| Secondary TT&C Downlink: | (UHF) | 401-402 MHz |
| Primary TT&C Uplink | (S-band) | 2025-2100 MHz |
| Secondary TT&C Uplink: | (UHF) | 449.75–450.25 MHz |
| GPS Receiver (receive-only): | (L-band) | 1575.42 MHz |

Further detail is provided in the technical exhibits.

### 3. Power Flux Density Calculations in the 8025-8400 MHz Band

Table 21-4 of the ITU Radio Regulations states that the power flux density (PFD) at the Earth's surface produced by emissions from an EESS space station in the 8025-8400 MHz band, including emissions from a reflecting satellite, for all conditions and for all methods of modulation, shall not exceed the following values:

- -150 dB(W/m) in any 4 kHz band for angles of arrival between 0 and 5 degrees above the horizontal plane;
- -150 + 0.5(d-5) dB(W/m) in any 4 kHz band for angles of arrival d (in degrees) between 5 and 25 degrees above the horizontal plane; and
- -140 dB(W/m) in any 4 kHz band for angles of arrival between 25 and 90 degrees above the horizontal plane.

The PFD is calculated as follows:

- PFD [dB(W/m / 4 kHz] = EIRP (dBW) – 71 – 20log10(D) – 10log10(BW) – 24
  Where EIRP is the Maximum EIRP of the transmission;
  D is the distance between the satellite and affected surface area in km; and
  BW is the bandwidth of the transmission in MHz.

As the PFD calculation averages the power over the entire bandwidth of the transmission, the calculation was compared to the measured output power of the transmitter in a 4kHz band, and the greater of the two was used in order to ensure a conservative PFD is used. The figure below (Figure 1) illustrates the calculated PFD for the maximum and worst case minimum altitudes for the Global 1-4 satellites, and demonstrate compliance with the requirement. The upper altitude shown is 585 km, which is the insertion altitude of the highest of the four satellites. The lowest altitude shown is 400 km. Global-3 is the lowest altitude satellite with an initial insertion altitude of 460 km. Nonetheless 400 km is used as the lower bound as, in the event that the altitude were to lower over time, that is the lowest possible operating altitude of the satellite. While neither planned nor anticipated, as this would be the worst case, the PFD values reported in the Schedule S are also shown at an altitude of 400 km.

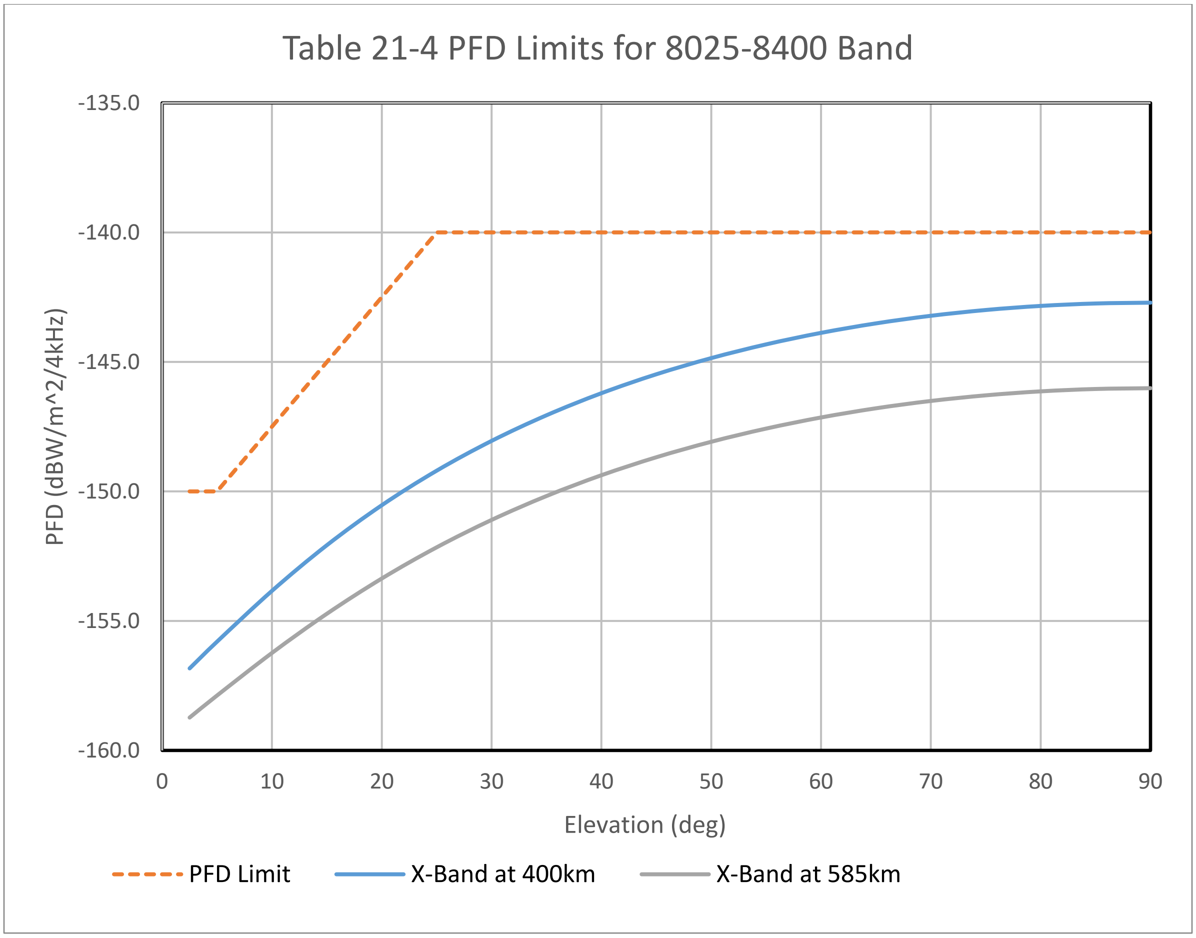


Figure 1: Global Satellite's Power Flux Density

ITU Radio Regulations No. 22.5 specifies that in the 8025-8400 MHz band, which is shared by EESS, fixed-satellite service (Earth-to-space), and the METS (Earth-to-space), the maximum PFD produced at the geostationary satellite orbit ("GSO") by any EESS space station shall not exceed -174 db (W/m) in any 4 kHz band. The calculation below shows that the PFD produced by the transmission from a Global satellite would not exceed that limit, even in the worst hypothetical case.

Using the worst case (i.e., highest altitude) orbit of the Global intended constellation (585 km), the distance to the geostationary orbit would be 35,186 km. At this orbital distance, for an antenna pointed towards the geostationary orbit having a maximum EIRP density of -19.7 dBW/4kHz , the PFD at the geostationary orbit would be approximately -181.6 dBW/m^2 in a 4kHz band.

### 4. Other Frequency Matters

#### (i) Overall Coordination with Federal Systems

Preliminary coordination has been conducted with relevant federal stakeholders. Specifically, BlackSky presented its constellation plans at the NASA DoD Frequency Pre-Coordination Meeting in Boulder, CO on March 2, 2017. BlackSky has had other communications regarding its plans with representatives of DoC , NASA and DoD . Most recently, BlackSky has been in communication with a representative of the NASA Goddard in the Spectrum Management division. The focus with NASA Goddard up to now has been on Global-1, but BlackSky will continue those coordination discussions as to Global-2, Global-3, and Global-4.

#### (ii) The 8025-8400 MHz Band

The 8025-8400 MHz band is allocated to a number of services, including EESS (space to Earth). BlackSky's proposed use of the frequencies in this band is consistent with this allocation.

Interference between the BlackSky satellites and those of other systems is very unlikely because EESS systems, including the one to be operated by BlackSky, operating in the 8025-8400 MHz band normally transmit only for short periods while they are visible from the dedicated receiving earth stations. For any interference to occur, one or more satellites belonging to different systems would have to travel through the antenna beam of the receiving earth station and transmit at the same time as the desired satellite. In such a very unlikely event, the interference can be avoided by coordinating the satellite transmissions so that they do not occur simultaneously. BlackSky will coordinate its operations with other satellite operators using the band to avoid such occurrence.

