Before the
Federal Communications Commission
Washington, DC 20554

In the Matter of	)	
	)	
HawkEye 360, Inc.	)	File No. SAT-MOD-_________
	)	
Application to Modify License	)	Call Sign: S3042
	)	
	)	
	)	

MODIFICATION APPLICATION

HawkEye 360, Inc. ("HE360") hereby requests that the Space Bureau ("Bureau") modify the company's space station license ("HE360 Constellation").[1] Specifically, HE360 seeks authority to:

- launch and operate an additional, single demonstration satellite, Kestrel-0A;
- revise the concept of operations ("CONOPS") and deorbit plan to allow a combination of beginning-of-life propulsive maneuvers, as necessary, and passive decay, which will ensure compliance with the FCC's recently adopted five-year deorbit rule;
- modify the operating altitude range for the HE360 Constellation from 475 - 615 km to 400 km - 600 km to reflect the revised CONOPS and deorbit plan;[2] and
- conduct sensing operations throughout the 30 MHz to 18 GHz frequency range.

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[1] *See* Stamp Grant, HE360, ICFS File No. SAT-LOA-20190102-00001 (granted in part Dec. 10, 2019); Stamp Grant, HE360, ICFS File Nos. SAT-MOD-20220906-00099, SAT-AMD-20221014-00136 (granted in part Mar. 13, 2024).

[2] HE360 previously requested to change the operating altitude range from 475-615 km to 400-615 km. *See* Application of HE360, ICFS File No. SAT-MOD-20230724-00181 (filed July 24, 2023). Accordingly, this application seeks only to lower the maximum operating altitude from 615 km to 600 km.

Kestrel-0A will operate as part of the authorized HE360 Constellation. It differs from the authorized satellites in the HE360 Constellation primarily in that it has an 8U cubesat form factor and will have onboard an Iridium satellite transceiver used for low-rate, real-time two-way communications between the Kestrel-0A satellite and the HE360 ground network via the Iridium constellation. Kestrel-0A will otherwise operate in the same frequencies within the same technical performance envelopes authorized for the HE360 Constellation and communicate with the same ground stations authorized for the system. Consistent with the public interest, the requested authorization will allow the company to test a new satellite form factor that would facilitate the company's ability to meet commercial demands and enhance the range of services HE360 is able to provide its customers. Moreover, the proposed demonstration satellite will not cause harmful interference or raise orbital debris mitigation concerns. Additional details regarding the Kestrel-0A satellite are provided in Attachment 1.

To ensure compliance with the FCC's recently adopted five-year deorbit rule,[3] consistent with the public interest, HE360 requests authority to modify its CONOPS and deorbit plan to utilize a combination of beginning-of-life propulsive maneuvers, as necessary, and passive decay. In short, within approximately three months after deployment, HE360 will execute beginning-of-life propulsive maneuvers, as necessary, to lower the orbit of any satellite in the HE360 Constellation to 556 km (circular).[4] As demonstrated in Attachments 2 and 3, this beginning-of-life maneuver and natural orbital decay at the end-of-mission will ensure that

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[3] *See Space Innovation; Mitigation of Orbital Debris in the New Space Age*, Second Report and Order, IB Docket Nos. 22-272, 18-313, FCC 22-74 (September 30, 2022). The new orbital debris mitigation requirements, amending 47 C.F.R. § 25.114, have not yet been published in the Federal Register.

[4] As explained in Attachment 2, for Kestrel-0A, HE360 will lower the orbit to 554 km, as necessary, to ensure compliance with the FCC's five-year deorbit requirement.

HE360 satellites deployed after September 2024, including Kestrel-0A, will comply with the Commission's five-year orbital debris mitigation requirements. For the same reasons, HE360 also requests that the authorized operating altitude range be modified to 400-600 km to reflect the revised CONOPS and orbital debris mitigation plan.[5]

With respect to Hawkeye's sensing authorization, the current license states:[6]

> HE360 satellites have antennas capable of receiving in the following bands: 100-182 MHz (VHF Dipole): 382-422 MHz (UHF Dipole): 1090 MHz (ADS-B Patch): 1.6-1.7 GHz (L-band Patch); 2.9-3.1 GHz (S-band Patch): 1.4-7.0 GHz (Molded Button Antenna); 6.0-18.0 GHz (Horn Antenna). Starting with HE360 satellite cluster two, the satellites include antennas capable of receiving signals in the frequency bands used by the GPS L1 (center frequency 1575.42 MHz), L2 (center frequency 1227.60) and L5 (center frequency 1176.45 MHz) signals (GNSS Antenna). Starting with HE360 satellite cluster four, the Molded Button Antenna has been replaced by a Spiral-Backed Antenna capable of receiving in the 600 MHz-10 GHz frequency bands. Starting with HE360 satellites in Cluster 7, the satellites will include antennas capable of receiving signals in the 250-350 MHz frequency band, and the 1090 MHz (ADS-B Patch) antenna will be removed. Starting with HE360 satellites in Cluster 9, the satellites will include additional antennas capable of receiving signals in the 30-88 and 120-800 MHz frequency bands.

Similarly, the license application identifies the antenna type, the relevant frequency tuning range, the intended use of the sensing, and the applicable clusters. See the table below.[7]

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[5] *See supra* note 2.

[6] Stamp Grant, HE360, ICFS File Nos. SAT-MOD-20220906-00099, SAT-AMD-20221014-00136, at footnote 8 (granted in part Mar. 13, 2024).

[7] *See* Application of HE360, ICFS File No. SAT-MOD-20220906-00099, at Attachment 1 (granted in part Mar. 13, 2024).

Table 1-1: FCC Authorized and Requested Passive RF Antennas and Sensed Spectrum Ranges

Antenna Types	Frequency Ranges	Intended Use	Clusters
E-Field Probe	30-88 MHz	VHF signal geolocation	Cluster 9+
VHF Monopole	100-182 MHz	AIS processing and signal geolocation	Cluster 2+
Wire Discone	120-800 MHz	VHF & UHF signal geolocation	Cluster 9+
UHF Monopole	250-350 MHz	UHF signal geolocation	Cluster 7+
UHF Monopole	382-422 MHz	EPIRB processing and geolocation	Cluster 2+
ADS-B Patch	1090 MHz (on frequency only)	L-band signal geolocation	Cluster 2 - 6
GNSS Antenna	1575.42 MHz (L1) 1227.60 MHz (L2) 1176.45 MHz (L5)	Geolocation of L-band signals from terrestrial sources	Cluster 2+
L-band Patch	1.6-1.7 GHz	L-band signal geolocation	Cluster 2+
S-band Patch	2.9-3.1 GHz	S-band signal geolocation	Cluster 2+
Spiral Backed Antenna (previously, Molded Button Antenna)	600 MHz to 10 GHz	Broadband spectrum scanning and monitoring; signal occupation and ID	Cluster 2+
Horn Antenna	6.0-18.0 GHz	Marine X-Band RADAR and Ku-band SATCOM geolocation and signal metadata	Cluster 2+
Rabbit	840-960 MHz and 1280-1410 MHz	Industrial, scientific, and medical, and L-band signal geolocation	Cluster 3

HE360 submits that the process and method for identifying sensing antennas and relevant sensing frequencies is unnecessarily complicated and does not appear relevant to any radiofrequency interference concern.[8] With respect to orbital debris matters, all antennas have

[8] The FCC has on many occasions concluded that receiving signals or electromagnetic energy cannot cause harmful interference to any service. *See, e.g.*, *Application of Iridium Constellation LLC*, Order and Authorization, 31 FCC Rcd 8675, para. 21 (IB 2016) ("The reception of transmissions, AIS or other, cannot cause harmful interference, and these transmissions will be present pursuant to existing authorizations using frequencies allocated to other services regardless of whether they are received by an Iridium second-generation satellite."); Stamp

been identified in submitted ODARs, and HE360 has conducted analyses to ensure that any permutation of antennas used on a spacecraft will comply with debris mitigation requirements.[9] Moreover, experience with the antennas on orbit has indicated that the antennas have a wider usable frequency tuning range than previously expected (albeit at reduced efficiency and/or performance).

Accordingly, HE360 requests that the Bureau simplify the sensing capabilities language provided in the license to state as follows: "HE360 satellites have antennas capable of sensing radiofrequency electromagnetic energy in the 30 MHz to 18 GHz range." HE360 further requests that the Bureau permit HE360 to use any combination of antennas that the company has identified in its ODARs.[10]

For the above reasons, HE360 submits that grant of this application serves the public interest and requests that the FCC grant the application prior to October 2024, which is the target date for the next launch and the start date for the FCC's new five-year deorbit requirement for current licensees.

HE360 is including a Schedule S that provides the technical parameters of Kestrel-0A and an orbital debris assessment report for that satellite.[11] Below is a list of the attachments included with the application narrative.

- Attachment 1 – Demonstration Mission Technical Description

Grant, HE360, ICFS File Nos. SAT-MOD-20220906-00099, SAT-AMD-20221014-00136, at footnotes 22, 25-27 (granted in part Mar. 13, 2024).

[9] HE360 is submitting a comprehensive ODAR that indicates all of the antennas that may be used to sense in the 30 MHz to 18 GHz frequency range.

[10] *See* Attachment 4 at p. 4.

[11] The Schedule S technical parameters for the authorized HE360 Constellation satellites are available in ICFS File No. SAT-MOD-20220906-00099. To be clear, nothing in this application modifies or changes the Schedule S technical parameters for those satellites.

- Attachment 2 – Demonstration Mission Orbital Debris Assessment Report
- Attachment 3 – HE360 Constellation Five-Year Deorbit Compliance Analysis
- Attachment 4 – HE360 Constellation Orbital Debris Assessment Report
- Attachment 5 – Technical Certification
- Attachment 6 – Ownership Information

Except as stated specifically in this application, including the Schedule S and attachments, HE360 is not requesting any other changes to its license or authorized satellite operations and certifies that such operations remain unchanged.

Respectfully submitted,

/s/ Dennis Burnett

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Dated: 03 April 2024

Attachment 1

Demonstration Mission Technical Description

Mission Description

HE360 plans to launch and operate a demonstration mission of a new spacecraft design, known as Block 3 Lite. The name of this demonstration spacecraft is Kestrel-0A. The demonstration satellite will be part of the HE360 Constellation and operate as one of the 60 simultaneously operating spacecraft and one of the 174 authorized spacecraft over the 15-year license term. Like the authorized spacecraft in the HE360 Constellation, Kestrel-0A will have payloads used to receive and/or sense radio frequency ("RF") spectrum,[1] use the same TT&C and payload communications frequencies authorized in the HE360 Constellation, and operate under the same technical performance envelope as the current system.[2]

Unlike the currently authorized satellites in the HE360 Constellation, Kestrel-0A will operate as a single spacecraft and not in a cluster of three spacecraft. Additionally, Kestrel-0A will have an 8U cubesat form factor. Kestrel-0A will also have onboard an Iridium satellite transceiver used for low-rate, real-time two-way communications with HE360, via the Iridium constellation and network.

Kestrel-0A Orbital Parameters

Kestrel-0A is expected to be launched on a SpaceX Falcon 9 dedicated rideshare mission and deployed via a cubesat dispenser with flight heritage. The orbital parameters for the Kestrel-0A mission are provided below:

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[1] As discussed below, Kestrel-0A will have onboard an RF sensing payload to perform the same mission as typical HE360 satellite but with modifications to accommodate the physical constraints of the 8U form factor.

[2] The communications frequencies are identified in Table 1-1 *infra*.

- Launch Window: NET October 1, 2024
- Nominal Deployment Altitude: 510 km +/- 20 km

  As explained in the ODAR, the current launch plan is to deploy at 510 km +/- 20 km. However, because this is a demonstration mission and the target launch may move, HE360 is showing compliance of the spacecraft up to a 575 km deployment altitude, which is the maximum altitude which Kestrel-0A will remain compliant with the 5-year deorbit requirement.
- Deployment Eccentricity: nearly circular
- Deployment Inclination: Sun Synchronous Orbit (SSO) +/- 0.1 deg.

RF Payload Sensing Suite

Kestrel-0A will have onboard an RF sensing payload to perform the same mission as that for the authorized HE360 Constellation, but with modifications to accommodate the smaller form factor satellite. For avoidance of doubt, Kestrel-0A will have an L-band patch antenna capable of sensing in the 1600-1700 MHz range, two S-band patch antennas capable of sensing in the 2900-3100 MHz range, a spiral-backed antenna capable of sensing in the 1300-18000 MHz range, and a horn antenna capable of sensing in the 6000-18000 MHz range.

Communications Links

Kestrel-0A will operate using communications links that have been already authorized for satellites in the HE360 Constellation. Specifically, Kestrel-0A will use the "Channel #2" links of the authorized constellation, as identified in Table 1-1 below. The telemetry, tracking, and command ("TT&C") links will use the same TT&C frequencies authorized in the HE360 Constellation and will operate under the same technical performance envelope as the current system. Kestrel-0A will use the same payload data transmitter as already authorized for the constellation and will operate using the same earth stations as already coordinated.

In addition to using already-authorized HE360 Constellation communication links, Kestrel-0A will have onboard an inter-satellite link ("ISL") transceiver, which will communicate with the Iridium satellite network, as a customer of Iridium. The Iridium terminal will transmit and receive in the 1618.725-1626.5 MHz frequency band, which is allocated for the Mobile-Satellite Service. HE360 requests to use the frequencies in order to communicate through the Iridium system. HE360 requests a waiver of the U.S. Table of Frequency Allocations and any other applicable FCC rule to communicate with Iridium satellites. HE360 expects Iridium to file a separate companion application for authority to conduct such communications.

The Commission may waive any of its rules if there is "good cause" to do so.[3] In general, waiver is appropriate if (1) special circumstances warrant a deviation from the general rule; and (2) such deviation would better serve the public interest than would strict adherence to the rule.[4] Generally, the Commission will grant a waiver of its rules in a particular case if the relief requested would not undermine the policy objective of the rule in question and would otherwise serve the public interest.[5] HE360 submits that good cause exists to waive the U.S. Table of Frequency Allocations.

HE360 is a customer of Iridium. Transmissions will occur only on frequencies that Iridium assigns to the terminals onboard the HE360 spacecraft. HE360 understands that

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[3] *See* 47 C.F.R. § 1.3; *Northeast Cellular Tel. Co. v. FCC,* 897 F.2d 1164 (D.C. Cir. 1990); *WAIT Radio v. FCC,* 418 F.2d 1153 (D.C. Cir. 1969).

[4] *See Northeast Cellular,* 897 F.2d at 1166.

[5] *See WAIT Radio,* 418 F.2d at 115.

transmissions are on a non-conforming basis. For the above reasons, grant of the waiver is justified.

For clarity, Table 1-1 below details the communications links for the Kestrel-0A spacecraft.

Table 1-1: Kestrel-0A Communications Links

Frequency Band (MHz)	Use	Transmit Center Frequency (MHz)
X-band: 8025-8400 MHz	Payload downlink	8165 MHz
X-band: 8025-8400 MHz	TT&C downlink	8297 MHz
S-band: 2025-2110 MHz	Payload uplink	2049.3 MHz
S-band: 2025-2110 MHz	TT&C uplink	2053 MHz
L-band: 1618.725-1626.5 MHz	Inter-satellite Link (transmit & receive)	1618.725-1626.5 MHz

For the X-band payload transmitters, the following interference analysis is provided to show compliance with the FCC's and ITU's usage requirements.

A. 8025-8400 MHz

a. Interference with the Fixed Service and the FSS in the band 8025-8400 MHz

Section 25.208 of the Commission's rules does not contain Power Flux Density ("PFD") limits at the Earth's surface produced by emissions from NGSO EESS space stations operating in the 8025-8400 MHz band.[6] Table 21-4 of the ITU Radio Regulations, however, states that the PFD at the Earth's surface produced by emissions from an EESS space station in the 8025-8400

[6] *See* 47 C.F.R. § 25.208.

MHz band, including emissions from a reflecting satellite, for all conditions and for all methods of modulation, shall not exceed the following values:[7]

- -150 dB(W/m²) in any 4 kHz band for angles of arrival between 0 and 5 degrees above the horizontal plane;
- -150 +0.5(δ -5) dB(W/m²) in any 4 kHz band for angles of arrival (in degrees) between 5 and 25 degrees above the horizontal plane; and
- -140 dB(W/m²) in any 4 kHz band for angles of arrival between 25 and 90 degrees above the horizontal plane.

These limits relate to the PFD that would be obtained under assumed free-space propagation conditions. As shown in Figure 1 below, the PFD at the Earth's surface produced by the satellite telemetry transmissions from the TT&C transceiver onboard Kestrel-0A satisfies the PFD limits in the ITU Radio Regulations for all angles of arrival. This PFD is based on the narrowest expected transmitter bandwidths and lowest operating altitude of 400 km to show the worst-case operating conditions. The X-band TT&C downlink can operate with emission bandwidths as narrow as 10 kHz and as wide as 300 kHz. As the bandwidth is increased so is the RF power such that the EIRP density and PFD stay constant.

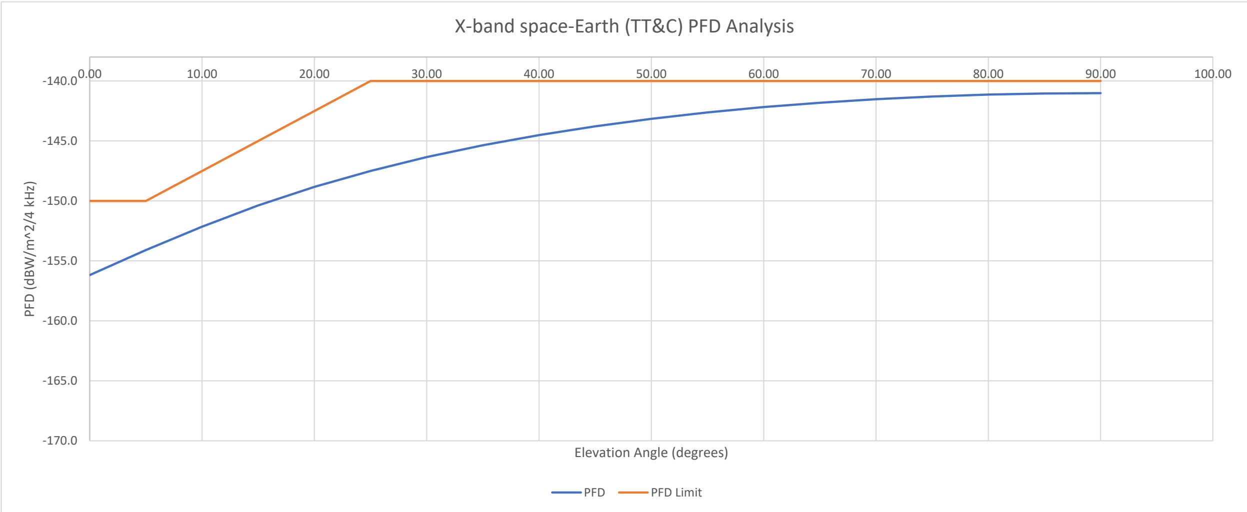


Figure 1: X-band Demo TT&C at the Surface of the Earth (EIRP: -21 dBW; BW: 10 kHz; ALT: 400 km)

[7] ITU Radio Regulations, Article 21, Table 21-4.

As shown in Figure 2 below, the PFD at the Earth's surface produced by the satellite telemetry transmissions from the payload mission data transmitter satisfies the PFD limits in the ITU Radio Regulations for all angles of arrival. This PFD is based on the narrowest expected transmitter bandwidth and lowest operating altitude of 400 km to show the worst-case operating conditions. The X-band payload downlink can operate with emission bandwidths as narrow as 8 MHz and as wide as 80 MHz.

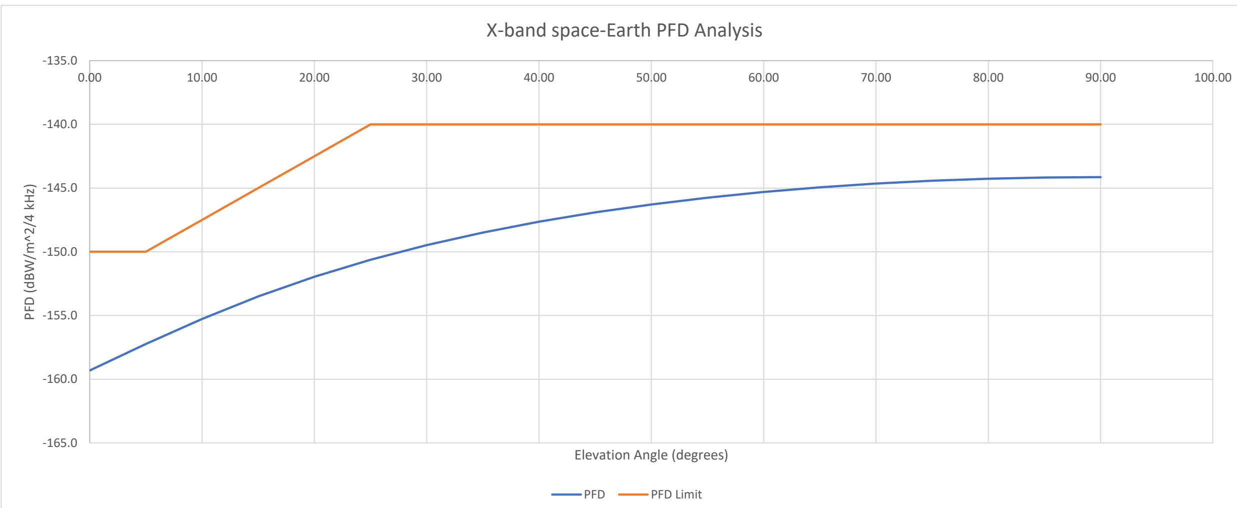


Figure 2: X-band Demo Mission Downlink at the Surface of the Earth (EIRP: 11.9 dBW; BW: 8.0 MHz; ALT: 400 km)

b. <u>PFD at the Surface of the Earth in the band 8400-8450 MHz</u>

ITU-R Recommendation SA-1157 specifies a maximum allowable interference power spectral flux-density level at the Earth's surface of -255.1 dBW/($m^2 \cdot$Hz) to protect ground receivers in the deep-space research band 8400-8450 MHz.[8] HE360 does not operate in this frequency range and the narrow bandwidth nature of the demonstration TT&C transmitter centered over 100 MHz away from the DSN band ensures no interference with the DSN.

[8] Recommendation ITU-R SA.1157-1, Table 5.

c. PFD at the Geostationary Satellite Orbit

No. 22.5 of the ITU Radio Regulations specifies that in the frequency band 8025-8400 MHz, which the Earth Exploration-Satellite Service (EESS) (using non-geostationary satellites) shares with the Fixed-Satellite Service (FSS) (Earth-to-space) and the meteorological-satellite service (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^2) in any 4 kHz band.[9] The calculation below shows that the PFD produced by the transmissions from the demonstration TT&C transmitter on Kestrel-0A does not exceed the limit in No. 22.5, even in the worst possible hypothetical case.

The PFD at the GSO produced by the HE360 transmission is:

PFD [dBW/(m^2·4 kHz)] = EIRP (dBW) - 71 - 20log10(D) - 10log10(BW) - 24

Where:

- EIRP is the Maximum EIRP of the transmission, in dBW;
- D is distance between the HE360 satellite and GSO, in km; and
- BW is the symbol bandwidth of the transmission, in MHz.

The closest distance between Kestrel-0A and the GSO is 35,786 - 575 = 35,211 km for the highest possible orbit of 575 km. Under a hypothetical assumption that the Kestral-0A satellite antenna is radiating at its peak EIRP toward the GSO, the X-band transmitter produces the following PFD (at the GSO arc) in worst case scenarios, all in compliance with ITU regulations:

Transmitter	Distance (km)	EIRP (dBW)	Bandwidth (MHz)	PFD (dBW/m^2/4kHz)
TT&C Downlink	35211	-14.0	0.01	-179.93

[9] ITU Radio Regulations, Article 22, Section 4.

Ground Plots

Ground plots are included below to provide the necessary technical inputs for the Kestrel-0A X-band TT&C transmitter.

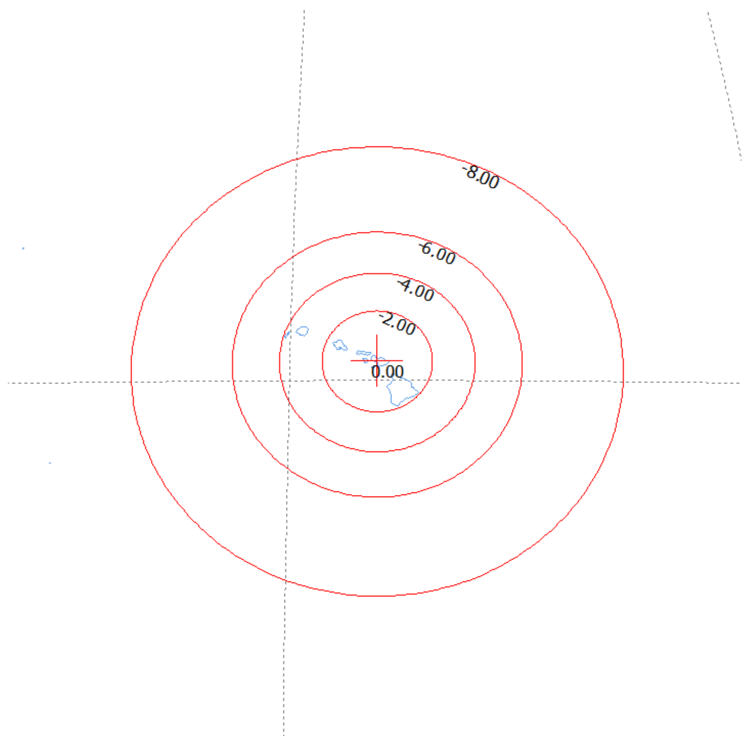


Figure 3 S-band Earth-space Antenna Beam Projection over Hawaii, USA (400 km)

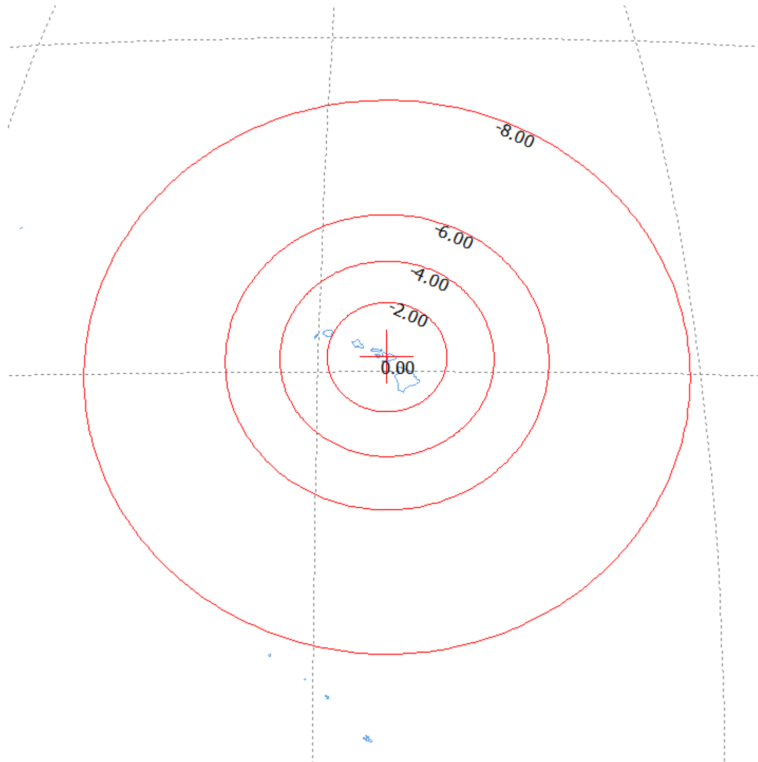


Figure 4 S-band Earth-space Antenna Beam Projection over Hawaii, USA (550 km)

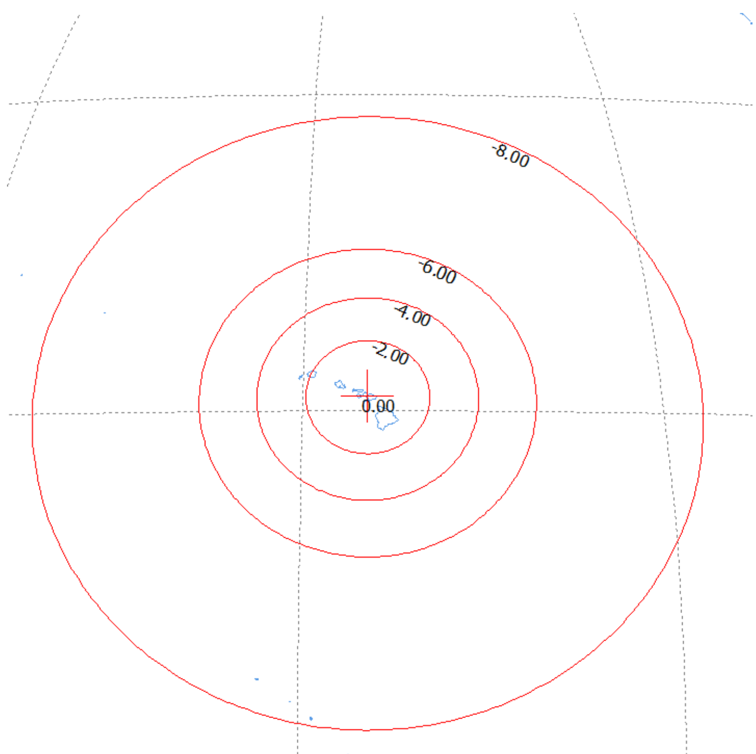


Figure 5 S-band Earth-space Antenna Beam Projection over Hawaii, USA (600 km)

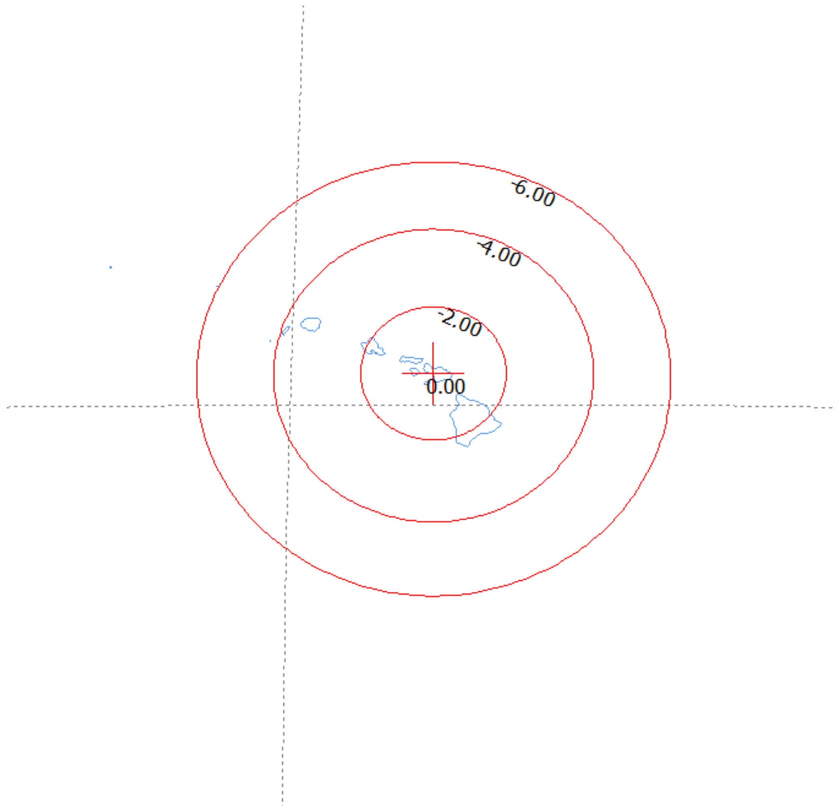


Figure 6 X-band space-Earth Antenna Beam Projection over Hawaii, USA (400 km)

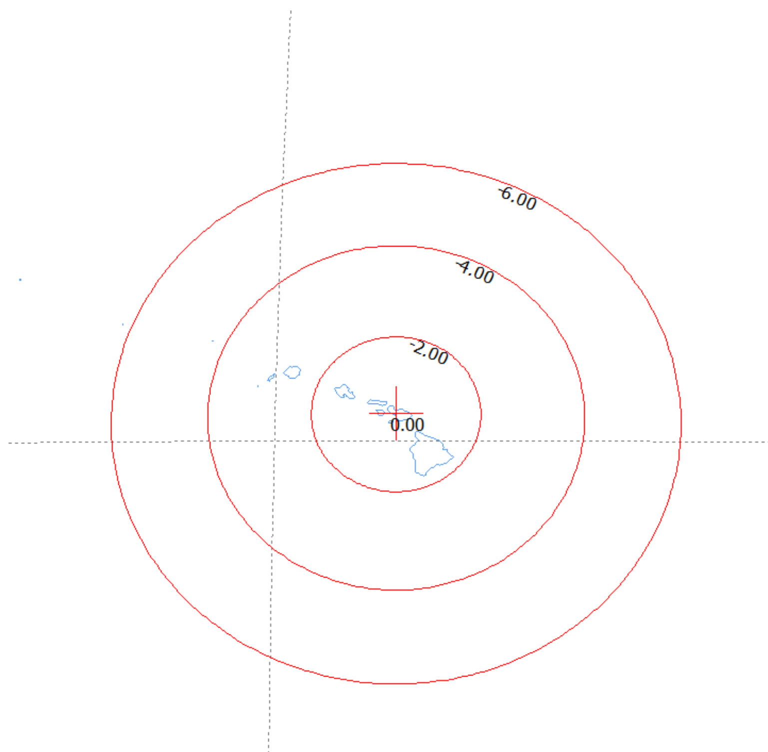


Figure 7 X-band space-Earth Antenna Beam Projection over Hawaii, USA (550 km)