With respect to any potential interference with the Fixed Service, BlackSky's demonstrates above that the its satellite transmissions will meet the PFD limits specified by the ITU for the protection of the Fixed Service in the 8025-8400 MHz band.

**(iii) 2025-2110 MHz Band**

Non-federal EESS (Earth-to-space and space to Earth) may operate in the 2025-2100 MHz band, subject to such conditions as may be applied on a case-by-case basis. Transmission to satellites operating in this band shall not cause harmful interference to federal and non- federal stations operating in accordance with the U.S. Table of Frequency Allocations.[7] BlackSky will coordinate with federal and non-federal operators in this band to ensure compliance with this requirement.

**(iv) 401-402 MHz Band**

The 401-402 MHz band is allocated to several services, include Space Operation (space to Earth). BlackSky's proposed use of the frequencies in this band is consistent

[7] *See* 47 C.F.R. § 2.106, note US 347.

with this allocation. BlackSky will coordinate with federal and non-federal operators in this band as needed to avoid harmful interference.

**(v) 449.75–450.25 MHz Band**

The 449.75-450.25 MHz may be used by federal and non-federal stations for space telecommand (Earth-to-space) at specific locations, subject to such conditions as may be applied on a case-by-case basis. [8] BlackSky's proposed use of the frequencies in this band is consistent with the guidance in US Table note 87 and has designed the carrier frequency close to 450 MHz (450.2 MHz).

**5. Clarifications as to Certain Schedule S Responses**

Receiving Beams URC and URX in the Schedule S describe a UHF omni directional whip antenna. The signal is described as having linear polarization and it is intended to close the link in almost any spacecraft orientation. With the spacecraft telescope oriented to nadir and the spacecraft in a high elevation pass over a ground station, the polarization will be predominately horizontal so 0 deg has been selected for the polarization angle in the Schedule S. Similar to the X/S patterns, no specific control in z axis rotation is assumed, so the provided patterns can rotate 0-360 deg, still assuming nadir pointing of the telescope.

Similarly, the ground station antennas for this beam use circularly polarized antennas to be able to close the link regardless of spacecraft orientation, so only RHCP patterns were developed for the spacecraft. The UHF co-polar patterns submitted reflect

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[8] *See* 47 C.F.R. § 2.106, note US 87.

a linear co-polar by adding 3dB to these circular patterns, while the cross-polar patterns are simply the original RHCP.

With regard to the gain patterns and contour plots, the X/S fixed beam is directed at ground station location by orienting spacecraft. There is no specific control in z axis rotation, so schedule S patterns may be rotated in any direction 0-360.

With regard to the Orbital Planes defined in the Schedule S, Orbital Planes 3 and 4 are for 45 degree inclination orbits. The Right Ascension of the Ascending Node of these two planes will be a function of the day and time of launch which is not yet finalized, so it has been listed as 0 degrees.

**B. Public Interest Considerations**

As set forth above, grant of the Application will allow BlackSky to support and enhance its global information platform, thereby providing its customers with an affordable and comprehensive means of understanding the world in real-time. Employing its own fleet of satellites operating at various inclinations, BlackSky will be better able to respond to its customer requirements for real-time information about human and environmental activities at critical locations around the world. Further, BlackSky's ability to build and place into service satellites at a fraction of the cost of today's high resolution imagery satellites will allow BlackSky to offer its customers quality imagery at a fraction of today's prices. Bringing access to earth observation not just to the wealthy, but to the world, as reflected in BlackSky's above-described planned collaboration with UNITAR is an important part of BlackSky's mission. BlackSky submits that this mission well serves the public interest.

### C. Orbital Debris Mitigation

BlackSky has conducted an orbital debris assessment for all Global satellites. Details of this assessment are shown in Exhibit B to this Narrative. This assessment demonstrates that all systems are compliant with applicable policies.

## IV. Waiver Requests

### A. Modified Processing Round Rules

BlackSky requests waiver of Sections 25.156 and 25.157 of the Commission's rules, which provide for the processing of "NGSO-like satellite systems" under a modified processing round framework. BlackSky requests instead that this Application be processed pursuant to the first-come, first-served procedure adopted for "GSO-like satellite systems" under Section 25.158 of the Commission's rules.

The Commission has waived the modified processing round requirement and allowed EESS NGSO satellite systems to be processed on a first-come, first-served basis on multiple occasions. In *Space Imaging, LLC*, the Commission concluded that authorizing Space Imaging to operate in its requested EESS frequency bands would not preclude other NGSO operators from operating in those bands because EESS NGSO operators are generally capable of sharing spectrum in the same frequency.[9] Subsequent waivers have been granted to other EESS operators, each premised on a showing that such operators would be capable of sharing with current and future NGSO systems operating in the same frequency bands.[10] As demonstrated in Section III.A.4 (ii) above, BlackSky is equally capable of such sharing.

As the Commission stated in its space imaging Order, "[t]he purpose of the modified processing round rule is to preserve opportunities for competitive market entry in frequency bands where licensing the first applicant to operate throughout the band would prevent subsequent applicants from using the spectrum."[11] Because, as with EESS NGSO applications previously granted, grant of BlackSky's application would not prevent subsequent applications from using the spectrum, grant of the waiver would not undermine the policy objectives of the rule and, as shown herein, would otherwise serve the public interest. Accordingly, good cause exists to waive the modified processing round rules.[12]

**B. Default Service Rules**

BlackSky requests a waiver of the default service rules under Section 25.217(b) of the Commission's rules. Although the Commission has not adopted band-specific rules

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[9] *See Space Imaging, LLC, Declaratory Order and Order and Authorization,* 20 FCC Rcd 11694, 11968 (2005) ("*Space Imaging Order*").
[10] *See e.g., Spire Global, Inc.* SAT-LOA-20151123-00078 (granted Oct. 14, 2016)*; Planet Labs, Inc.,* SAT-LOA-20130626-00087 (granted Dec. 3, 2013)*; Skybox Imaging, Inc.,* SAT-LOA-20120322-00058 (granted Sep. 20, 2012).
[11] *Space Imaging Order*, 20 FCC Rcd at ¶ 10.
[12] *See WAIT Radio v. FCC*, 418 F.2d 1153, 1157 (D.C. Cir 1969).

for EESS NGSO operations in the 8025-8400 MHz band, the Commission has granted to NGSO EESS system licensees on multiple occasions waivers of the default service rules contained in Section 25.217(b), based on the fact that EESS operators in the 8025-8400 MHz band are required to comply with technical requirements in Part 2 of the Commission's rules and applicable ITU rules.[13] In these cases, the Commission concluded that because the cited requirements had been sufficient to prevent harmful interference in the 8025-8400 MHz band, there was no need to impose additional technical requests.[14] For these same reasons, the Commission should grant BlackSky a waiver of the default service rules contained in Section 25.217(b)

## V. Other Matters

### A. Milestones

Pursuant to Section 25.164(b) of the Commission's rules, NGSO system licensees are required to launch and operate their NGSO constellations within six years of grant. BlackSky will demonstrate compliance with the FCC requirement by submitting Section 25.164(f) information as and when required.

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[13] *See Space Imaging Order*, 20 FCC Rcd at 11973-74 ¶¶ 26-31; *DigitalGlobe, Inc.*, Order and Authorization, 20 FCC Rcd 15696 ¶¶ 1, 15 (2005); *see also* Planet Labs, Inc., SAT-MOD-20150802-00053 (granted Sept. 15, 2016), SAT-LOA-20130626-00087 (granted Dec. 3, 2013); Skybox Imaging, Inc., SAT-LOA-20120322-00058 (granted Sep. 20, 2012).

[14] *Id.*

### B. Posting of Bond

Pursuant to Section 25.165(a) of the Commission's rules, NGSO system licensees are subject to post-grant bond requirements. BlackSky will comply with these requirements.

### C. ITU Advance Publication Materials and Cost Recovery

BlackSky is preparing ITU filing information as required under Section 25.111(d) of the Commission's rules and will provide this information along with a signed declaration of unconditional acceptance of all consequent ITU cost-recovery responsibility under separate cover.

### D. Notification of Intent to Commence Space Station Construction

Pursuant to Section 25.113(f) of the Commission's rules, BlackSky hereby notifies the Commission of its intent to commence construction at its own risk of the Global satellites that are the subject of this Application.