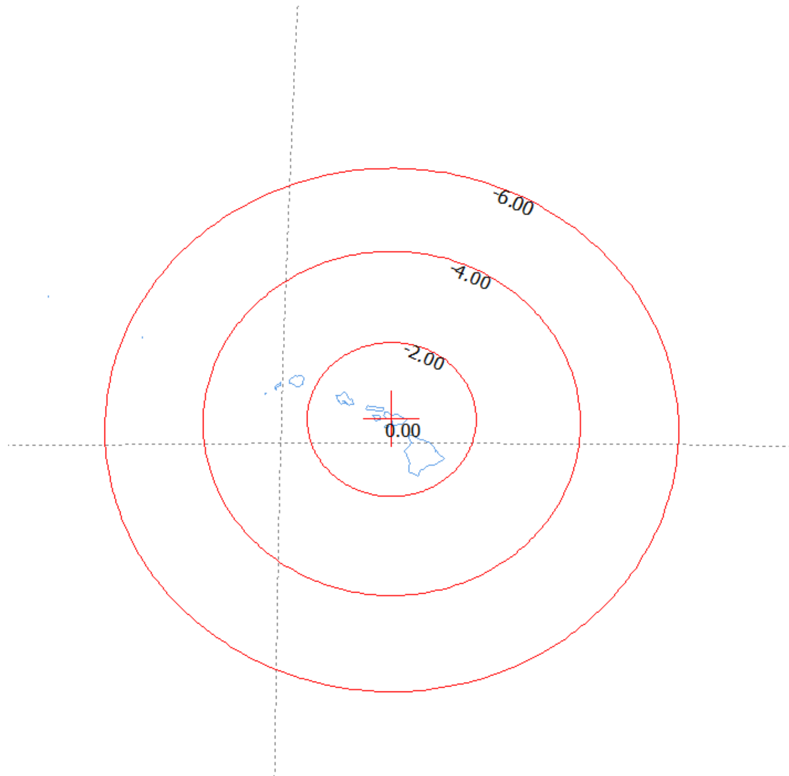


Figure 8 X-band space-Earth Antenna Beam Projection over Hawaii, USA (600 km)

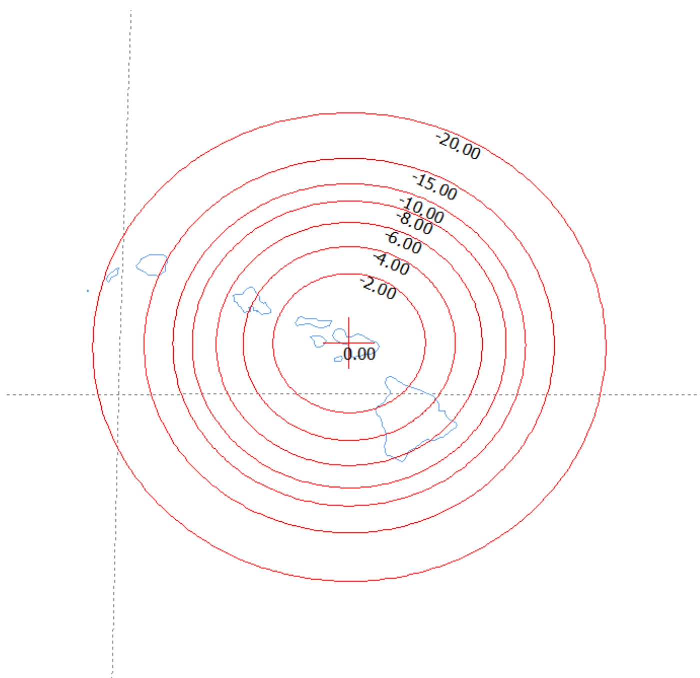


Figure 9 X-band 2x2 space-Earth Antenna Beam Projection over Hawaii, USA (400 km)

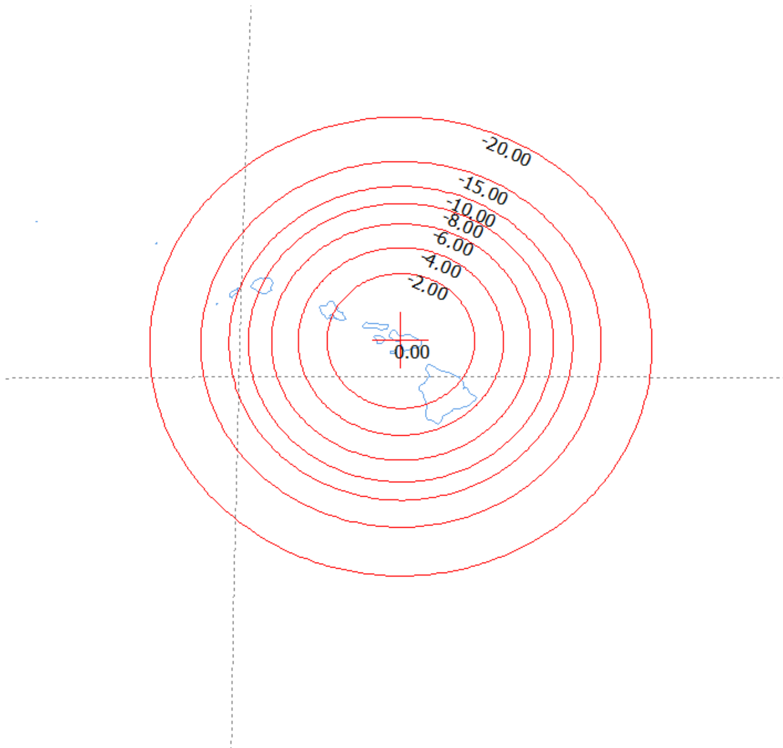


Figure 10 X-band 2x2 space-Earth Antenna Beam Projection over Hawaii, USA (550 km)

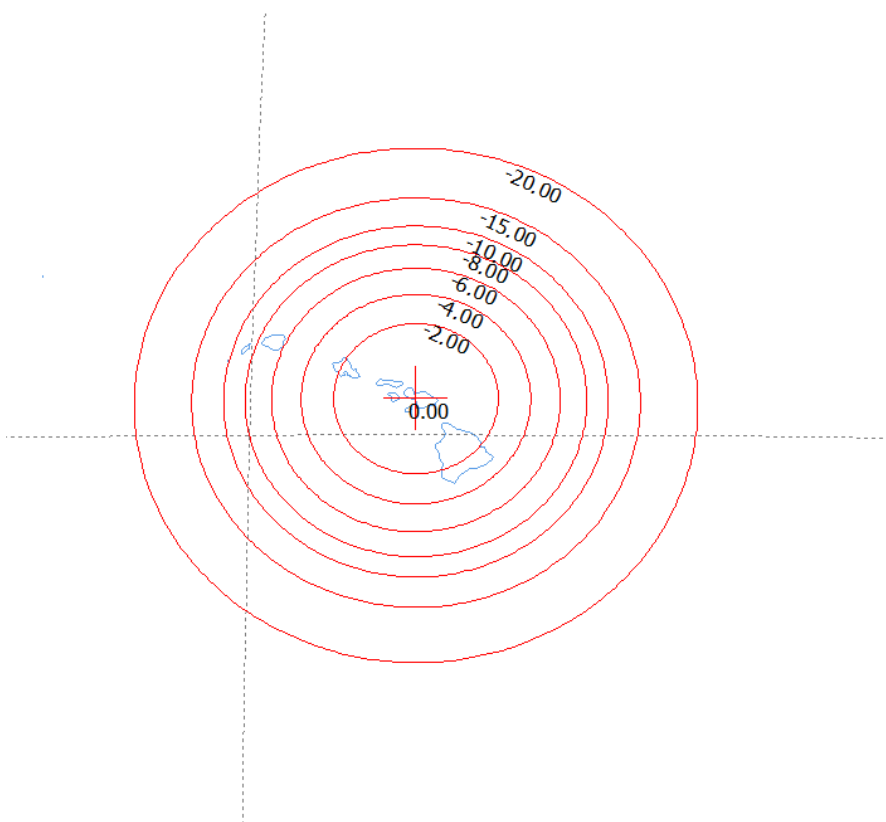


Figure 11 X-band 2x2 space-Earth Antenna Beam Projection over Hawaii, USA (600 km)

Attachment 2

Demonstration Mission Orbital Debris Assessment Report

FCC Form 312

Orbital Debris Analysis Report for Kestrel-0A
HawkEye 360, Inc.

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

Document Data is Not Restricted.
This document contains no proprietary, ITAR, or export controlled information.
DAS Software Version Used in Analysis: v3.2.6

Change Log

ODAR Version	Date	DAS Version Used
Kestrel-0A	February 16, 2024	v3.2.6

INTRODUCTION

HawkEye 360, Inc. ("HE360") is a U.S. company headquartered in Herndon, Virginia.

This ODAR is for a single, smaller form factor, demonstration spacecraft, Kestrel-0A, that will fly as part of the HE360 constellation. This spacecraft will be launched into a near-polar (97-98 degree) orbit at an orbit altitude of no greater than 575 km.

The NASA Debris Assessment Software confirmed that the Kestrel-0A spacecraft satisfy all the Requirements for Limiting Orbital Debris including:

a. Mission-Related Debris Passing Through LEO
b. Mission-Related Debris Passing Near GEO
c. Long-Term Risk from Planned Breakups
d. Probability of Collision with Large Objects
e. Probability of Damage from Small Objects
f. Post-mission Disposal
g. Casualty Risk from Reentry Debris

HE360 confirms that the spacecraft will not undergo any planned release of debris during their normal operations. In addition, all separation and deployment mechanisms, and any other potential source of debris will be retained by the spacecraft or launch vehicle. HE360 has also assessed the probability of the spacecraft becoming a source of debris by collision with small debris or meteoroids of less than one centimeter in diameter that could cause loss of control and prevent post-mission disposal. HE360 has taken steps to limit the effects of such collisions through shielding, the placement of components, and the use of redundant systems.

HE360 has assessed and limited the probability of accidental explosions during and after completion of mission operations through a failure mode verification analysis. As part of the spacecraft manufacturing process, HE360 has taken steps to ensure that debris generation will not result from the conversion of energy sources on board the spacecraft into energy that fragments the spacecraft. All sources of stored energy onboard the spacecraft will have been depleted or safely contained when no longer required for mission operations or post-mission disposal.

HE360 has assessed and limited the probability of the space stations becoming a source of debris by collisions with large debris or other operational spacecraft. HE360 does not intend to place any spacecraft in an orbit that is identical to or very similar to an orbit used by other spacecraft, and, in any event, will work closely with the cluster launch providers to ensure that the spacecraft are deployed in such a way as to minimize the potential for collision with any other spacecraft. This specifically includes minimizing the potential for collision with manned spacecraft.

The Kestrel-0A spacecraft will not perform station-keeping maneuvers to maintain particular orbital parameters. However, Kestrel-0A will perform propulsive maneuvers at the beginning of life for orbit lowering, if required to support collision avoidance activities, and to demonstrate operational capabilities.

HE360's disclosure of the above parameters and other orbital information in this document can assist third parties in identifying potential problems. This information also lends itself to coordination between HE360 and other operators located in similar orbits.

The instant ODAR applies to the Kestrel-0A demonstration spacecraft. The ODARs associated with the HE360 constellation more generally appear in previously approved or pending HE360 applications. *See, e.g.,* Application of HE360, ICFS File No. SAT-MOD-20220906-00099, at Exhibit 7, ODAR (granted in part/deferred in part Mar. 13, 2024) (providing the ODAR for Clusters 7-10); Application of HE360, ICFS File No. SAT-MOD-20210114-00010, at Exhibit 2, ODAR (granted May 25, 2021) (providing the ODAR for Clusters 3-6); Letter from Tony Lin, Counsel to HE360, to Marlene H. Dortch, Secretary, FCC, ICFS File No. SAT-AMD-20200728-00090 (filed Sept. 23, 2020) (providing the ODAR for Cluster 2); Application of HE360, ELS File No. 0024-EX-CN-2017, at Exhibit 3, ODAR (filed Mar. 10, 2017) (providing the ODAR for Cluster 1).

1. Self Assessment of the ODAR using the format in Appendix A.2 of NASA-STD-8719.14 Revision C

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

Table 1: Orbital Debris Self-Assessment Report Evaluation for the Kestrel-0A Demonstration Spacecraft

Req		Spacecraft			Comments
#	Description	Compliant or N/A	Not Compliant	Incomplete	
4.3-1a	Debris-LEO	x			No debris released in LEO.
4.3-1b	Debris-LEO	x			No debris released in LEO.
4.3-2	Debris-GEO	x			No debris released near GEO.
4.4-1	Explosions	x			
4.4-2	Passivation	x			
4.4-3	Long-term risk	x			No planned breakups.
4.4-4	Short-term risk	x			No planned breakups.
4.5-1	Debris from collisions-large obj	x			
4.5-2	Debris from collisions-small obj	x			
4.6-1a	Disposal by re-entry	x			
4.6-1b	Disposal by maneuvers	x			
4.6-1c	Disposal by retrieval	x			No planned retrieval.
4.6-2	Disposal near GEO	x			LEO orbits only.
4.6-3	Disposal between LEO, GEO	x			LEO orbits only.
4.6-4	Reliability of disposal	x			No planned disposal operations.
4.7-1	Risk of human casualty	x			
4.8-1	Special Classes of Space Missions	x			

2. Assessment Report Format

ODAR Technical Sections Format Requirements:

This ODAR follows the format recommended in NASA-STD-8719.14 Revision C, Appendix A.1 and includes the content indicated at a minimum in each section 2 through 8 below for the spacecraft in the commercial constellation. Sections 9 through 14 apply to the launch platform and are not covered here.

3. ODAR Section 1: Program Management and Mission Overview

Project Manager: HE360

Foreign government or space agency participation: No foreign government or space agency participation is anticipated.

Schedule of upcoming mission milestones:
Launch: No earlier than October 2024.

Mission Overview:
This spacecraft will be launched and deployed from its restraint mechanisms and commissioned. The spacecraft orbit will initially be lowered, if above 554 km circular, to ensure passive deorbit in less than 5 years from the end of mission life. The spacecraft will then begin payload operations that will continue for an estimated 3 years.

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 post-mission de-orbit lifetime is less than 5 years, as calculated by DAS.

Launch vehicle and launch site: Launch vehicle is expected to be a SpaceX Transporter mission from Cape Canaveral, FL or Vandenberg, CA.

Proposed launch date: No earlier than October 2024.

Mission duration: Nominal orbit lifetime is 3 years. The estimated nominal post-mission de-orbit lifetime is less than 5 years.

Launch and deployment profile, including all parking, transfer, and operational orbits with apogee, perigee, and inclination: The Kestrel-0A spacecraft is presently planned to be launched on a rideshare mission with a target 510 km +/- 20 km circular deployment. If HE360 chooses to launch on a later mission, HE360 will ensure that the planned deployment altitude, with error margin applied, is less than 575 km to ensure compliance with the 5-year deorbit requirement.

The Kestrel-0A spacecraft has propulsion for orbit lowering at the beginning of mission and collision avoidance. If the Kestrel-0A spacecraft is deployed into an orbit above 554 km circular, then the propulsion system will be used at the beginning of life to lower the orbit to 554 km circular to ensure a 5-year post-mission deorbit.

Reason for selection of operational orbit(s): Orbit was chosen based upon ride-share opportunities that meet mission requirements.

Identification of any interaction or potential physical interference with other operational spacecraft: The Kestrel-0A spacecraft are not expected to interact or physically interfere with other operational spacecraft.

4. ODAR Section 2: Spacecraft Description

Physical description of the spacecraft:
The Kestrel-0A spacecraft is a 8U cubesat, with a launch mass of less than 16.0 kg[1].

Basic physical outside dimensions are: 136 mm x 301 mm x 536 mm.

The spacecraft is composed of an aluminum structure with deployable solar arrays.

Power storage is provided by two batteries each of four Lithium-Ion cells. The batteries will be recharged by solar cells mounted on both deployed arrays and on the body of the spacecraft.

Detailed illustration of the entire spacecraft in the mission operation configuration with clear overall dimensional markings: Figures 1-2 show the external layout of the Kestrel-0A spacecraft with dimensional markings.

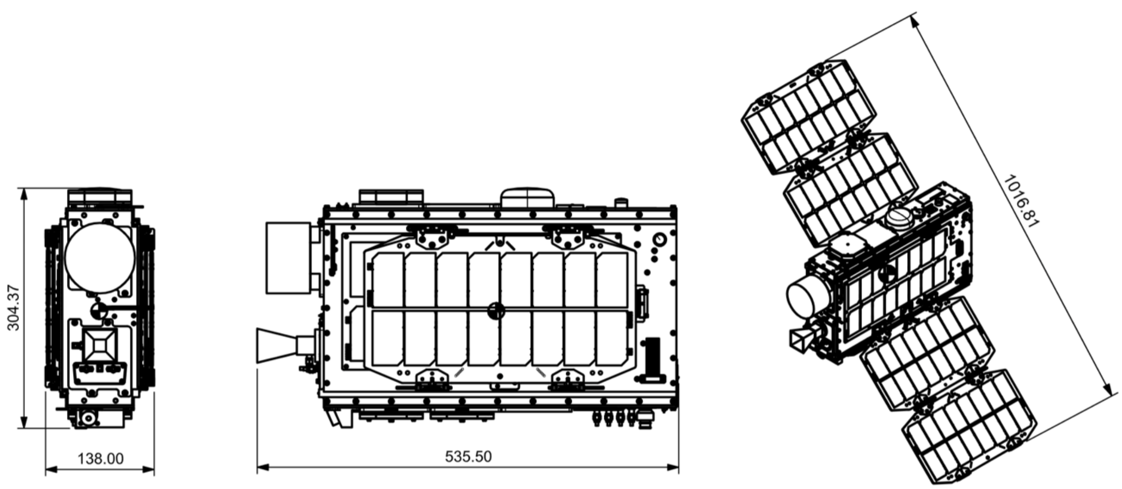


Figure 1: Kestrel-0A Spacecraft in Stowed and Deployed Configurations

Total satellite mass at launch, including all propellants and fluids:
15.34 kg including launch adapter

[1] The currently planned spacecraft has a launch mass between 12 and 16 kg. HE360 is conducting analysis assuming 16 kg launch mass to be conservative and therefore limit the need to update the ODAR as a result of minor manufacturing changes that might slightly raise the spacecraft mass.

Dry mass of satellites at launch, excluding propellant:
15.14 kg including launch adapter

Description of all propulsion systems (cold gas, mono-propellant, bi-propellant, electric, nuclear):
Kestrel-0A will employ a chemical bi-propellant propulsion system.

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: Nitrous Oxide oxidizer (169.0 g) at a maximum pressure of 50.5 bar and Propene propellant (29.7 g) at a maximum pressure of 10.2 bar. Fluid will be loaded into the propulsion system by the manufacturer prior to installation to the spacecraft or by HE360 at launch site prior to integration with the launch vehicle.

Fluids in Pressurized Batteries: None. The spacecraft use heritage, unpressurized, standard COTS 18650 Lithium-Ion batteries in a 4S1P configuration.

Description of attitude control system and indication of the normal attitude of the spacecraft with respect to the velocity vector:
Spacecraft attitude is controlled by magnetorquers and reaction wheels. The nominal attitude is an align/constrain sun-tracking mode where a particular fixed body-frame vector, chosen to maximize power generation, is aligned with the sun, and rotation about the sun vector is constrained to point a second fixed body-frame axis to nadir. Other possible attitude modes include: nadir-pointing, target-tracking, tumble/de-tumble and low/high drag profiles.

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 batteries are charged before payload integration and provide electrical energy during the mission. The cells are recharged by the solar arrays on orbit. A battery protection circuit protects against over and undercharge conditions.

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

Identification of any radioactive materials on board: None.

Address the trackability of the spacecraft. Spacecraft operating in low-Earth orbit will be presumed trackable if each individual spacecraft is 10 cm or larger in its smallest dimension, excluding deployable components:
The spacecraft are in low-Earth orbit and has a smallest dimension measuring at least 10 cm. Thus, they are trackable.

The statement shall also disclose the following:

How the operator plans to identify the spacecraft following deployment and whether spacecraft tracking will be active or passive:
Spacecraft tracking will be active. Prior to deployment, an initial ephemeris is produced by the launch service that will be used to schedule a contact time window with the ground station. The accuracy of the ephemeris will depend on the launch vehicle's performance, delays, and deployment times. A more accurate ephemeris will be made available shortly after deployment. After deployment when the spacecraft establishes contact with the nearest available contracted ground station, active spacecraft tracking will be employed to enhance and maintain spacecraft ephemeris data. The collected data will be used to identify the spacecraft from two-line element sets once they become available by the 18th Space Defense Squadron.

Whether, prior to deployment, the spacecraft will be registered with the 18th Space Control Squadron or successor entity:
Prior to deployment, the spacecraft will be registered with the 18th Space Defense Squadron via their Satellite Registration Form and Space Situational Awareness (SSA) Sharing Agreement.

The extent to which the spacecraft operator plans to share information regarding initial deployment, ephemeris, and/or planned maneuvers with the 18th Space Control Squadron or successor entity, other entities that engage in space situational awareness or space traffic management functions, and/or other operators:
HE360 will provide the 18th Space Defense Squadron information regarding initial deployment, owner/operator (O/O) ephemeris, and planned maneuvers. This is intended to provide better space situational awareness and improve the accuracy of conjunction analysis (CA). The higher accuracy O/O ephemeris will improve the quality of the CA and reduce the frequency of Conjunction Data Messages (CDMs). HE360 intends to publish its ephemeris online three times daily, via Space-Track.org, and coordinate with LeoLabs, Inc., to publish HE360-generated ephemeris.

Planned Proximity Operations

Not applicable.

5. ODAR Section 3: Assessment of Spacecraft Debris Released during Normal Operation

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):

Requirement 4.3-1: Mission Related Debris Passing Through LEO. a. Requirement 4.3-1a: All debris released during the deployment, operation, and disposal phases shall be limited to a maximum orbital lifetime of 25 years from date of release (Requirement 56398). b. Requirement 4.3-1b: The total object-time product shall be no larger than 100 object-years per mission (Requirement 56399). The object-time product is the sum of all debris of the total time spent below 2,000 km altitude during the orbital lifetime of each object. (See section 4.3.4.2 for methods to calculate the object-time product.)
Compliance Statement: COMPLIANT There are no intentional releases.

Requirement 4.3-2: Mission Related Debris Passing Near GEO. For missions leaving debris in orbits with the potential of traversing GEO (GEO altitude +/- 200 km and +/- 15 degrees latitude), released debris with diameters of 5 cm or greater shall be left in orbits which will ensure that within 25 years after release the apogee will no longer exceed GEO – 200 km (Requirement 56400).
Compliance Statement: COMPLIANT No released debris.

6. 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 explosive rupture. 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 explosive rupture. The batteries include vent-before-burst features to minimize the chances of explosive rupture.

Detailed plan for any designed spacecraft breakup, including explosions and intentional collisions: There are no planned breakups.

List of components which shall be passivated at End of Mission (EOM) including method of passivation and amount which cannot be passivated: None. At end of mission, any remaining propellant may be used to decay orbit as much as possible or vented, therefore depleting propellant. The two batteries will not be passivated at End of Mission due to the low risk and low impact of explosive rupturing, and the extremely short lifetime at mission conclusion. The maximum total chemical energy stored in the battery is approximately 369kJ.

Rationale for all items which are required to be passivated, but cannot be due to their design: The battery charge circuits include overcharge protection 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. The electrical power system and batteries are both COTS components with flight heritage.

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: COMPLIANT Expected probability: 0.000

Supporting Rationale and FMEA details:
Battery explosion:

Effect: All failure modes below might theoretically result in battery explosive rupture 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. Furthermore, each battery has a pressure relief burst disc that prevents catastrophic battery enclosure failure.
Probability: Extremely low. It is believed to be a much less than 0.01% probability that multiple independent (not common mode) faults occur for each failure mode to cause the ultimate effect (explosion). The spacecraft uses Panasonic NCR18650B battery sells which have extensive flight heritage. Each battery cell is UN/UL certified with individual over-voltage and over-current protection.

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 fail for this failure mode to occur..

Failure Mode 2: Internal thermal rise due to high load discharge rate.
Mitigation 2: Battery cells were UN/UL tested in lab for high load discharge rates by short circuiting the terminal to determine the feasibility of an out-of-control thermal rise in the cell.
Combined faults required for realized failure: Spacecraft thermal design must be incorrect AND external over-current detection and disconnect function must fail for this failure mode to occur.

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 must fail for this failure mode to occur.

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 cell manufacturer and the spacecraft integrator must fail to install proper venting for this failure mode to occur.

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 spacecraft must be in a naturally sustained orbit at the time the crushing occurs for this failure mode to occur.

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 for this failure mode to occur.

Failure Mode 7: Excess battery cell temperature 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 post-mission disposal or control to a level which cannot cause an explosion or deflagration large enough to release orbital debris or break up the spacecraft (Requirement 56450).
Compliance statement: COMPLIANT At end of mission, all remaining propellant will be used to lower orbit altitude or vented, if possible.[2] Onboard sources of energy include onboard batteries for energy storage. The battery charge circuits include overcharge protection to limit the risk of battery failure. As previously mentioned, the integrated burst disc should prevent any explosion altogether. 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. There is no expectation of producing orbital debris or spacecraft breakup from an unlikely battery explosion.

Requirement 4.4-3. Limiting the long-term risk to other space systems from planned breakups. Planned explosions or intentional collisions shall: a. Be conducted at an altitude such that for orbital debris fragments larger than 10 cm the object-time product does not exceed 100 object-years (Requirement 56453). For example, if the debris fragments greater than 10 cm decay in the maximum allowed 1 year, a maximum of 100 such fragments can be generated by the breakup.

[2] Propulsion will not be used to actively lower the orbit altitude through the ISS orbit.

b. Not generate debris larger than 1 mm that remains in Earth orbit longer than one year (Requirement 56454).
Compliance statement: Not applicable; there are no planned breakups.

Requirement 4.4-4: Limiting the short-term risk to other space systems from planned breakups. Immediately before a planned explosion or intentional collision, the probability of debris, orbital or ballistic, larger than 1 mm colliding with any operating spacecraft within 24 hours of the breakup shall be verified to not exceed 10^-6 (Requirement 56455).
Compliance statement: N/A; There are no planned breakups.

7. 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, and calculation methods provided in NASA-STD-8719.14 Revision A with Change 1, 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).
Compliance Statement: COMPLIANT **Large Object Impact and Debris Generation Probability:** Collision Probability: < 5.2806E-06

Supporting Deployment and Collision Risk Analysis
The above collision probability is a product of NASA's DAS software.

Previous HE360 ODAR submissions have analyzed the aggregate probably of collision from the 174 spacecraft planned over the life of the HE360 constellation. This Kestrel-0A demonstration spacecraft will replace one of the 174 spacecraft over the constellation life. Since the calculated probability of collision with large objects for Kestrel-0A is comparable to the individual probability of collision with large objects estimate for the HE360 constellation, replacing one of the HE360 spacecraft with a Kestrel-0A should not have any material impact to the previously reported aggregate probability (most recently conservatively estimated at 0.001357).

The Kestrel-0A spacecraft has a propulsion system and will, if possible, conduct collision avoidance maneuvers when warranted. Indeed, the FCC has stated that the large object collision probability should be treated as zero when spacecraft are capable of propulsive maneuvers.[3] Furthermore, under nominal situations, the remaining propellant at end of life may be employed to reduce the orbit altitude and orbital life of spacecraft, which will also reduce the probability of collision with large objects due to reduced orbital lifetime. To be clear, no such action is necessary to meet regulatory requirements.

Detailed description and assessment of efficacy of any planned debris avoidance capability intended to help in meeting requirement 4.5-1
There is no significant risk of collision based on orbital parameters coupled with a propulsion capability. Furthermore, HE360 will register the Kestrel-0A spacecraft with the US Space Force's 18th Space Defense Squadron, which provides active monitoring in conjunction with the Combined Space Operations Center.

HE360 will contact and work with any entity who operates a spacecraft that has the potential to collide with the Kestrel-0A spacecraft to avoid collision.

If at any time during the spacecraft's mission or de-orbit phase the spacecraft will operate in or transit through the orbits used by any planned or inhabitable spacecraft, including the International Space Station, describe the design and operational strategies, such as coordination, that will be used to minimize the risk of collision and avoid posing any operational constraints to the spacecraft
Under nominal situations, the remaining propellant at end of mission may be employed to reduce the orbit altitude and orbital life of spacecraft. The spacecraft orbit will be actively lowered to just above the ISS, to the extent possible given remaining propellant, and then passivated. With respect to the operational strategies to minimize risk to the ISS or any other inhabitable spacecraft in low Earth orbit, HE360 intends to monitor the location of its spacecraft and work closely with organizations, such as the 18th Space Defense Squadron. More generally, HE360 also works with the Space Data Association to coordinate physical operation of its constellation with other operators.[4]

Certify that upon receipt of a space situational awareness conjunction warning, the operator will review and take all possible steps to assess the collision risk, and will mitigate the collision risk if necessary
Upon receipt of a space situational awareness conjunction warning, HE360 certifies that it will attempt to contact the operator of any active spacecraft involved in such a warning, share

[3] *See* 47 C.F.R. § 25.114(d)(14)(iv)(A)(1)("The collision risk may be assumed zero for a space station during any period in which the space station will be maneuvered effectively to avoid colliding with large objects."); *Mitigation of Orbital Debris in the New Space Age,* Report and Order and Further Notice of Proposed Rulemaking, IB Docket No. 18-313, 35 FCC Rcd 4156, at para. 35 (2020)("[F]or purposes of conducting the analysis, and absent evidence to the contrary, the collision risk with large objects should be assumed zero or near zero during the period of the time when the space station is able to conduct collision avoidance maneuvers."); *Space Exploration Holdings, LLC,* Request for Modification of the Authorization for the SpaceX NGSO Satellite System, Memorandum Opinion and Order, 35 FCC Rcd 5649, at para. 20 (2020) ("[I]t is the Commission's established licensing practice to consider spacecraft equipped with propulsion capability to have a collision risk of zero or near zero, absent specific information to the contrary."); Mitigation of Orbital Debris in the New Space Age, *Order on reconsideration*, IB Docket No. 18-313, FCC-24-6, at para. 9 (rel. Jan. 26, 2024).
[4] *See* Letter from Michael Mineiro, HE360, to Merissa Velez, FCC (dated October 21, 2021).

ephemeris data and other appropriate operational information with any such operator, and modify the spacecraft's attitude, orbit, and/or operations in order to avoid a collision. If the operator of the other spacecraft does not have maneuvering capabilities or is not expedient in response, HE360 will upload potential maneuvers via API to the 18th Space Defense Squadron in order to avoid a collision. High risk events will be mitigated to at least one and a half orders of magnitude below the collision probability mitigated action threshold of 1E-5.

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 post-mission disposal requirements is less than 0.01 (Requirement 56507).
Compliance Statement: COMPLIANT **DAS Analysis for Small Object Impact and Debris Generation Probability:** COMPLIANT. In order to meet the 5-year deorbit requirement, HE360 will lower the orbit altitude (as necessary) to 554 km circular during the first 3-month of operation. From an orbit altitude of 554 km or below, the spacecraft will passively deorbit in less than 5-years, following a nominal 3-year mission. Based upon this approach, the probability of collision with small objects has been conducted based upon an operational duration of only 3 months. Given such a short time period, we were able to make extremely conservative assumptions. The critical surface was defined as the largest surface of the spacecraft body. Solar panels were not included due to the inherently parallel nature of solar power generation. Even with the extremely conservative assumption described above, the probability of collision with small objects is only 1.1901E-03, which is compliant.