### E. NOAA Authorization

On August 28, 2017, the National Oceanic and Atmospheric Administration ("NOAA") issued a BlackSky a license to operate the Global 1-4 satellites. A copy of NOAA's public summary indicated that grant is attached to this Narrative as Exhibit C.

BlackSky notes that, since the NOAA license was issued, the planned altitudes of some the Global satellites have been adjusted. BlackSky has submitted a request to

NOAA to amend BlackSky's license to reflect these changes. BlackSky will notify the Commission when this amendment is granted and will submit a copy of the updated NOAA public summary reflecting this amendment when it becomes available.

## VI. CONCLUSION

In view of the foregoing, grant of BlackSky's Application is in the public interest, and it is respectfully requested that the Commission grant the application expeditiously.

Respectfully submitted,

/s/

Henry Goldberg
Jonathan L. Wiener
GOLDBERG, GODLES, WIENER
& WRIGHT, LLP
1025 Connecticut Ave, N.W., Suite 1000
Washington, DC 20036
(202) 429-4900

March 19, 2018

## ATTACHMENT A

## CERTIFICATION OF PERSON RESPONSIBLE FOR PREPARING ENGINEERING INFORMATION

I hereby certify that I am the technically qualified person responsible for preparation of the engineering information contained in this application and associated attachments, that I am familiar with Part 25 of the Commission's rules, that I have either prepared or reviewed the engineering information submitted in this Application and that it is complete and accurate to the best of my knowledge and belief.

/s/______________________
John Springmann, Ph.d.
Director, BlackSky Constellation

## EXHIBIT A

## EARTH STATION INFORMATION

Expected parameters for the earth stations to be transmitting to the Global constellation are shown below. A commercial application for use of the planned Alaska earth station that will be filed separately. BlackSky will seek additional authority from the Commission, as needed, if and to the extent that additional earth stations are sought to be used to communicate to the Global constellation.

**Locations:**

- North Pole, Alaska
  - Lat/Long: 64° 47' 38" N, 147° 32' 09" W
  - Site elevation: 144 m AMSL
  - Site address: 1625 Richardson Highway, North Pole, AK 99705, USA
- Awarua Plains, New Zealand
  - Lat/Long: 46° 31' 43" S, 168° 22' 52" E
  - Site elevation: 24 m AMSL
  - Site address: 781 Colyer Road, Awarua Plains 9877, New Zealand

**Transmitter information (applicable to both locations):**

**UHF uplink:**

- Center frequency: 450.2 MHz
- Bandwidth: 30 kHz
- Emission designator: 30K0F1D
- Modulating signal: GMSK
- Polarization: RHCP
- EIRP: 22.8 dBW
- Beamwidth: 30 deg
- Azimuth: 0-360 deg (LEO tracking)
- Elevation: 5-90 deg (LEO tracking)

**S-band uplink:**

- Center frequency: 2071.875 MHz
- Bandwidth: 200 kHz
- Emission designator: 200KF1D
- Modulating signal: GMSK
- Polarization: RHCP

- EIRP: 43.0 dBW
- Beamwidth: 1 deg from Alaska antenna, 2.7 deg from New Zealand antenna
- Azimuth: 0-360 deg (LEO tracking)
- Elevation: 5-90 deg (LEO tracking)

# EXHIBIT B

# ORBITAL DEBRIS MITIGATION

# BlackSky Global Global-1,2,3, & 4 satellites Orbital Debris Assessment Report (ODAR)

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

**Report Version: C, March 14, 2018**

Revision history:

| Version | Date | Author | Description |
|---|---|---|---|
| 1 | 1/4/17 | Lang Kenney | Creation of report for Global-1 spacecraft |
| 2 | 1/20/2017 | Lang Kenney | Update of the report to include Global-2,3,4 |
| 3 (B) | 4/26/2017 | John Springmann | Modified Global-1 orbit |
| C | 3/14/2018 | John Springmann | Update to the satellite altitudes and latest launch windows. Satellite mass and volume updated to final as-built values. |

**Document Data is Not Restricted.**

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

**DAS Software Version Used In Analysis: v2.0.2**
**DAS Solar flux file Used: Released 14 August 2017**

## Table Contents



## Table of figures



## Table of tables

# 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: Global-1, -2, -3, -4 Satellites

| Requirement # | Launch Vehicle | | | | Spacecraft | | | Comments |
|---|---|---|---|---|---|---|---|---|
| | Compliant | Not Compliant | Incomplete | Standard Non Compliant | Compliant or N/A | Not Compliant | Incomplete | |
| 4.3-1.a | ☐ | ☐ | ☐ | ☐ | ☒ | ☐ | ☐ | No Debris Released in LEO. |
| 4.3-1.b | ☐ | ☐ | ☐ | ☐ | ☒ | ☐ | ☐ | No Debris Released in LEO. |
| 4.3-2 | ☐ | ☐ | ☐ | ☐ | ☒ | ☐ | ☐ | No Debris Released in GEO. |
| 4.4-1 | ☐ | ☐ | ☐ | ☐ | ☒ | ☐ | ☐ | Not applicable. |
| 4.4-2 | ☐ | ☐ | ☐ | ☐ | ☒ | ☐ | ☐ | Warm-gas propulsion tank will be deplete during operations |
| 4.4-3 | ☐ | ☐ | ☐ | ☐ | ☒ | ☐ | ☐ | No planned breakups. |
| 4.4-4 | ☐ | ☐ | ☐ | ☐ | ☒ | ☐ | ☐ | No planned breakups. |
| 4.5-1 | ☐ | ☐ | ☐ | ☐ | ☒ | ☐ | ☐ | Collision probability 0.00001 |
| 4.5-2 | ☐ | ☐ | ☐ | ☐ | ☒ | ☐ | ☐ | Damage probability < 0.0099 |
| 4.6-1(a) | ☐ | ☐ | ☐ | ☐ | ☒ | ☐ | ☐ | Natural forces cause atmospheric reentry |
| 4.6-1(b) | ☐ | ☐ | ☐ | ☐ | ☒ | ☐ | ☐ | Not applicable. |
| 4.6-1(c) | ☐ | ☐ | ☐ | ☐ | ☒ | ☐ | ☐ | Not applicable. |
| 4.6-2 | ☐ | ☐ | ☐ | ☐ | ☒ | ☐ | ☐ | Spacecraft does not go to GEO. |
| 4.6-3 | ☐ | ☐ | ☐ | ☐ | ☒ | ☐ | ☐ | Spacecraft does not go beyond LEO. |
| 4.6-4 | ☐ | ☐ | ☐ | ☐ | ☒ | ☐ | ☐ | Requirements 4.6-1 through 4.6-3 are met |
| 4.7-1 | ☐ | ☐ | ☐ | ☐ | ☒ | ☐ | ☐ | DAS reports human casualty probability < 1:10,000 |
| 4.8-1 | | | | | ☒ | ☐ | ☐ | No tethers used. |

# Assessment Report Format:

ODAR Technical Sections Format Requirements:

BlackSky Global, LLC is a US company; this ODAR, for BlackSky Global's Global-1,2,3, & 4 satellites, 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. Sections 9 through 14 apply to the launch vehicles ODAR and are not covered here.

All files created from the DAS 2.0.2 software and calculation files are located on windchill.

Windchill Link (This is a BlackSky Global, LLC internal reference)

# ODAR Section 1: Program Management and Mission Overview

**Project Manager:** John Springmann

**Foreign government or space agency participation:** none

**Schedule of upcoming mission milestones:**

| Satellite | Flight Readiness Review | Launch |
|---|---|---|
| Global-1 | April 2018 | June 2018 |
| Global-2 | 1 month prior to launch | August 2018 |
| Global-3 | 1 month prior to launch | October 2018 |
| Global-4 | 1 month prior to launch | December 2018 |

*Table 1: Mission Milestones*

**Mission Overview:**
Global-1, 2, 3, and 4 are commercial Earth observation satellites. These are the first of many satellites planned for BlackSky's earth-observing constellation. This ODAR covers these four satellites, which are launching throughout 2018 (see table 1 above). Two of the satellites will be deployed into sun-synchronous orbits, and two will be deployed to 45 degree orbits; each orbit is given in Table 3 below.