Because Kestrel-0A relies upon a beginning-of-mission propulsive maneuver to ensure compliance with the 5-year post-mission deorbit rule, the reliability of completing this maneuver must be demonstrated to be at least 90%. Given that the propulsion maneuver is planned during the first three months of operation, a 90% reliability translates to a mean time between failure (MTBF) of ~30 months and would translate to a mission reliability after 36 months of only 33%. This is a very low reliability threshold to achieve.[5] The Kestrel-0A spacecraft is a new spacecraft design. However, the spacecraft component selection was based upon flight-proven hardware and redundancy of critical subsystems and functions. Also, the Kestrel-0A spacecraft will undergo rigorous testing and environmental stress screening at subsystem and system levels. Furthermore, HE360 currently operates a constellation of 21 spacecraft and has extensive

[5] A study of 178 launched CubeSats launched by 2014 demonstrates a 36-month mission reliability of greater than 50% with 95% confidence interval. Since this study, the availability of cubesat components with significant flight heritage has increased dramatically.

experience managing and conducting integration and environmental stress screening (ESS) testing and conducting flight operations, monitoring telemetry and identifying/predicting component anomalies and degradation.

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

Description of spacecraft disposal option selected: The Kestrel-0A spacecraft will be disposed of by atmospheric re-entry.

Identification of all systems or components required to accomplish any post-mission disposal operation, including passivation and maneuvering: Nothing is required for post-mission disposal to meet the 5-year deorbit requirement. However, if the Kestrel-0A spacecraft is injected into an orbit greater that 554 km circular, it will be lowered to an orbit of 554 km circular during the first three months of operation. In order to achieve this orbit lowering maneuver, all primary bus functionality will be required, including: TT&C, flight computer, AODC, EPS, and propulsion.

Plan for any spacecraft maneuvers required to accomplish post-mission disposal:
Any remaining propellant at EOM may be used to further decrease the perigee and reduce the post-operations lifetime.

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

The area-to-mass ratio calculations presented below are worst-case with additional mass margin to provide a buffer to address manufacturing changes over the life of the constellation which might increase spacecraft mass. By selecting a worst-case mass, HE360 is over-estimating the orbital lifetime.

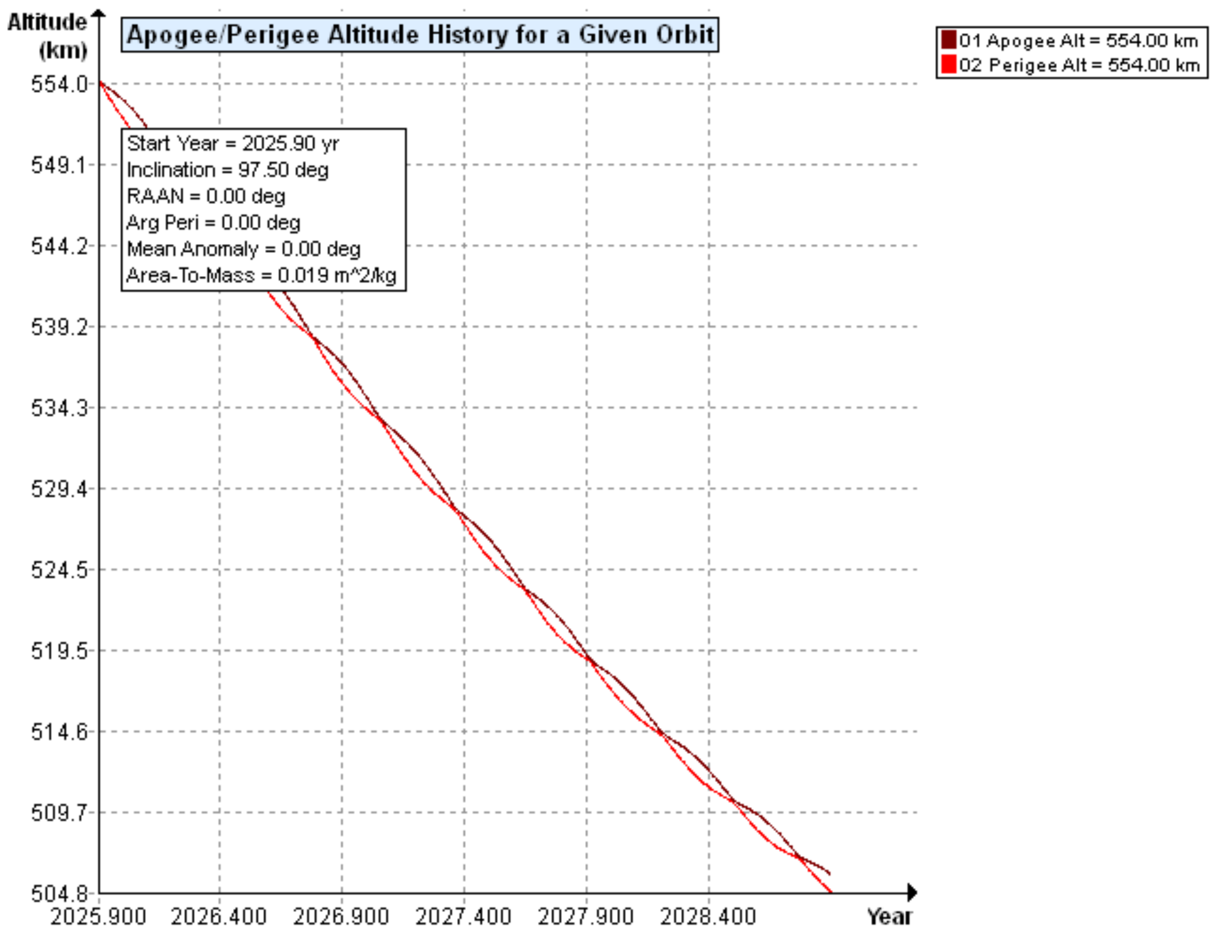
Spacecraft Mass: 15.34 kg
Cross-sectional Area:
Maximum Drag Area: 0.4125 m^2 (drag area)
Average Drag Area: 0.29 m^2 (drag area)
Minimum Drag Area: 0.034 m^2 (drag area)

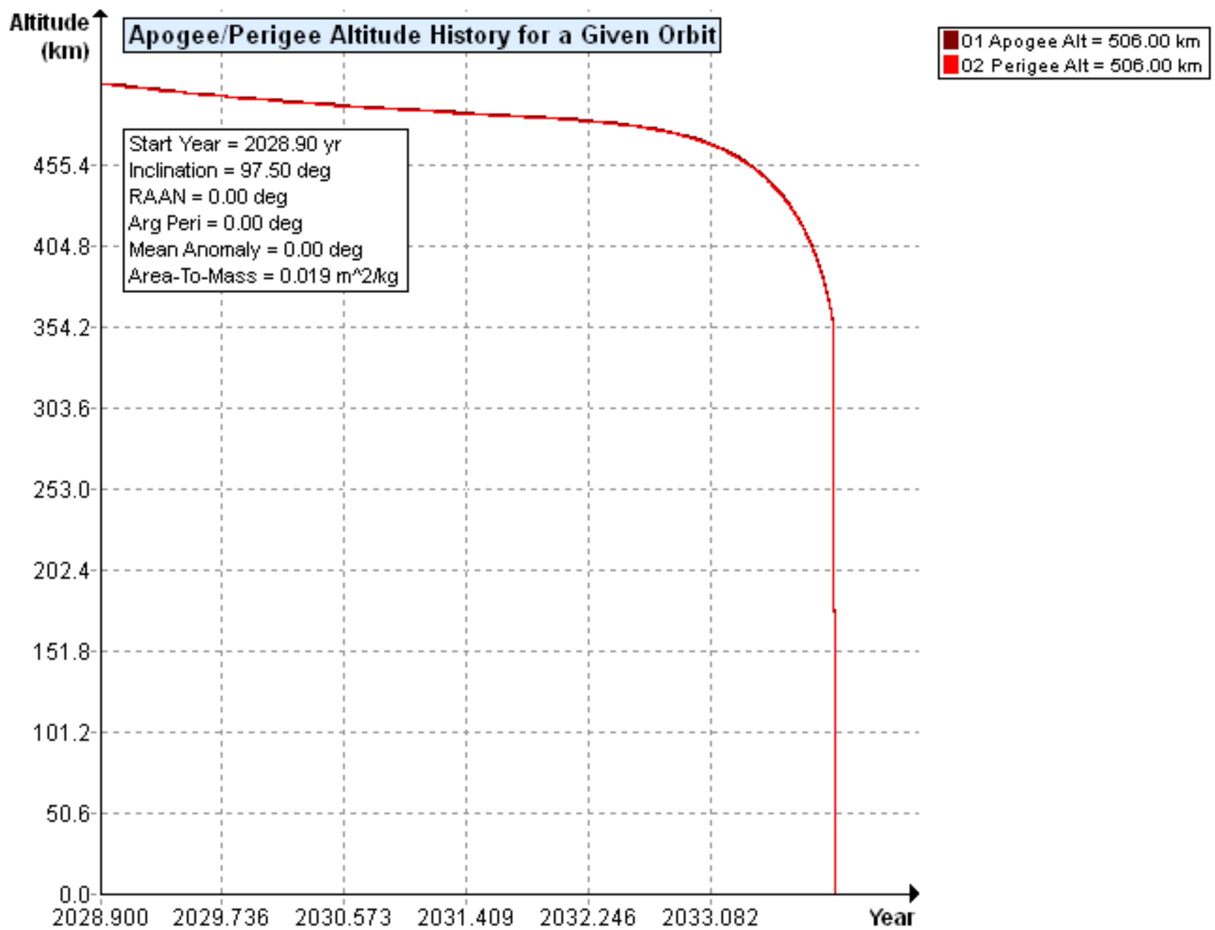
Average area to mass ratio: 0.01888 m^2/kg

Assessment of spacecraft compliance with Requirements 4.6-1 through 4.6-5 (per DAS and NASA-STD-8719.14 Revision C):

At the beginning of mission, the Kestrel-0A spacecraft will be lowered, if necessary, to an orbit altitude of 554 km (circular). Under nominal conditions, the Kestrel-0A spacecraft is expected to conduct mission operations for 3 years without station keeping such that the natural orbital decay during the three years of mission operations is allowed. At the end of mission, assuming the worst-case scenario that no further propulsion is possible, the Kestrel-0A spacecraft will passively deorbit in less than 5 years.

The below plot shows the predicted orbit for the three years of operation. At the end of the 3-year mission operations, the orbit altitude is approximately 506 km (circular). The next plots show that the Kestrel-0A spacecraft will passively deorbit within 5 years after EOM.
This analysis was conducted for every launch date (in 1/10th year increments) from 2024.8 to 2026.5. Out of all of the options, a date of 2025.9 (for reaching the reduced orbit of 554 km) was determined to be the worst-case scenario for achieving a 5-year deorbit following a 3-year mission.





Requirement 4.6-1: Disposal for space structures passing through LEO: A spacecraft or orbital stage with a perigee altitude below 2000 km shall be disposed of by one of three methods: (Requirement 56557) a) Atmospheric reentry option: □ Leave the space structure in an orbit in which natural forces will lead to atmospheric reentry within 25 years after the completion of mission but no more than 30 years after launch; or □ Maneuver the space structure into a controlled de-orbit trajectory as soon as practical after completion of mission. b) Storage orbit option: Maneuver the space structure into an orbit with perigee altitude greater than 2000 km and apogee less than GEO - 500 km. c) Direct retrieval: Retrieve the space structure and remove it from orbit within 10 years after completion of mission
Compliance Statement: COMPLIANT **DAS Analysis:** The Kestrel-0A spacecraft disposal plan is COMPLIANT using the atmospheric re-entry option. Results from DAS analysis show the following:

For Worst-Case Orbit: 554 km x 554 km Post-Mission Lifetime: < 5 years (assuming spacecraft is deployed in an operable, deployed configuration, with 3-year mission life)

Requirement 4.6-2: Disposal for space structures near GEO. A spacecraft or orbital stage in an orbit near GEO shall be maneuvered at EOM to a disposal orbit above GEO with a predicted minimum perigee of GEO +200 km (35,986 km) or below GEO with an apogee of GEO – 200 km (35,586 km) for a period of at least 100 years after disposal (Requirement 56563).
Compliance Statement: Not applicable; no orbits planned near GEO.

Requirement 4.6-3: Disposal for space structures between LEO and GEO. a. A spacecraft or orbital stage shall be left in an orbit with a perigee greater than 2000 km above the Earth's surface and apogee less than 500 km below GEO (Requirement 56565). b. A spacecraft or orbital stage shall not use nearly circular disposal orbits near regions of high value operational space structures, such as between 19,200 km and 20,700 km (Requirement 56566).
Compliance Statement: Not applicable; no orbits planned between LEO and GEO.

Requirement 4.6-4: Reliability of Post-mission Disposal Operations in Earth orbit. NASA space programs and projects shall ensure that all post mission disposal operations to meet Requirements 4.6-1, 4.6-2, and/or 4.6-3 are designed for a probability of success as follows: (Requirement 56567) a. Be no less than 0.90 at EOM. b. For controlled reentry, the probability of success at the time of reentry burn must be sufficiently high so as not to cause a violation of Requirement 4.7-1 pertaining to limiting the risk of human casualty.
Compliance Statement: N/A; No plans for post-mission disposal operations. However, to meet the post-mission deorbit requirement, the HE360 spacecraft will conduct a beginning-of-mission orbit lowering maneuver if the spacecraft is inserted into an orbit greater than 554 km (circular).

9. ODAR Section 7: Assessment of Spacecraft Reentry Hazards

HE360 has analyzed the demise analysis for the Kestrel-0A spacecraft configurations.

Results from DAS show that, in both configurations, no components are expected to survive re-entry with an impacting kinetic energy in excess of 15 joules from any of the planned orbits. Details of the DAS analysis are illustrated in Annex A below.

Assessment of spacecraft compliance with Requirement 4.7-1:

Requirement 4.7-1a: Limit the risk of human casualty. The potential for human casualty is assumed for any object with an impacting kinetic energy in excess of 15 joules: a) For uncontrolled reentry, the risk of human casualty from surviving debris shall not exceed 0.0001 (1:10,000) (Requirement 56626).
Compliance Statement: COMPLIANT. Analysis performed using DAS shows that no part of the spacecraft is expected to have an impacting kinetic energy in excess of 15 joules, and that the risk of human casualty is zero (0) for all planned orbits and inclinations.

Requirement 4.7-1b: For controlled reentry, the selected trajectory shall ensure that no surviving debris impact with a kinetic energy greater than 15 joules is closer than 370 km from foreign landmasses, or is within 50 km from the continental U.S., territories of the U.S., and the permanent ice pack of Antarctica (Requirement 56627).
Compliance Statement: Not Applicable; no plans to use controlled re-entry.

Requirement 4.7-1c: For controlled reentries, the product of the probability of failure of the reentry burn (from Requirement 4.6-4.b) and the risk of human casualty assuming uncontrolled reentry shall not exceed 0.0001 (1:10,000) (Requirement 56628).
Compliance Statement: Not Applicable; no plans to use controlled re-entry.

10. ODAR Section 7A: Assessment of Spacecraft Hazardous Materials

Kestrel-0A spacecraft does not contain any hazardous materials.

11. ODAR Section 8: Special Classes of Space Missions

Requirement 4.8-1: Mitigate the collision hazards of space tethers in Earth or Lunar orbits. Intact and remnants of severed tether systems in Earth and lunar orbit shall meet the requirements limiting the generation of orbital debris from on-orbit collisions (Requirements 4.5-1 and 4.5-2) and the requirements governing post-mission disposal (Requirements 4.6-1 through 4.6-4) to the limits specified in those paragraphs (Requirement 56652).
Compliance Statement: Not Applicable; there are no tethers in the Kestrel-0A mission.