The planned mission duration is for each Global satellite is 36 months (3 years). At the end of its mission, the satellite will release any remaining propellant (which is expected to be depleted during operations) and rely on atmospheric drag to fully deorbit the spacecraft.

**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 (max is 24.4 years including 3 years of operations, as calculated by DAS 2.0.2).

**Launch vehicles and launch sites:**

| Project | Launch Vehicle | Launch location |
|---|---|---|
| **Global-1** | **PSLV** | **Satish Dhawan Space Centre, Sriharikota, India** |
| **Global-2** | **SpaceX Falcon 9** | **Vandenberg Air Force Base, CA** |
| **Global-3** | **PSLV** | **Satish Dhawan Space Centre, Sriharikota, India** |
| **Global-4** | **Rocket Lab Electron** | **Mahia Peninsula, New Zealand** |

*Table 2: Launch Vehicles and Launch Sites*

**Mission duration:** Maximum Nominal Operations: 36 months (3 years)

**Post-Operations Orbit lifetime:** See table 5 in section 6.4

**Constellation Launch and deployment profile:**

| Project | Altitude | Inclination | LTDN or LTAN | Comments |
|---|---|---|---|---|
| Global-1 | 550 km circular | 97.59° | 09:30 LTDN | |
| Global-2 | 585 km circular | 97.73° | 10:30 LTAN | |
| Global-3 | 460 km circular | 45° | Not applicable | RAAN will vary over time; precessing orbit |
| Global-4 | 475 km circular | 45° | Not applicable | RAAN will vary over time; precessing orbit |

*Table 3: Orbit profiles*

# ODAR Section 2: Spacecraft Description

**Physical description of the spacecraft:**

Each Global satellite has a launch mass of 56.4 kg. Basic physical dimensions are 55 cm x 67 cm x 86 cm. A CAD model of the spacecraft is shown in Figure 1 (each of the four Global satellites are identical).

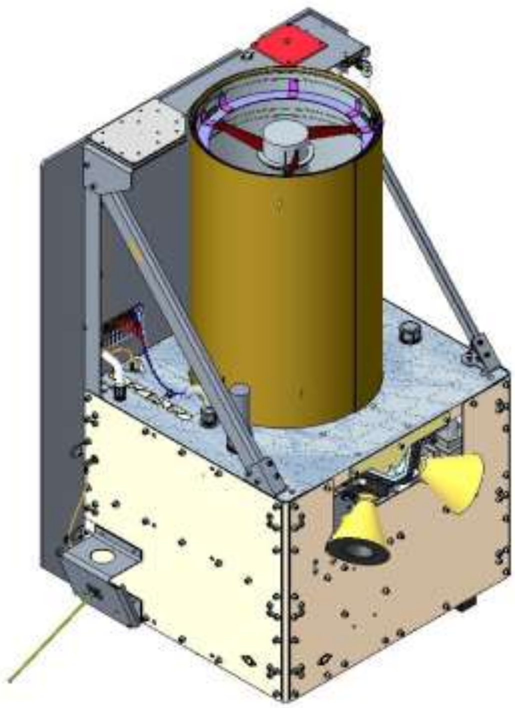

*Figure 1. CAD model of the Global-1 spacecraft.*

Each Global satellite's load bearing structure is comprised of three 45 cm x 50 cm skeleton deck plates, radiating side plates, and a vertical mounted 66.5cm x 86 cm side solar panel connected with struts. The Global satellites maintain 3-axis attitude control. Attitude knowledge is provided primarily by two orthogonally mounted star trackers. Attitude actuators include four reaction wheels and three orthogonal magnetorquers.

**Total satellite mass at launch, including all propellants and fluids:** 56.4 kg.

**Dry mass of satellites at launch, excluding solid rocket motor propellants:** 52.7 kg

**Description of all propulsion systems (cold gas, mono-propellant, bi-propellant, electric, nuclear):**

Each Global satellite contains a single propulsion system with a single valve and a single thruster. This system uses electrically warmed butane as the working fluid. Butane is stored at saturation conditions (normally 1 to 100 psi) within two interconnected tanks. The butane is warmed to several hundred degrees Celsius via an electrically heated aluminum block just before exiting the nozzle. Propulsion is not required to deorbit the satellite, but is part of the satellite to allow for orbit phasing and minor orbit adjustments.

**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:** 3.76 kg of butane at saturation conditions not to exceed 100psia

**Fluids in Pressurized Batteries:** None. Each Global sat uses two unpressurized standard COTS Lithium-Ion batteries. Each battery has a height of 98mm, a width of 96mm, a length of 176mm, and a mass of 1.6 kg.

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

The long axis of the spacecraft can be oriented parallel to the nadir vector during imaging, but the satellite will typically be oriented in a sun-pointing attitude. For the purposes of orbital debris assessment, the smallest (worst-case for orbital lifetime) cross-sectional area is used, meaning that a face of 55 x 55 cm is in the velocity direction (the actual area of the deck plates are 45 x 50 cm, but there are some protrusions from the plates, such as the start trackers, so 55 x 55 cm is used). This results in a cross-section area of 0.3025$m^2$. The cross sectional area in a nadir-pointing configuration would be between 0.47 $m^2$ and 0.57 $m^2$.

**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 solar 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.

In addition to the battery protection mentioned about, the Global-1 battery unit features two temperature sensors which monitor battery cells for high temperatures.

**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:**

It is expected that all propellant (butane) in the propulsion system will be consumed by EOM. In the event that it is not, it will be released (used to lower the orbit as much as possible) before EOM. In the event of a system failure that prevents release of all propellant, it has no detrimental impact; the orbital lifetime predictions assume the worst-case scenario that propulsion is not used to lower the orbit, and the butane itself does not pose a risk if not passivated.

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

Global 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.

**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.

*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 3:* 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 4:* 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 5:* 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 6:* 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 7:* 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 cannot cause an explosion or deflagration large enough to release orbital debris or break up the spacecraft (Requirement 56450).*

**Compliance statement:**
Global 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:**

| Satellite | Collision Probability | Compliance status |
|---|---|---|
| Global-1 | 0.00001 | COMPLIANT |
| Global-2 | 0.00001 | COMPLIANT |
| Global-3 | 0.00000 | COMPLIANT |
| Global-4 | 0.00000 | COMPLIANT |

*Table 4: Large Debris Generation*

***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: not applicable; COMPLIANT.

The satellite orbits decay naturally; no propulsion is required for most-mission disposal. Thus there are no parts of the satellite that are critical to be in compliance with post-mission disposal requirements.

**Identification of all systems or components required to accomplish any postmission disposal operation, including passivation and maneuvering:**
No systems or components are required. The orbits for Global-1, -2, -3, and -4 naturally decay with no maneuvering required.

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

6.1 **Description of spacecraft disposal option selected:** After completing its planned operations, the satellites will deorbit naturally by atmospheric re-entry. At the end of each of the Global satellite's operational life (i.e. at EOM) the attitude control system will stop counteracting the aerodynamic disturbance torques. This will result in the satellite gradually assuming a dynamically stable configuration. For atmospheric drag / re-entry calculations in DAS, the minimum plausible cross-section drag area of 55 x 55 cm was assumed. This is conservative because it represents the minimum cross section possible and ignores the fact that the satellite may be in other orientations after the end of the mission.

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

No maneuvers are required following normal operations.

**6.3 Calculation of area-to-mass ratio after postmission disposal, if the controlled reentry option is**

**not selected:**

**Spacecraft Mass (EOL):** 52.7 kg

**Cross-sectional Area:** 0.3025 $m^2$

**Area to mass ratio:** 0.0057 $m^2$/kg

### 6.4 Assessment of spacecraft compliance with Requirements 4.6-1 through 4.6-5 (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.*

The analysis of this requirement for each satellite is shown below.

| Satellite Name | Operational Orbit | Post-ops Life | Total Lifetime |
|---|---|---|---|
| Global-1 | 550 km circular | 15.2 | 18.2 years |
| Global-2 | 585 km circular | 21.4 years | 24.4 years |
| Global-3 | 460 km circular | 3.9 years | 6.9 years |
| Global-4 | 475 km circular | 4.4 years | 7.4 years |

*Table 5: Lifetimes*

Altitude history versus time was analyzed for each Global satellite and is shown on the following pages.

**Global-1 Altitude history over time:**

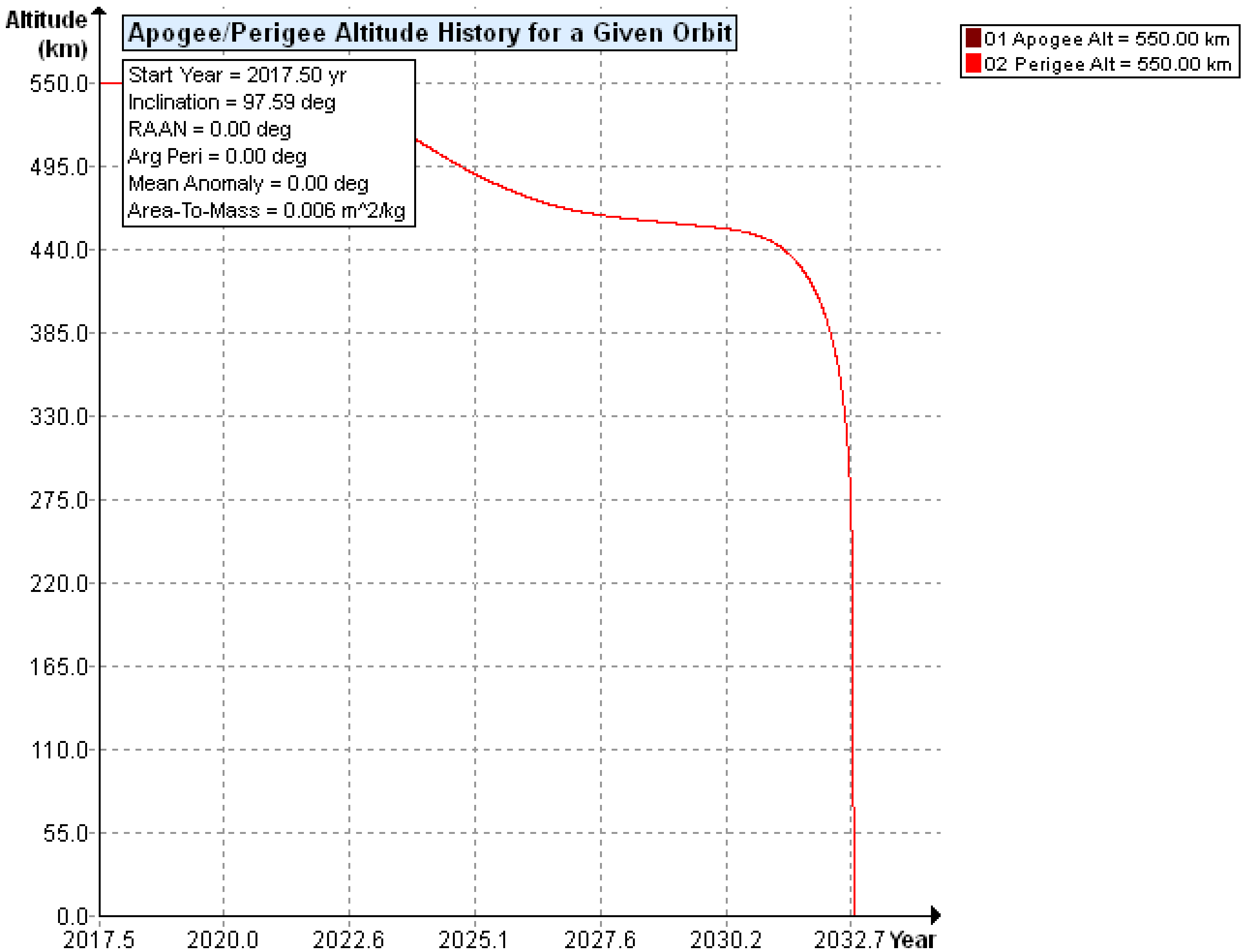


*Figure 2: Global-1 Apogee/Perigee Altitude History for a Given Orbit*

**Analysis:** The Global-1 satellite reentry is COMPLIANT using method "a: *Atmospheric reentry option*".

**Global-2 Altitude history over time:**

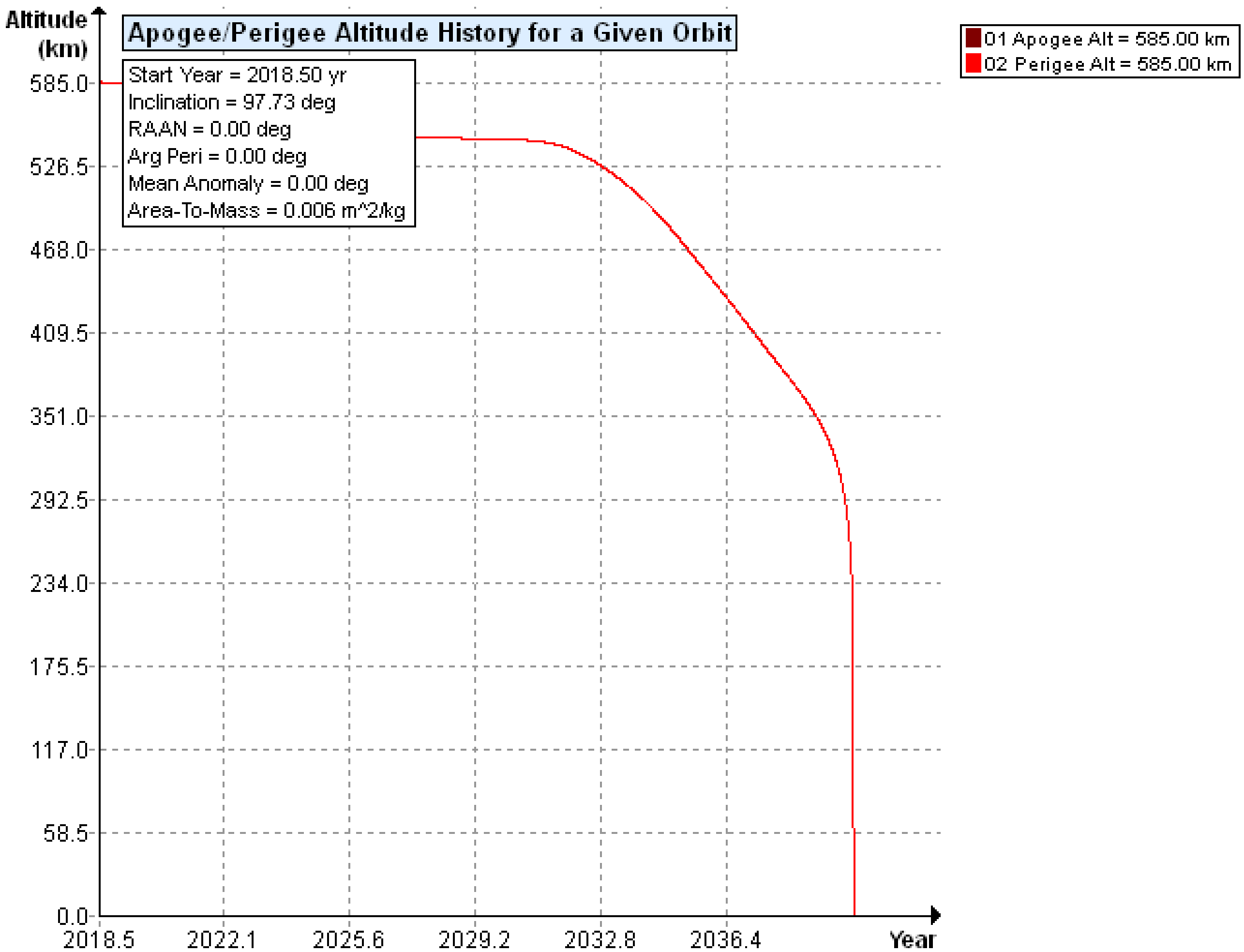


*Figure 3: Global-2 Apogee/Perigee Altitude History for a Given Orbit*

**Analysis:** The Global-2 satellite reentry is COMPLIANT using method "a: *Atmospheric reentry option*".

**Global-3 Altitude history over time:**

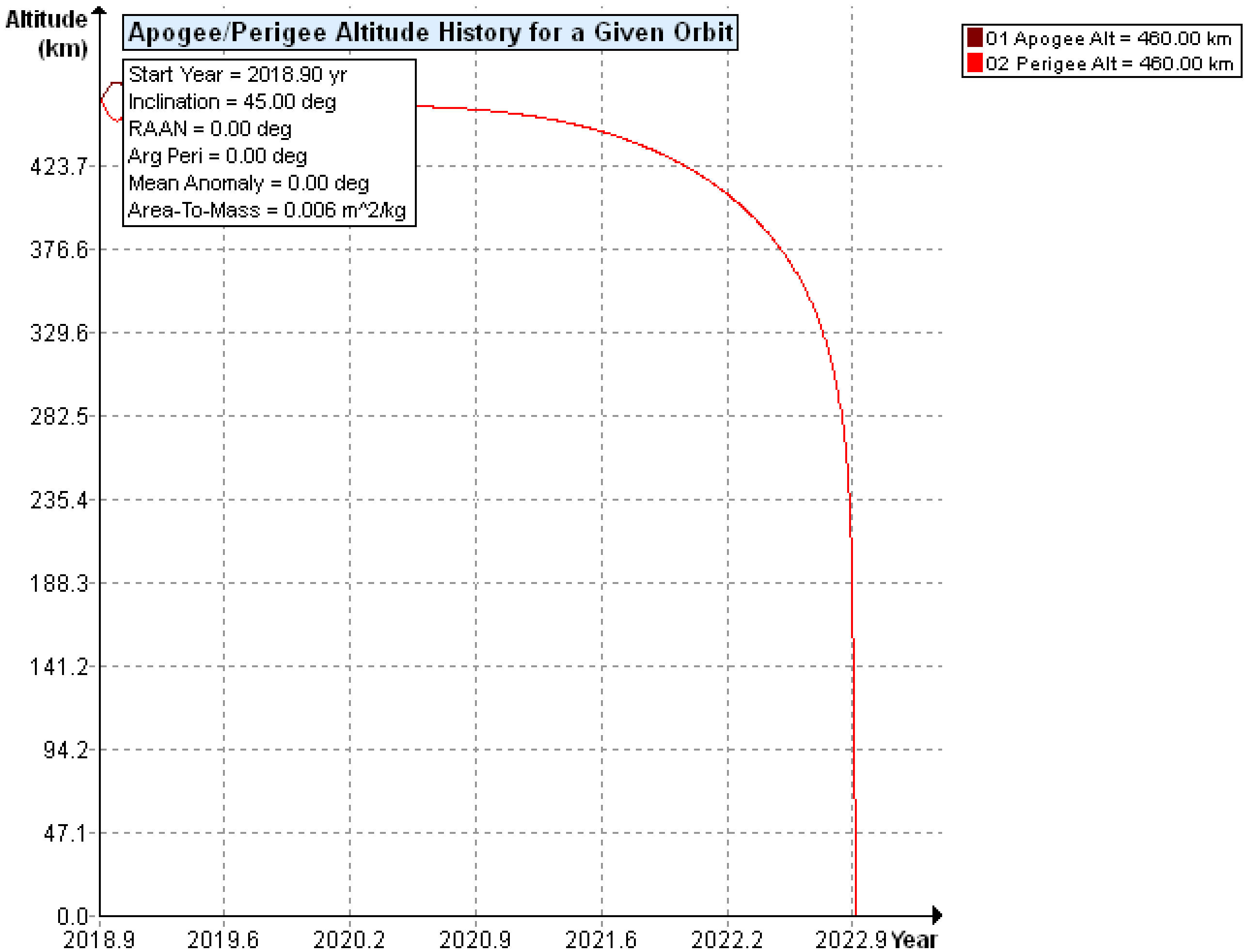