Annex A – DAS Log Results

04 01 2024; 07:12:48AM Project Data Saved To File
04 01 2024; 07:13:02AM Processing Requirement 4.3-1: Return Status : Not Run

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

=============== End of Requirement 4.3-1 ===============
04 01 2024; 07:13:05AM Processing Requirement 4.3-2: Return Status : Passed

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

=============== End of Requirement 4.3-2 ===============
04 01 2024; 07:35:09AM Processing Requirement 4.5-1: Return Status : Passed

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

INPUT

Space Structure Name = HE360-Lite
Space Structure Type = Payload
Perigee Altitude = 554.000 (km)
Apogee Altitude = 554.000 (km)
Inclination = 97.500 (deg)
RAAN = 0.000 (deg)
Argument of Perigee = 0.000 (deg)
Mean Anomaly = 0.000 (deg)
Final Area-To-Mass Ratio = 0.0189 (m^2/kg)
Start Year = 2025.900 (yr)
Initial Mass = 15.340 (kg)
Final Mass = 15.140 (kg)
Duration = 3.000 (yr)
Station-Kept = False
Abandoned = True
Long-Term Reentry = False

OUTPUT

Collision Probability = 5.2806E-06

Returned Message: Normal Processing
Date Range Message: Normal Date Range
Status = Pass

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

INPUT

Space Structure Name = HE360-Lite-Orbit-Lower
Space Structure Type = Payload
Perigee Altitude = 575.000 (km)
Apogee Altitude = 575.000 (km)
Inclination = 97.500 (deg)
RAAN = 0.000 (deg)
Argument of Perigee = 0.000 (deg)
Mean Anomaly = 0.000 (deg)
Final Area-To-Mass Ratio = 0.0189 (m^2/kg)
Start Year = 2025.900 (yr)
Initial Mass = 15.340 (kg)
Final Mass = 15.140 (kg)
Duration = 0.250 (yr)
Station-Kept = False
PMD Perigee Altitude = 100.000 (km)
PMD Apogee Altitude = 100.000 (km)
PMD Inclination = 97.500 (deg)
PMD RAAN = 0.000 (deg)
PMD Argument of Perigee = 0.000 (deg)
PMD Mean Anomaly = 0.000 (deg)
Long-Term Reentry = False

OUTPUT

Collision Probability = 2.6212E-07
Returned Message: Normal Processing
Date Range Message: Normal Date Range
Status = Pass

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

=============== End of Requirement 4.5-1 ===============

04 01 2024; 07:36:00AM Project Data Saved To File
04 01 2024; 07:46:14AM Requirement 4.5-2: Compliant

===

Spacecraft = HE360-Lite-Orbit-Lower

Critical Surface = Critical Surface
===

INPUT

Apogee Altitude = 575.000 (km)
Perigee Altitude = 575.000 (km)
Orbital Inclination = 97.500 (deg)
RAAN = 0.000 (deg)
Argument of Perigee = 0.000 (deg)
Mean Anomaly = 0.000 (deg)
Final Area-To-Mass = 0.0189 (m^2/kg)
Initial Mass = 15.140 (kg)
Final Mass = 15.140 (kg)
Station Kept = No
Start Year = 2025.900 (yr)
Duration = 0.250 (yr)
Orientation = Random Tumbling
CS Areal Density = 0.550 (g/cm^2)
CS Surface Area = 0.1610 (m^2)
Vector = (0.000000 (u), 0.000000 (v), 0.000000 (w))
CS Pressurized = No
Outer Wall 1   Density: 0.550 (g/cm^2) Separation: 2.000 (cm)

OUTPUT

Probability of Penetration = 1.1901E-03 (1.1908E-03)
Returned Error Message: Normal Processing
Date Range Error Message: Normal Date Range

=============== End of Requirement 4.5-2 ===============

04 01 2024; 07:48:05AM   Processing Requirement 4.6   Return Status : Passed

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

INPUT

Space Structure Name = HE360-Lite
Space Structure Type = Payload

Perigee Altitude = 554.000000 (km)
Apogee Altitude = 554.000000 (km)
Inclination = 97.500000 (deg)

RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Area-To-Mass Ratio = 0.018880 (m^2/kg)
Start Year = 2025.900000 (yr)
Initial Mass = 15.340000 (kg)
Final Mass = 15.140000 (kg)
Duration = 3.000000 (yr)
Station Kept = False
Abandoned = True
PMD Perigee Altitude = 498.042914 (km)
PMD Apogee Altitude = 499.043946 (km)
PMD Inclination = 97.414195 (deg)
PMD RAAN = 349.879880 (deg)
PMD Argument of Perigee = 181.952156 (deg)
PMD Mean Anomaly = 0.000000 (deg)
Long-Term Reentry = False

OUTPUT

Suggested Perigee Altitude = 498.042914 (km)
Suggested Apogee Altitude = 499.043946 (km)
Returned Error Message = Passes LEO reentry orbit criteria.

Released Year = 2033 (yr)
Requirement = 61
Compliance Status = Pass

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

INPUT

Space Structure Name = HE360-Lite-Orbit-Lower
Space Structure Type = Payload

Perigee Altitude = 575.000000 (km)
Apogee Altitude = 575.000000 (km)
Inclination = 97.500000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Area-To-Mass Ratio = 0.018880 (m^2/kg)
Start Year = 2025.900000 (yr)
Initial Mass = 15.340000 (kg)
Final Mass = 15.140000 (kg)
Duration = 0.250000 (yr)

Station Kept = False
Abandoned = False
Long-Term Reentry = False

OUTPUT

Suggested Perigee Altitude = 100.000000 (km)
Suggested Apogee Altitude = 100.000000 (km)
Returned Error Message = Passes LEO reentry orbit criteria.

Released Year = 2026 (yr)
Requirement = 61
Compliance Status = Pass

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

=============== End of Requirement 4.6 ===============
04 01 2024; 07:48:09AM *********Processing Requirement 4.7-1
Return Status : Passed

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

name = HE360-Lite
quantity = 1
parent = 0
materialID = 8
type = Box
Aero Mass = 15.140000
Thermal Mass = 15.140000
Diameter/Width = 0.301100
Length = 0.535500
Height = 0.136000

name = +X Panel
quantity = 1
parent = 1
materialID = 8
type = Flat Plate
Aero Mass = 0.135747
Thermal Mass = 0.135747
Diameter/Width = 0.096000
Length = 0.247000

name = -X Panel
quantity = 1

parent = 1
materialID = 8
type = Flat Plate
Aero Mass = 0.156603
Thermal Mass = 0.156603
Diameter/Width = 0.096000
Length = 0.247000

name = +Y Panel
quantity = 1
parent = 1
materialID = 8
type = Flat Plate
Aero Mass = 0.778169
Thermal Mass = 0.778169
Diameter/Width = 0.247000
Length = 0.545000

name = -Y Panel
quantity = 1
parent = 1
materialID = 8
type = Flat Plate
Aero Mass = 0.738424
Thermal Mass = 0.738424
Diameter/Width = 0.247000
Length = 0.545000

name = +Z Panel
quantity = 1
parent = 1
materialID = 8
type = Flat Plate
Aero Mass = 0.211199
Thermal Mass = 0.211199
Diameter/Width = 0.086200
Length = 0.448000

name = -Z Panel
quantity = 1
parent = 1
materialID = 8
type = Flat Plate
Aero Mass = 0.226409
Thermal Mass = 0.226409
Diameter/Width = 0.086200

Length = 0.448000

name = GPS antenna
quantity = 1
parent = 1
materialID = 8
type = Cylinder
Aero Mass = 0.221021
Thermal Mass = 0.221021
Diameter/Width = 0.050000
Length = 0.066800

name = TTAC
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.497882
Thermal Mass = 0.497882
Diameter/Width = 0.088000
Length = 0.117000
Height = 0.045400

name = Propulsion Unit
quantity = 1
parent = 1
materialID = 54
type = Box
Aero Mass = 1.161724
Thermal Mass = 1.161724
Diameter/Width = 0.096000
Length = 0.096000
Height = 0.086400

name = Battery Unit
quantity = 2
parent = 1
materialID = 8
type = Box
Aero Mass = 0.375061
Thermal Mass = 0.375061
Diameter/Width = 0.084300
Length = 0.094500
Height = 0.023000

name = OBC

quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.357157
Thermal Mass = 0.357157
Diameter/Width = 0.090900
Length = 0.111000
Height = 0.023700

name = SDR Payload
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.544965
Thermal Mass = 0.544965
Diameter/Width = 0.096400
Length = 0.111600
Height = 0.052400

name = EPS
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.181074
Thermal Mass = 0.181074
Diameter/Width = 0.090500
Length = 0.115500
Height = 0.015800

name = Antenna DB
quantity = 5
parent = 1
materialID = 8
type = Box
Aero Mass = 0.041172
Thermal Mass = 0.041172
Diameter/Width = 0.052000
Length = 0.059500
Height = 0.020000

name = Bus SRX Antenna
quantity = 2
parent = 1

materialID = 8
type = Box
Aero Mass = 0.167448
Thermal Mass = 0.167448
Diameter/Width = 0.080000
Length = 0.080000
Height = 0.029850

name = Antenna Bay
quantity = 3
parent = 1
materialID = 8
type = Box
Aero Mass = 0.319098
Thermal Mass = 0.319098
Diameter/Width = 0.080000
Length = 0.080000
Height = 0.043500

name = DSN Filter
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.081932
Thermal Mass = 0.081932
Diameter/Width = 0.059000
Length = 0.080500
Height = 0.015000

name = Backplane
quantity = 1
parent = 1
materialID = 23
type = Flat Plate
Aero Mass = 0.325355
Thermal Mass = 0.325355
Diameter/Width = 0.220000
Length = 0.426000

name = Reaction Wheel Pyramid
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.704000

Thermal Mass = 0.704000
Diameter/Width = 0.090560
Length = 0.090560
Height = 0.053110

name = Magnetorquer
quantity = 3
parent = 1
materialID = 38
type = Box
Aero Mass = 0.031000
Thermal Mass = 0.031000
Diameter/Width = 0.015000
Length = 0.077000
Height = 0.015000

name = CBS Antenna
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.428868
Thermal Mass = 0.428868
Diameter/Width = 0.089250
Length = 0.096750
Height = 0.089250

name = Horn Antenna
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.329825
Thermal Mass = 0.329825
Diameter/Width = 0.080000
Length = 0.114500
Height = 0.080000

name = X-band Array Antenna
quantity = 2
parent = 1
materialID = 8
type = Flat Plate
Aero Mass = 0.023150
Thermal Mass = 0.023150
Diameter/Width = 0.060000

Length = 0.060000

name = Earth Sensor
quantity = 2
parent = 1
materialID = 8
type = Box
Aero Mass = 0.018000
Thermal Mass = 0.018000
Diameter/Width = 0.025000
Length = 0.035000
Height = 0.018900

name = Sun Sensor
quantity = 2
parent = 1
materialID = 8
type = Box
Aero Mass = 0.015000
Thermal Mass = 0.015000
Diameter/Width = 0.024000
Length = 0.035000
Height = 0.021680

name = Deployable Magnetometer
quantity = 1
parent = 1
materialID = 38
type = Box
Aero Mass = 0.015500
Thermal Mass = 0.015500
Diameter/Width = 0.017000
Length = 0.049800
Height = 0.010000

name = Compact Magnetometer
quantity = 1
parent = 1
materialID = 38
type = Box
Aero Mass = 0.008000
Thermal Mass = 0.008000
Diameter/Width = 0.024000
Length = 0.024000
Height = 0.007280

name = ISL Modem
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.052754
Thermal Mass = 0.052754
Diameter/Width = 0.032590
Length = 0.064000
Height = 0.023700

name = ISL Antenna
quantity = 1
parent = 1
materialID = 8
type = Cylinder
Aero Mass = 0.030000
Thermal Mass = 0.030000
Diameter/Width = 0.020000
Length = 0.035000

name = X-band Transmitter
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.588746
Thermal Mass = 0.588746
Diameter/Width = 0.088860
Length = 0.132000
Height = 0.036000

name = Fixed Solar Panel
quantity = 1
parent = 1
materialID = 23
type = Flat Plate
Aero Mass = 0.235594
Thermal Mass = 0.235594
Diameter/Width = 0.178000
Length = 0.431000

name = ADCC
quantity = 1
parent = 1
materialID = 8

type = Box
Aero Mass = 0.312756
Thermal Mass = 0.312756
Diameter/Width = 0.083830
Length = 0.119000
Height = 0.032620

name = Solar Panel
quantity = 4
parent = 1
materialID = 23
type = Flat Plate
Aero Mass = 0.427137
Thermal Mass = 0.427137
Diameter/Width = 0.187450
Length = 0.390000

name = Bracketry
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.661902
Thermal Mass = 0.661902
Diameter/Width = 0.060000
Length = 0.100000
Height = 0.060000

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

name = HE360-Lite
Demise Altitude = 77.996644
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = +X Panel
Demise Altitude = 77.662813
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = -X Panel
Demise Altitude = 77.611465
Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****
name = +Y Panel
Demise Altitude = 77.474409
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = -Y Panel
Demise Altitude = 77.503796
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = +Z Panel
Demise Altitude = 77.612536
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = -Z Panel
Demise Altitude = 77.583227
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = GPS antenna
Demise Altitude = 76.009070
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = TTAC
Demise Altitude = 76.496312
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Propulsion Unit
Demise Altitude = 68.767559
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Battery Unit

Demise Altitude = 76.262107
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = OBC
Demise Altitude = 76.613745
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = SDR Payload
Demise Altitude = 76.418825
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = EPS
Demise Altitude = 77.254118
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Antenna DB
Demise Altitude = 77.617455
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Bus SRX Antenna
Demise Altitude = 77.125847
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Antenna Bay
Demise Altitude = 76.574388
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = DSN Filter
Demise Altitude = 77.410245
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Backplane
Demise Altitude = 77.219122
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Reaction Wheel Pyramid
Demise Altitude = 75.565922
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Magnetorquer
Demise Altitude = 75.926463
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = CBS Antenna
Demise Altitude = 76.882145
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Horn Antenna
Demise Altitude = 77.192453
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = X-band Array Antenna
Demise Altitude = 77.706069
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Earth Sensor
Demise Altitude = 77.624339
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Sun Sensor
Demise Altitude = 77.705162
Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****
name = Deployable Magnetometer
Demise Altitude = 76.342151
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Compact Magnetometer
Demise Altitude = 76.307897
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = ISL Modem
Demise Altitude = 77.476144
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = ISL Antenna
Demise Altitude = 77.034719
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = X-band Transmitter
Demise Altitude = 76.285055
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Fixed Solar Panel
Demise Altitude = 77.356148
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = ADCC
Demise Altitude = 76.928081
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Solar Panel

Demise Altitude = 76.791112
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Bracketry
Demise Altitude = 75.813394
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****

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

name = HE360-Lite-Orbit-Lower
quantity = 1
parent = 0
materialID = 8
type = Box
Aero Mass = 15.140000
Thermal Mass = 15.140000
Diameter/Width = 0.301100
Length = 0.535500
Height = 0.136000

name = H
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 15.140000
Thermal Mass = 15.140000
Diameter/Width = 0.301100
Length = 0.535500
Height = 0.136000

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

name = HE360-Lite-Orbit-Lower
Demise Altitude = 77.996644
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****

name = H
Demise Altitude = 72.653734
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****

=============== End of Requirement 4.7-1 ===============
04 01 2024; 07:48:09AM Project Data Saved To File

END of ODAR for HawkEye 360

Attachment 3

HE360 Constellation Five-Year Deorbit Compliance Analysis

Deorbit Compliance Analysis

HawkEye 360 has updated its mission concept of operations and orbital debris mitigation plan to comply with the Commission's five-year deorbit requirement from end of mission life. The following sections will describe compliance for the currently authorized spacecraft of the HE360 Constellation and the demonstration mission - Kestrel-0A separately.

HE360 Constellation Spacecraft

As described in previously submitted Orbital Debris Assessment Reports ("ODARs"),[1] the HE360 Constellation is comprised of satellites that, with launch altitudes up to 615 km circular, would passively decay in less than 25 years from launch. To ensure compliance with the FCC's new 5-year deorbit rule, HE360 will limit its maximum deployment altitude to 600 km, circular and, when required, utilize propulsive maneuvers at the beginning of life to lower the initial operating altitude, for satellites deployed after September 29, 2024.

Based on information from 21 launched HE360 satellites, HE360 expects a nominal mission life of five years, commencing after an eleven-week commissioning period. As a result, HE360 expects that all spacecraft launching after September 29, 2024, will nominally deorbit within 10 years and 11 weeks from launch and within five years of the EOM. With the current propulsion system onboard and assuming a launch in October 2024,[2] HE360 expects to meet a 5-year deorbit requirement from end of mission following initial deployment altitudes:

- Up to 556 km circular altitude; and

[1] *See, e.g.*, Application of HE360, ICFS File No. SAT-MOD-20220906-00099, at Attachment 7, Orbital Debris Assessment Report (granted in part Mar. 3, 2023, reissued Mar. 23, 2023).

[2] October 2024 is the worst-case launch period for the HE360 constellation spacecraft due to the solar activity forecasts over the next 7 years.

- Up to 600 km circular altitude with a beginning-of-life altitude-lowering maneuver down to 556 km circular altitude.

HE360 will ensure that all launches after September 29, 2024, fall within this performance envelope to ensure 5-year deorbit compliance.