*Figure 4: Global-3 Apogee/Perigee Altitude History for a Given Orbit*

**Analysis:** The Global-3 satellite reentry is COMPLIANT using method "a: *Atmospheric reentry option*".

**Global-4 Altitude history over time:**

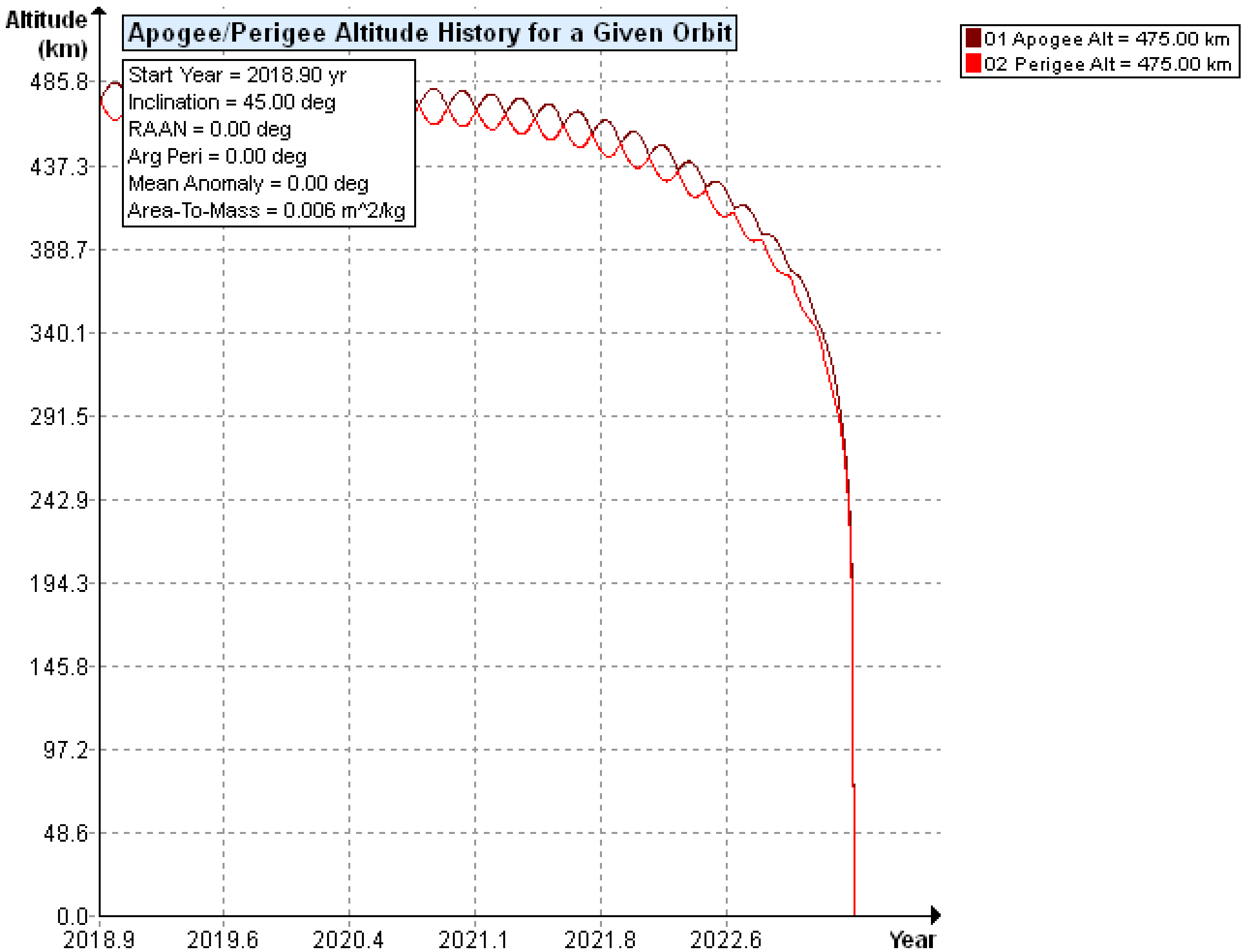


*Figure 5: Global-4 Apogee/Perigee Altitude History for a Given Orbit*

**Analysis: The Global-4 satellite reentry is COMPLIANT using method "a: Atmospheric reentry option".**

***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 minimum drag configuration is the aerodynamically stable state, and provides the worst-case re-entry time. This minimum drag configuration was assumed for atmospheric re-entry analysis.