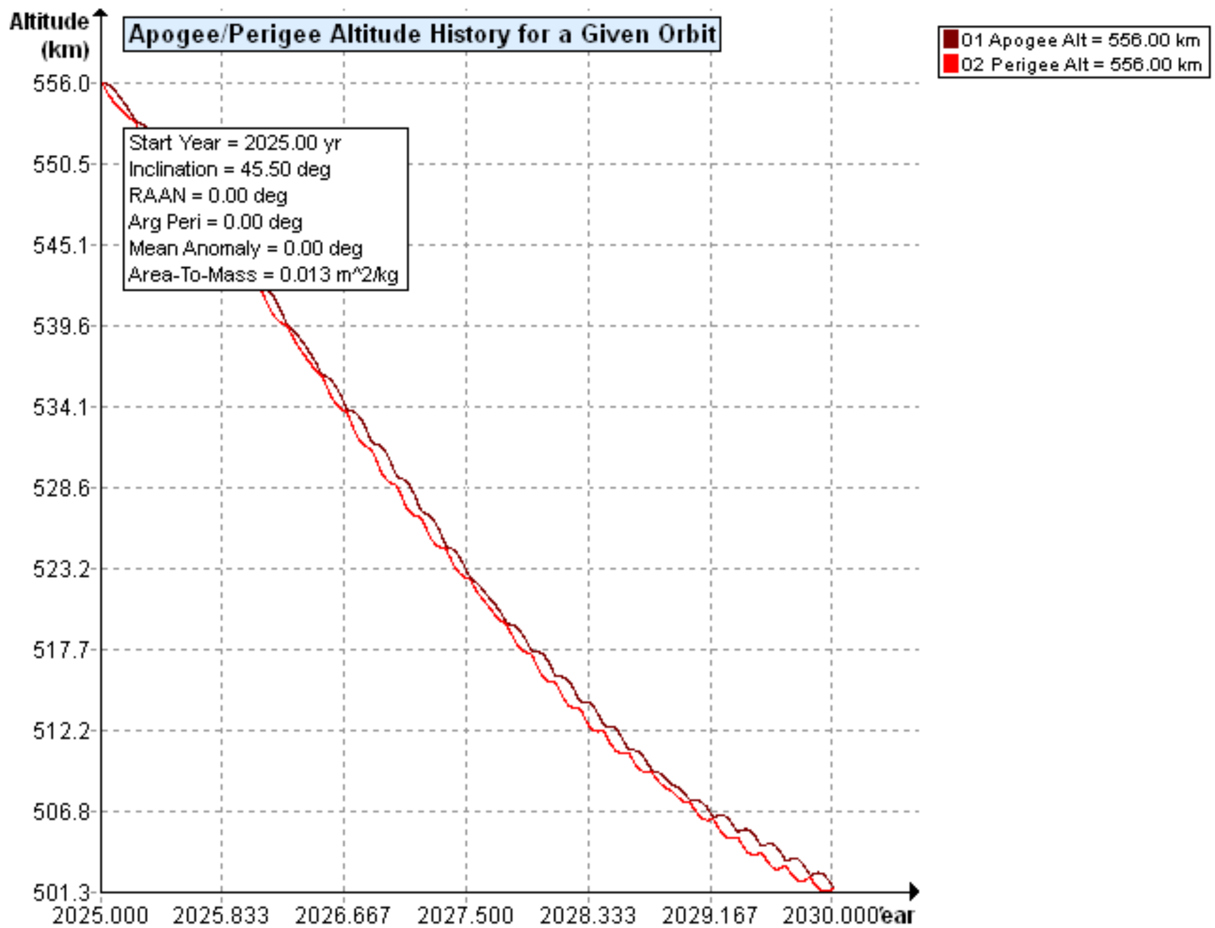
HE360 carefully analyzed the satellite Delta-V budget and concluded that 24 m/s of Delta-V can be allocated to a beginning of life maneuver to ensure that after five years of mission operation, the spacecraft will be capable of passively deorbiting within 5 years. This beginning of life Delta-V maneuver is predicted to take 11 weeks to complete. Combining the pre-mission checkout and orbit lowering, 5 years of mission operations, and 5 years of passive decay results in a total spacecraft on-orbit lifetime of 10 years, 11 weeks.

HE360 plans to launch most of its constellation on ride-share missions. As a result, a detailed analysis has been conducted to determine the maximum orbital altitude, over time, from which, the spacecraft can comply with the 5-year deorbit requirement. Transporter and Bandwagon rideshare missions typically have an upper target orbit altitude of 600 km x 600 km.

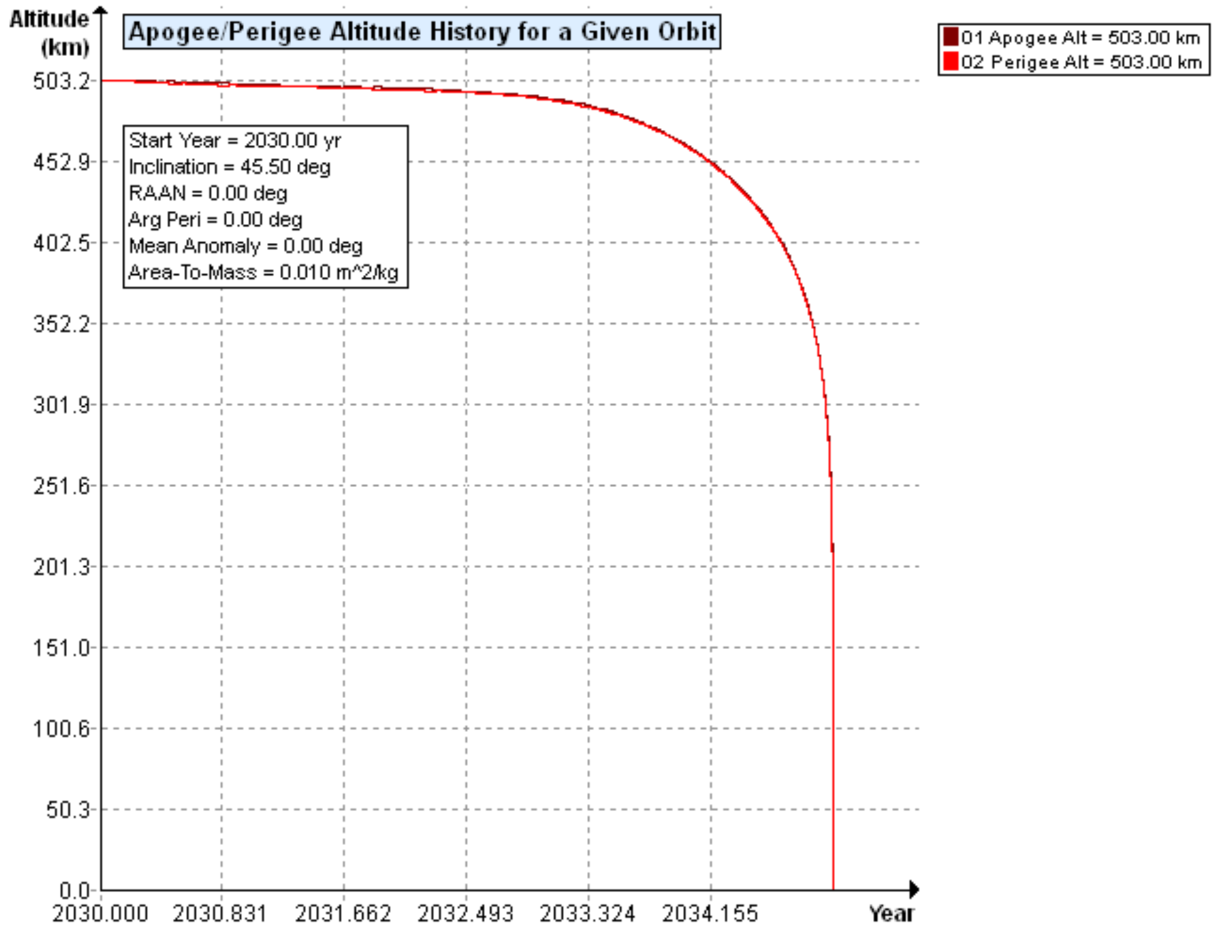
Analyzing passive orbit decay times using the NASA DAS software, the HE360 spacecraft will passively deorbit within 10 years from an orbit of 556 km x 556 km for spacecraft launched after September 29^{th}, 2024. Analysis was conducted for launch dates 15 years into the future to ensure that the passive deorbit time remains below 10 years throughout each solar cycle.

Assuming a budget of 24 m/s of Delta-V, the maximum launch orbit altitude from which the spacecraft can be lowered to the target starting operational orbit altitude of 556 km x 556 km is 600 km x 600 km. Therefore, for any launches to orbits of 600 km x 600 km or below, the spacecraft will be lowered to a circular orbit that allows passive deorbit with 10 years (thus allowing for 5 years of mission operations followed by 5 years of passive deorbit).

The following two curves illustrate the passive orbital decay from 503 km x 503 km and the passive transit from 556 x 556 km to 503 x 503 km during 5 years of operations. Propulsion system analysis demonstrates that a budget of 24 m/s Delta-V enable reducing the orbit altitude from 600 km x 600 km to 556 km x 556 km over the course of the first 11 weeks of operation. Based upon this upper limit of 600 km x 600 km, HE360 will ensure that it selects launches for its spacecraft with deployments altitudes (including error bounds) compliant with this operational limit.



Apogee/Perigee Altitude History for a Given Orbit
Altitude (km)
556.0
550.5
545.1
539.6
534.1
528.6
523.2
517.7
512.2
506.8
501.3
2025.000
2025.833
2026.667
2027.500
2028.333
2029.167
2030.000
Year
Start Year = 2025.00 yr
Inclination = 45.50 deg
RAAN = 0.00 deg
Arg Peri = 0.00 deg
Mean Anomaly = 0.00 deg
Area-To-Mass = 0.013 m^2/kg
01 Apogee Alt = 556.00 km
02 Perigee Alt = 556.00 km



Kestrel-0A

For the Kestrel-0A demonstration mission, planned to launch NET October 2024, HE360 has performed detailed deorbit analysis using NASA's Debris Assessment Software v3.2.6. HE360 has allocated approximately 12 m/s of Delta-V budget for beginning of life propulsive maneuvers. Based on the spacecraft mass and deployed envelope, propulsive capability, attitude control capability, and a 3-year mission life,[3] Kestrel-0A will be compliant with the 5-year deorbit requirement with the following initial deployment altitudes:[4]

- Up to 554 km circular altitude; and
- Up to 575 km circular altitude with a beginning-of-life altitude-lowering maneuver down to 554 km circular altitude.

As such, the Kestrel-0A spacecraft will meet the FCC 5-year deorbit rule for its mission with a launch deployment altitude of up to 575 km circular. Additionally, information regarding compliance with the 5-year deorbit rule is in the ODAR associated with this filing.

The planned mission is a rideshare mission with a target 510 km circular deployment. If HE360 chooses to launch on a later mission, HE360 will ensure that the planned deployment altitude, with error margin applied, is less than 575 km to ensure compliance with the 5-year deorbit requirement.

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[3] Because of the new form factor for the Kestrel-0A spacecraft, HE360 is estimating only a 3-year mission life rather than a 5-year mission life, which HE360 expects for its other satellites.

[4] This assumes a November 2025 launch, which is the worst-case launch period for the Kestrel-0A spacecraft due to the solar activity forecasts over the next 7 years.

Attachment 4

HE360 Constellation Orbital Debris Assessment Report

FCC Form 312

Orbital Debris Analysis Report for Cluster 11 and Later

HawkEye 360, Inc.

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

Document Data is Not Restricted.
This document contains no proprietary, ITAR, or export controlled information.
DAS Software Version Used in Analysis: v3.2.6

Change Log

ODAR Version	Date	DAS Version Used
Cluster 11+	March 29, 2024	v3.2.6

INTRODUCTION

HawkEye 360, Inc. ("HE360"), a U.S. company headquartered in Herndon, Virginia, plans to launch a commercial constellation of up to 60 simultaneously operating microsatellites. The satellites will fly in groups of 3 in proximate formation and work together to form a single observation platform ("cluster").

The HE360 satellites will deploy from the launch vehicle into a low Earth orbit at altitudes between 400 km and 600 km, with representative deployment altitudes of 525 and 575 km and nominal inclinations between 5 and 97 degrees. The satellites are calculated to re-enter the Earth's atmosphere and burn up completely in 5 years or less after a nominal 5-year mission life. To meet the post-mission deorbit requirement, the HE360 spacecraft will conduct a beginning-of-life perigee lowering maneuver if the spacecraft is inserted into an orbit greater than 556 km (circular).[1] Due to the satellite composition and small size, the entire satellite will burn up and be consumed due to atmospheric heating. There is 0% probability of human casualty as no pieces of the spacecraft will survive to the Earth's surface with energy greater than 15J.

The NASA Debris Assessment Software confirmed that the HE360 satellites satisfy all the Requirements for Limiting Orbital Debris including:

a. Mission-Related Debris Passing Through LEO
b. Mission-Related Debris Passing Near GEO
c. Long-Term Risk from Planned Breakups
d. Probability of Collision with Large Objects
e. Probability of Damage from Small Objects
f. Post-mission Disposal
g. Casualty Risk from Reentry Debris

HE360 confirms that the satellites will not undergo any planned release of debris during their normal operations. In addition, all separation and deployment mechanisms, and any other potential source of debris will be retained by the spacecraft or launch vehicle. HE360 has also assessed the probability of the space stations becoming sources of debris by collision with small debris or meteoroids of less than one centimeter in diameter that could cause loss of control and prevent post-mission disposal. HE360 has taken steps to limit the effects of such collisions through shielding, the placement of components, and the use of redundant systems.

[1] This threshold will change for each cluster based upon the launch date and current solar flux predictions at time of DAS analysis. The reported value reflects the limit for Cluster 11.

HE360 has assessed and limited the probability of accidental explosions during and after completion of mission operations through a failure mode verification analysis. As part of the satellite manufacturing process, HE360 has taken steps to ensure that debris generation will not result from the conversion of energy sources on board the satellites into energy that fragments the satellites. All sources of stored energy onboard the spacecraft will have been depleted or safely contained when no longer required for mission operations or post-mission disposal.

HE360 has assessed and limited the probability of the space stations becoming a source of debris by collisions with large debris or other operational spacecraft. HE360 does not intend to place any satellites in an orbit that is identical to or very similar to an orbit used by other space stations, and, in any event, will work closely with the cluster launch providers to ensure that the satellites are deployed in such a way as to mitigate the potential for collision with any other spacecraft. This specifically includes minimizing the potential for collision with manned spacecraft.

The HE360 satellites will perform station-keeping maneuvers to maintain separation between the satellites within a cluster and sustain the desired geometry. Typical inter-satellite distances between the satellites will be approximately 125 km and maintenance maneuvers will be conducted relatively infrequently – approximately once a week. However, the cluster will not maintain the satellites' inclination angles, apogees, perigees, and right ascension of the ascending node to any specified degrees of accuracy beyond the goals of maintaining the cluster geometry.

HE360's disclosure of the above parameters, as well as the number of space stations, the number and inclination of orbital planes, and the orbital period to be used, can assist third parties in identifying potential problems. This information also lends itself to physical coordination between HE360 and other operators.

The instant ODAR applies to Clusters 11+. The ODARs associated with prior clusters appear in previously approved HE360 applications. *See, e.g.,* Application of HE360, ICFS File No. SAT-MOD-20220906-00099, at Exhibit 7, ODAR (granted in part Mar. 3, 2023) (providing the ODAR for Clusters 7-10); Application of HE360, ICFS File No. SAT-MOD-20210114-00010, at Exhibit 2, ODAR (Granted May 25, 2021) (providing the ODAR for Clusters 3-6); Letter from Tony Lin, Counsel to HE360, to Marlene H. Dortch, Secretary, FCC, ICFS File No. SAT-AMD-20200728-00090 (filed Sept. 23, 2020) (providing the ODAR for Cluster 2); Application of HE360, ELS File No. 0024-EX-CN-2017, at Exhibit 3, ODAR (filed Mar. 10, 2017) (providing the ODAR for Cluster 1).