# 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 each Global satellite is compliant with the requirement. The total risk of human casualty for each spacecraft is given in the table below. According to DAS calculations, there is a low probability that some spacecraft components may reach the ground (see DAS input data below for input parameters). However, the DAS software does not currently allow explicit modeling of the specific geometries for these components, so these numbers are expected to be larger than anticipated due to conservatism in the inputs provided to DAS.

| Satellite | Risk of Human Casualty | Compliance status |
|---|---|---|
| Global-1 | 1:26,600 | COMPLIANT |
| Global-2 | 1:25,500 | COMPLIANT |
| Global-3 | 1:11,700 | COMPLIANT |
| Global-4 | 1:11,600 | COMPLIANT |

*Table 6. Casualty risk from re-entry debris.*

Below is a full output from the DAS software for Global-1, but each satellite has a similar report with the only difference in inputs being the varying orbital elements.

**Analysis (per DAS v2.0.2):**

```
03 01 2018; 11:19:01AM  DAS Application Started
03 01 2018; 11:19:01AM  Opened Project C:\Users\jspringmann\Downloads\DAS
files from WC\Global-1 in 550km orbit\
03 01 2018; 11:19:09AM  Processing Requirement 4.3-1: Return Status :  Not Run

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

=============== End of Requirement 4.3-1 ===============
03 01 2018; 11:19:10AM  Processing Requirement 4.3-2: Return Status : Passed

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

```
=====================

=============== End of Requirement 4.3-2 ===============
03 01 2018; 11:19:11AM  Requirement 4.4-3:  Compliant

=============== End of Requirement 4.4-3 ===============
03 01 2018; 11:19:15AM  Processing Requirement 4.5-1: Return Status :  Passed

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

**INPUT**

      Space Structure Name = Global-1
      Space Structure Type = Payload
      Perigee Altitude = 550.000000 (km)
      Apogee Altitude = 550.000000 (km)
      Inclination = 97.590000 (deg)
      RAAN = 0.000000 (deg)
      Argument of Perigee = 0.000000 (deg)
      Mean Anomaly = 0.000000 (deg)
      Final Area-To-Mass Ratio = 0.005700 (m^2/kg)
      Start Year = 2018.000000 (yr)
      Initial Mass = 56.400000 (kg)
      Final Mass = 52.600000 (kg)
      Duration = 3.000000 (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 = 0.000007
      Returned Error Message: Normal Processing
      Date Range Error Message: Normal Date Range
      Status = Pass

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

=============== End of Requirement 4.5-1 ===============
03 01 2018; 11:19:16AM  Processing Requirement 4.6    Return Status :  Passed

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

**INPUT**

      Space Structure Name = Global-1
```

```
      Space Structure Type = Payload

      Perigee Altitude = 550.000000 (km)
      Apogee Altitude = 550.000000 (km)
      Inclination = 97.590000 (deg)
      RAAN = 0.000000 (deg)
      Argument of Perigee = 0.000000 (deg)
      Mean Anomaly = 0.000000 (deg)
      Area-To-Mass Ratio = 0.005700 (m^2/kg)
      Start Year = 2018.000000 (yr)
      Initial Mass = 56.400000 (kg)
      Final Mass = 52.600000 (kg)
      Duration = 3.000000 (yr)
      Station Kept = False
      Abandoned = True
      PMD Perigee Altitude = 548.586933 (km)
      PMD Apogee Altitude = 548.586933 (km)
      PMD Inclination = 97.641091 (deg)
      PMD RAAN = 359.716472 (deg)
      PMD Argument of Perigee = 3.482473 (deg)
      PMD Mean Anomaly = 0.000000 (deg)

**OUTPUT**

      Suggested Perigee Altitude = 548.586933 (km)
      Suggested Apogee Altitude = 548.586933 (km)
      Returned Error Message = Passes LEO reentry orbit criteria.

      Released Year = 2032 (yr)
      Requirement = 61
      Compliance Status = Pass

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

=============== End of Requirement 4.6 ===============
03 01 2018; 11:19:19AM  *********Processing Requirement 4.7-1
      Return Status :  Passed

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

name = Global-1
quantity = 1
parent = 0
materialID = 5
type = Box
Aero Mass = 52.599998
Thermal Mass = 52.599998
Diameter/Width = 0.500000
Length = 0.845000
Height = 0.450000

name = Payload Deck
quantity = 1
parent = 1
```

```
materialID = 8
type = Flat Plate
Aero Mass = 12.770090
Thermal Mass = 5.400000
Diameter/Width = 0.450000
Length = 0.500000

name = Telescope
quantity = 1
parent = 2
materialID = 5
type = Cylinder
Aero Mass = 5.860000
Thermal Mass = 5.860000
Diameter/Width = 0.300000
Length = 0.478000

name = Camera
quantity = 1
parent = 2
materialID = -2
type = Box
Aero Mass = 0.319000
Thermal Mass = 0.319000
Diameter/Width = 0.045000
Length = 0.045000
Height = 0.039000

name = Star Tracker
quantity = 2
parent = 2
materialID = 5
type = Cylinder
Aero Mass = 0.158000
Thermal Mass = 0.158000
Diameter/Width = 0.100000
Length = 0.120000

name = IMU
quantity = 2
parent = 2
materialID = 8
type = Box
Aero Mass = 0.055000
Thermal Mass = 0.055000
Diameter/Width = 0.038600
Length = 0.044800
Height = 0.021500

name = Magnetometer 1
quantity = 1
parent = 2
materialID = 8
type = Box
Aero Mass = 0.080090
```

```
Thermal Mass = 0.080090
Diameter/Width = 0.043000
Length = 0.099170
Height = 0.017000

name = DC-DC Converter 1
quantity = 5
parent = 2
materialID = 8
type = Box
Aero Mass = 0.137000
Thermal Mass = 0.137000
Diameter/Width = 0.077500
Length = 0.083000
Height = 0.018230

name = Antenna Deck
quantity = 1
parent = 1
materialID = 8
type = Flat Plate
Aero Mass = 1.173090
Thermal Mass = 0.363000
Diameter/Width = 0.450000
Length = 0.500000

name = X-Band Antenna
quantity = 1
parent = 9
materialID = 8
type = Flat Plate
Aero Mass = 0.300000
Thermal Mass = 0.300000
Diameter/Width = 0.103403
Length = 0.149936

name = S-Band Antenna
quantity = 1
parent = 9
materialID = 8
type = Flat Plate
Aero Mass = 0.120000
Thermal Mass = 0.120000
Diameter/Width = 0.083820
Length = 0.083820

name = Magnetometer 2
quantity = 1
parent = 9
materialID = 8
type = Box
Aero Mass = 0.080090
Thermal Mass = 0.080090
Diameter/Width = 0.045000
Length = 0.099170
```

```
Height = 0.017000

name = Coarse Sun Sensor
quantity = 2
parent = 9
materialID = 8
type = Cylinder
Aero Mass = 0.005000
Thermal Mass = 0.005000
Diameter/Width = 0.015300
Length = 0.064000

name = UHF Patch
quantity = 1
parent = 9
materialID = -2
type = Flat Plate
Aero Mass = 0.300000
Thermal Mass = 0.300000
Diameter/Width = 0.088900
Length = 0.088900

name = Propulsion Deck
quantity = 1
parent = 1
materialID = 8
type = Flat Plate
Aero Mass = 13.033000
Thermal Mass = 5.400000
Diameter/Width = 0.450000
Length = 0.500000

name = Tank 1
quantity = 1
parent = 15
materialID = 5
type = Cylinder
Aero Mass = 3.440000
Thermal Mass = 3.440000
Diameter/Width = 0.159766
Length = 0.249936

name = Tank 2
quantity = 1
parent = 15
materialID = 5
type = Cylinder
Aero Mass = 3.440000
Thermal Mass = 3.440000
Diameter/Width = 0.159766
Length = 0.249936

name = Valve Assembly
quantity = 1
parent = 15
```

```
materialID = 8
type = Box
Aero Mass = 0.210000
Thermal Mass = 0.210000
Diameter/Width = 0.046355
Length = 0.096500
Height = 0.025400

name = HEX
quantity = 1
parent = 15
materialID = 54
type = Box
Aero Mass = 0.388000
Thermal Mass = 0.388000
Diameter/Width = 0.054940
Length = 0.127000
Height = 0.007620

name = Couse Sun Sensor
quantity = 4
parent = 15
materialID = 8
type = Cylinder
Aero Mass = 0.005000
Thermal Mass = 0.005000
Diameter/Width = 0.015300
Length = 0.064000

name = Fine Sun Sensor
quantity = 1
parent = 15
materialID = 5
type = Box
Aero Mass = 0.035000
Thermal Mass = 0.035000
Diameter/Width = 0.032000
Length = 0.034000
Height = 0.021000

name = UHF Patch Antenna
quantity = 1
parent = 15
materialID = 8
type = Flat Plate
Aero Mass = 0.100000
Thermal Mass = 0.100000
Diameter/Width = 0.088900
Length = 0.088900

name = Avionics Deck
quantity = 1
parent = 1
materialID = 8
type = Flat Plate
```

```
Aero Mass = 18.226700
Thermal Mass = 5.400000
Diameter/Width = 0.450000
Length = 0.500000

name = PCU
quantity = 1
parent = 23
materialID = 5
type = Box
Aero Mass = 0.990000
Thermal Mass = 0.990000
Diameter/Width = 0.147000
Length = 0.202000
Height = 0.050000

name = Battery
quantity = 2
parent = 23
materialID = -1
type = Box
Aero Mass = 1.600000
Thermal Mass = 1.600000
Diameter/Width = 0.098000
Length = 0.176000
Height = 0.096000

name = DC-DC Converter 2
quantity = 3
parent = 23
materialID = 8
type = Box
Aero Mass = 0.137000
Thermal Mass = 0.137000
Diameter/Width = 0.077500
Length = 0.083000
Height = 0.018230

name = X-Band Radio
quantity = 1
parent = 23
materialID = 8
type = Box
Aero Mass = 1.000000
Thermal Mass = 1.000000
Diameter/Width = 0.115000
Length = 0.160000
Height = 0.046000

name = S-Band Radio
quantity = 1
parent = 23
materialID = 8
type = Box
Aero Mass = 0.200000
```

```
Thermal Mass = 0.200000
Diameter/Width = 0.050000
Length = 0.135000
Height = 0.025000

name = UHF Radio/Splitter
quantity = 1
parent = 23
materialID = 54
type = Box
Aero Mass = 0.230000
Thermal Mass = 0.230000
Diameter/Width = 0.057150
Length = 0.082550
Height = 0.015748

name = FC
quantity = 1
parent = 23
materialID = 8
type = Box
Aero Mass = 4.280000
Thermal Mass = 4.280000
Diameter/Width = 0.121920
Length = 0.216408
Height = 0.092202

name = Reaction Wheels
quantity = 4
parent = 23
materialID = 8
type = Box
Aero Mass = 0.226000
Thermal Mass = 0.226000
Diameter/Width = 0.140000
Length = 0.140000
Height = 0.041900

name = Torque Rods
quantity = 3
parent = 23
materialID = 54
type = Cylinder
Aero Mass = 0.420000
Thermal Mass = 0.420000
Diameter/Width = 0.022220
Length = 0.227000

name = GPS Receiver
quantity = 1
parent = 23
materialID = 54
type = Box
Aero Mass = 0.214700
Thermal Mass = 0.214700
```

```
Diameter/Width = 0.057150
Length = 0.060320
Height = 0.012060

name = DC-DC Converter 3
quantity = 1
parent = 23
materialID = 8
type = Box
Aero Mass = 0.137000
Thermal Mass = 0.137000
Diameter/Width = 0.077500
Length = 0.083000
Height = 0.018230

name = Solar Array
quantity = 1
parent = 1
materialID = 24
type = Flat Plate
Aero Mass = 3.800000
Thermal Mass = 3.800000
Diameter/Width = 0.665000
Length = 0.845000

name = Radiating Side Panel
quantity = 2
parent = 1
materialID = 8
type = Flat Plate
Aero Mass = 0.700000
Thermal Mass = 0.700000
Diameter/Width = 0.380000
Length = 0.431000

name = Support Strut
quantity = 2
parent = 1
materialID = 8
type = Box
Aero Mass = 0.144000
Thermal Mass = 0.144000
Diameter/Width = 0.150000
Length = 0.582000
Height = 0.020000

name = Front Side Panel
quantity = 1
parent = 1
materialID = 8
type = Flat Plate
Aero Mass = 0.700000
Thermal Mass = 0.700000
Diameter/Width = 0.380000
Length = 0.480000
```

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

name = Global-1
Demise Altitude = 77.997738
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Payload Deck
Demise Altitude = 68.789425
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Telescope
Demise Altitude = 58.137268
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Camera
Demise Altitude = 68.789425
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Star Tracker
Demise Altitude = 67.243152
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = IMU
Demise Altitude = 66.135363
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Magnetometer 1
Demise Altitude = 66.673597
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = DC-DC Converter 1
Demise Altitude = 65.178812
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Antenna Deck
Demise Altitude = 77.361043
Debris Casualty Area = 0.000000
```

```
Impact Kinetic Energy = 0.000000

************************************
name = X-Band Antenna
Demise Altitude = 72.365089
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = S-Band Antenna
Demise Altitude = 73.436082
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Magnetometer 2
Demise Altitude = 75.114863
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Coarse Sun Sensor
Demise Altitude = 76.979519
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = UHF Patch
Demise Altitude = 77.361043
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Propulsion Deck
Demise Altitude = 68.836691
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Tank 1
Demise Altitude = 57.202401
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Tank 2
Demise Altitude = 57.202401
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Valve Assembly
Demise Altitude = 64.189874
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
```

```
************************************
name = HEX
Demise Altitude = 0.000000
Debris Casualty Area = 0.439607
Impact Kinetic Energy = 439.467926

************************************
name = Couse Sun Sensor
Demise Altitude = 68.506175
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Fine Sun Sensor
Demise Altitude = 66.439527
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = UHF Patch Antenna
Demise Altitude = 65.667777
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Avionics Deck
Demise Altitude = 69.335386
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = PCU
Demise Altitude = 61.782218
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Battery
Demise Altitude = 69.335386
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = DC-DC Converter 2
Demise Altitude = 66.339042
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = X-Band Radio
Demise Altitude = 60.916089
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
```

```
************************************
name = S-Band Radio
Demise Altitude = 66.407894
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = UHF Radio/Splitter
Demise Altitude = 0.000000
Debris Casualty Area = 0.428833
Impact Kinetic Energy = 185.805313

************************************
name = FC
Demise Altitude = 49.900959
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Reaction Wheels
Demise Altitude = 67.090363
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Torque Rods
Demise Altitude = 60.721546
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = GPS Receiver
Demise Altitude = 0.000000
Debris Casualty Area = 0.416913
Impact Kinetic Energy = 217.247711

************************************
name = DC-DC Converter 3
Demise Altitude = 66.339042
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Solar Array
Demise Altitude = 0.000000
Debris Casualty Area = 1.821465
Impact Kinetic Energy = 419.436310

************************************
name = Radiating Side Panel
Demise Altitude = 76.005504
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
```

```
name = Support Strut
Demise Altitude = 77.545371
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Front Side Panel
Demise Altitude = 76.215902
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

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

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

# ODAR Section 8: Assessment for Tether Missions

Not applicable. There are no tethers on the Global satellites.

**END of ODAR for Globa1s -1, -2, -3, -4**

**EXHIBIT C**

**NOAA PUBLIC SUMMARY**

**Global 1-4 Constellation Private Remote Sensing Space System**

On August 28, 2017, the Commercial Remote Sensing Regulatory Affairs Office of the National Oceanic and Atmospheric Administration, an agency of the Department of Commerce, granted a license to BlackSky Global, LLC to operate the first phase of the Global Constellation, satellites 1-4, a private, commercial, space-based, remote sensing system (the “Global Constellation”).

These first four satellites, which make up the initial phase of the Global Constellation, are licensed to collect images of the Earth and will operate in circular orbits with altitudes ranging from 500-575 km and inclinations near 97 degrees. The first phase will be followed by additional launches, culminating in the planned constellation of sixty satellites total, operating in mid-inclination and sun-synchronized orbits and at altitudes near 500 km.

Inquiries should be directed to legal@spaceflightindustries.com or

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