1. Self Assessment of the ODAR using the format in Appendix A.2 of NASA-STD-8719.14 Revision A with Change 1

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

Table 1: Orbital Debris Self-Assessment Report Evaluation for the HE360 Commercial Constellation

Req		Spacecraft			Comments
#	Description	Compliant or N/A	Not Compliant	Incomplete	
4.3-1a	Debris-LEO	x			No debris released in LEO.
4.3-1b	Debris-LEO	x			No debris released in LEO.
4.3-2	Debris-GEO	x			No debris released near GEO.
4.4-1	Explosions	x			
4.4-2	Passivation	x			
4.4-3	Long-term risk	x			No planned breakups.
4.4-4	Short-term risk	x			No planned breakups.
4.5-1	Debris from collisions-large obj	x			
4.5-2	Debris from collisions-small obj	x			
4.6-1a	Disposal by re-entry	x			
4.6-1b	Disposal by maneuvers	x			
4.6-1c	Disposal by retrieval	x			No planned retrieval.
4.6-2	Disposal near GEO	x			LEO orbits only.
4.6-3	Disposal between LEO,GEO	x			LEO orbits only.
4.6-4	Reliability of disposal	x			No planned disposal operations.
4.7-1	Risk of human casualty	x			
4.8-1	Special Classes of Space Missions	x			

2. Assessment Report Format

ODAR Technical Sections Format Requirements:

This ODAR follows the format recommended in NASA-STD-8719.14 Revision C, Appendix A.1 and includes the content indicated at a minimum in each section 2 through 8 below for the satellites in the commercial constellation. Sections 9 through 14 apply to the launch platform and are not covered here.

3. ODAR Section 1: Program Management and Mission Overview

Project Manager: HE360

Foreign government or space agency participation: No foreign government or space agency participation is anticipated.

Schedule of upcoming mission milestones:
Launch: No earlier than October 2024.

Mission Overview:
The satellites comprising each cluster will be launched and rapidly deployed from their restraint mechanisms and commissioned. Depending upon the insertion orbit, the spacecraft orbit altitude may be reduced during the first 11 weeks on orbit to ensure a 5-year deorbit following the completion of mission operations. The cluster will then begin payload operations that will continue for an estimated 5 years.

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 post-mission de-orbit lifetime is less than 5 years, as calculated by DAS.

Launch vehicle and launch site: Launch vehicle and site are to be determined for each HE360 cluster. One or more clusters of 3 satellites will be launched together on one launch vehicle in order to obtain the desired cluster formation. There are several launch vehicle options that are capable of launching the HE360 clusters of 3 satellites into the desired orbits. HE360 will select launch vehicles for each cluster based on vehicle and site availability, as well as cost and reliability.

Proposed launch date: No earlier than October 2024.

Mission duration: Nominal mission lifetime is 5 years, following 11 weeks of spacecraft checkout and beginning-of-life orbit lowering. The estimated nominal post-mission de-orbit lifetime is less than 5 years.

Launch and deployment profile, including all parking, transfer, and operational orbits with apogee, perigee, and inclination: The HE360 satellites will deploy from the launch vehicle into a low Earth orbit at altitudes between 400 km and 600 km, with representative deployment altitudes of 525 and 575 km.

Nominal Upper Insertion Case: Apogee: 575 km; Perigee: 575 km
Nominal **Inclination:** 5 degrees, 46.5 degrees, or 97 degrees

Nominal Lower Insertion Case: Apogee: 525 km; Perigee: 525 km
Nominal **Inclination:** 5 degrees, 46.5 degrees, or 97 degrees

The next HE360 launch is Cluster 11, which is expected to be deployed to the following orbit:

- Apogee: 510 km ±20 km
- Perigee: 510 km ±20 km
- Inclination: 45.0° ±1.1°

The HE360 satellites have propulsion for station-keeping, cluster formation establishment, collision avoidance, and orbit lowering. There is no parking or transfer orbit.

Reason for selection of operational orbit(s): Orbits were chosen to maximize global coverage and ground station communication opportunities.

Identification of any interaction or potential physical interference with other operational spacecraft: The HE360 satellites are not expected to interact or physically interfere with other operational spacecraft.

4. ODAR Section 2: Spacecraft Description

Physical description of the spacecraft:
The HE360 satellites are microsatellites, each with a launch mass of less than 33 kg. To perform the intended mission, the HE360 spacecraft have a variety of antennas mounted externally to the spacecraft. The specific antennas included on any individual cluster of spacecraft may vary, but the inclusive set of all possible antennas at this time have been included in this ODAR for analysis and to ensure that any combination of antennas meet the FCC's orbital debris requirements.

Basic physical outside dimensions are: 300 mm x 300 mm x 450 mm.

The spacecraft is composed of an aluminum structure with deployable solar arrays.

Power storage is provided by six prismatic Lithium-Ion cells. The batteries will be recharged by solar cells mounted on both deployed arrays and on the body of the satellite.

Detailed illustration of the entire spacecraft in the mission operation configuration with clear overall dimensional markings: Figures 1-2 show the external layout of the HE360 spacecraft with dimensional markings.

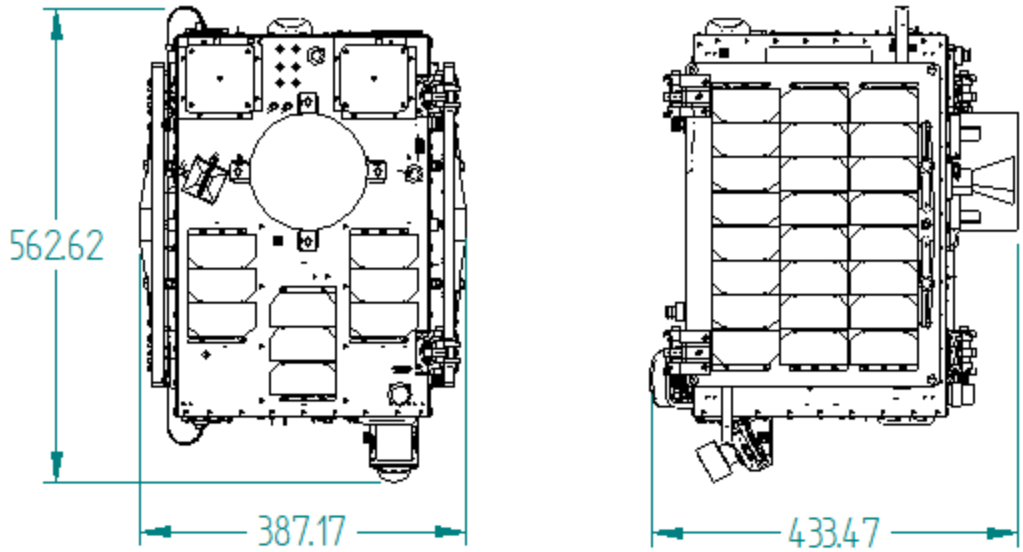


Figure 1: HE360 Spacecraft in Stowed Configuration

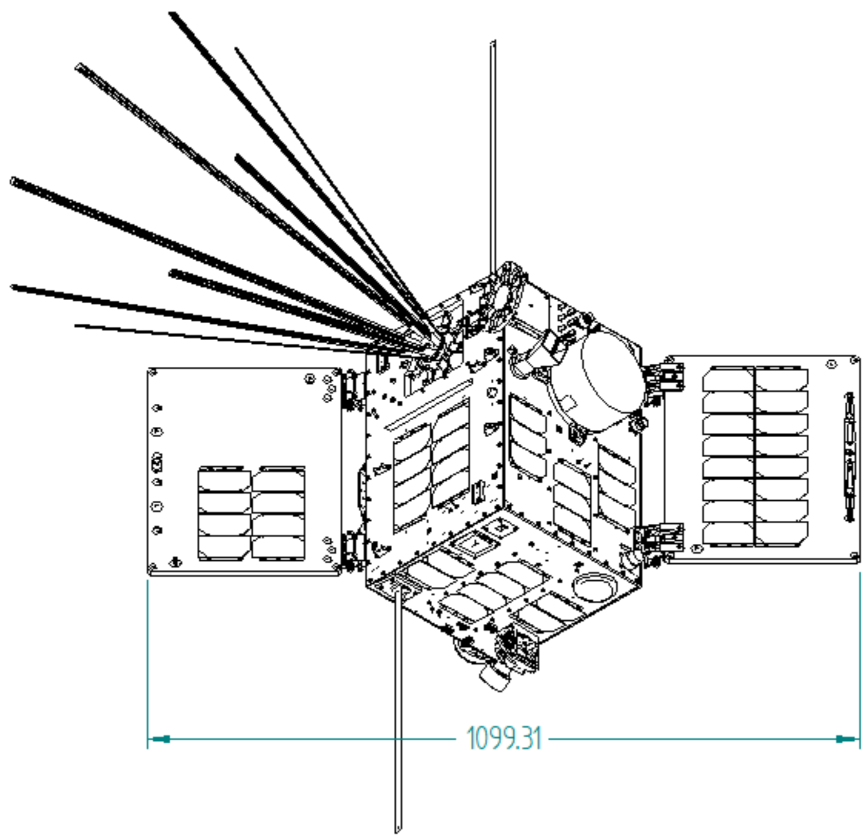


Figure 2: HE360 Spacecraft in Deployed Configuration

Total satellite mass at launch, including all propellants and fluids:
Water-based Propulsion Option – Maximum of 33.0 kg including separation system

Dry mass of satellites at launch, excluding propellant:
Water-based Propulsion Option – Maximum of 32.26 kg including separation system

Description of all propulsion systems (cold gas, mono-propellant, bi-propellant, electric, nuclear):
HE360 will employ a water-based propulsion system on its satellites.

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: Distilled water and methanol[2] (740 g) and FE-36 pressurant (40 g) at a maximum pressure of 3.7 barA. Fluid will be loaded into the propulsion system by the manufacturer and will be installed in a flight-ready configuration with no additional pressurization operations required.

Fluids in Pressurized Batteries: None. The satellites use heritage, unpressurized, standard COTS Lithium-Ion battery cells from SAFT.

Description of attitude control system and indication of the normal attitude of the spacecraft with respect to the velocity vector:
Satellite attitude is controlled by magnetorquers and reaction wheels. The nominal attitude is an align/constrain sun-tracking mode where a particular fixed body-frame vector, chosen to maximize power generation, is aligned with the sun, and rotation about the sun vector is constrained to point a second fixed body-frame axis to nadir. Other possible attitude modes include: nadir-pointing, target-tracking, tumble/de-tumble and low/high drag profiles.

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 triple-junction GaAs solar cells. A battery protection circuit protects against over and undercharge conditions.

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

Identification of any radioactive materials on board: None.

Address the trackability of the spacecraft. Spacecraft operating in low-Earth orbit will be presumed trackable if each individual spacecraft is 10 cm or larger in its smallest dimension, excluding deployable components:

[2] The lower the freezing point of the distilled water.

The spacecraft are in low-Earth orbit and has a smallest dimension measuring at least 10 cm. Thus, they are trackable.

The statement shall also disclose the following:

How the operator plans to identify the spacecraft following deployment and whether spacecraft tracking will be active or passive:
Spacecraft tracking will be active. Prior to deployment, an initial ephemeris is produced by the launch service that will be used to schedule a contact time window with the ground station. The accuracy of the ephemeris will depend on the launch vehicle's performance, delays, and deployment times. A more accurate ephemeris will be made available shortly after deployment. After deployment when the satellite establishes contact, active satellite tracking will be employed to enhance and maintain satellite ephemeris data. The collected data will be used to identify the spacecraft from two-line element sets once they become available by the 18th Space Defense Squadron.

Whether, prior to deployment, the spacecraft will be registered with the 18th Space Control Squadron or successor entity:
Prior to deployment, the spacecraft will be registered with the 18th Space Defense Squadron via their Satellite Registration Form and Space Situational Awareness (SSA) Sharing Agreement.

The extent to which the spacecraft operator plans to share information regarding initial deployment, ephemeris, and/or planned maneuvers with the 18th Space Control Squadron or successor entity, other entities that engage in space situational awareness or space traffic management functions, and/or other operators:
HE360 will provide the 18th Space Defense Squadron information regarding initial deployment, owner/operator (O/O) ephemeris, and planned maneuvers. This is intended to provide better space situational awareness and improve the accuracy of conjunction analysis (CA). The higher accuracy O/O ephemeris will improve the quality of the CA and reduce the frequency of Conjunction Data Messages (CDMs). HE360 intends to publish its ephemeris online three times daily, via Space-Track.org, and coordinate with LeoLabs, Inc., to publish HE360-generated ephemeris.

Planned Proximity Operations
The satellite clusters fly in formation in groups of 3 and work together to form a single observation platform. Spacing will be maintained with propulsion and differential drag to ensure ~125 km minimum separation.

5. ODAR Section 3: Assessment of Spacecraft Debris Released during Normal Operation

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):

Requirement 4.3-1: Mission Related Debris Passing Through LEO. a. Requirement 4.3-1a: All debris released during the deployment, operation, and disposal phases shall be limited to a maximum orbital lifetime of 25 years from date of release (Requirement 56398). b. Requirement 4.3-1b: The total object-time product shall be no larger than 100 object-years per mission (Requirement 56399). The object-time product is the sum of all debris of the total time spent below 2,000 km altitude during the orbital lifetime of each object. (See section 4.3.4.2 for methods to calculate the object-time product.)
Compliance Statement: COMPLIANT There are no intentional releases.

Requirement 4.3-2: Mission Related Debris Passing Near GEO. For missions leaving debris in orbits with the potential of traversing GEO (GEO altitude +/- 200 km and +/- 15 degrees latitude), released debris with diameters of 5 cm or greater shall be left in orbits which will ensure that within 25 years after release the apogee will no longer exceed GEO - 200 km (Requirement 56400).
Compliance Statement: COMPLIANT No released debris.

6. 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 explosive rupture. 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 explosive rupture. The batteries include vent-before-burst features to minimize the chances of explosive rupture.

Detailed plan for any designed spacecraft breakup, including explosions and intentional collisions: There are no planned breakups.

List of components which shall be passivated at End of Mission (EOM) including method of passivation and amount which cannot be passivated: None. At end of mission, under nominal situations, any remaining propellant may be used to decay orbit as much as possible, therefore depleting propellant. The six batteries will not be passivated at End of Mission due to the low risk and low impact of explosive rupturing, and the extremely short lifetime at mission conclusion. The maximum total chemical energy stored in the battery is approximately 543kJ.

Rationale for all items which are required to be passivated, but cannot be due to their design: The battery charge circuits include overcharge protection 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. This electrical power system has already been flight qualified on the GHGSat-D mission and has since been flown on multiple HE360 missions. Further, the battery technology baselined on HE360 spacecraft has flown on over a dozen UTIAS Space Flight Labs (SFL) spacecraft without failure.

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: COMPLIANT Expected probability: 0.000

Supporting Rationale and FMEA details:
Battery explosion:

Effect: All failure modes below might theoretically result in battery explosive rupture 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. Furthermore, each battery has a pressure relief burst disc that prevents catastrophic battery enclosure failure.

Probability: Extremely low. It is believed to be a much less than 0.1% probability that multiple independent (not common mode) faults 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 fail for this failure mode to occur.

Failure Mode 2: Internal thermal rise due to high load discharge rate.
Mitigation 2: Cells were tested in lab for high load discharge rates in a variety of flight-like configurations to determine likelihood and impact of an out of control thermal rise in the cell. Cells were also tested in a hot environment to test the upper limit of the cells capability. No failures were seen.
Combined faults required for realized failure: Spacecraft thermal design must be incorrect AND external over-current detection and disconnect function must fail for this failure mode to occur.

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 must fail for this failure mode to occur.

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 must fail to install proper venting for this failure mode to occur.

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 for this failure mode to occur.

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 for this failure mode to occur.

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. This design has been verified through the GHGSat-D and other SFL missions.
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 post-mission disposal or control to a level which cannot cause an explosion or deflagration large enough to release orbital debris or break up the spacecraft (Requirement 56450).
Compliance statement: COMPLIANT Onboard sources of energy include onboard batteries for energy storage. The battery charge circuits include overcharge protection to limit the risk of battery failure. And as previously mentioned, the integrated burst disc should prevent any explosion altogether. 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. There is no expectation of producing orbital debris or spacecraft breakup from an unlikely battery explosion.

Requirement 4.4-3. Limiting the long-term risk to other space systems from planned breakups. Planned explosions or intentional collisions shall: a. Be conducted at an altitude such that for orbital debris fragments larger than 10 cm the object-time product does not exceed 100 object-years (Requirement 56453). For example, if the debris

fragments greater than 10 cm decay in the maximum allowed 1 year, a maximum of 100 such fragments can be generated by the breakup. b. Not generate debris larger than 1 mm that remains in Earth orbit longer than one year (Requirement 56454).
Compliance statement: Not applicable; there are no planned breakups.

Requirement 4.4-4: Limiting the short-term risk to other space systems from planned breakups. Immediately before a planned explosion or intentional collision, the probability of debris, orbital or ballistic, larger than 1 mm colliding with any operating spacecraft within 24 hours of the breakup shall be verified to not exceed 10^-6 (Requirement 56455).
Compliance statement: N/A; There are no planned breakups.

7. 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, and calculation methods provided in NASA-STD-8719.14 Revision A with Change 1, 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).
Compliance Statement: COMPLIANT **Large Object Impact and Debris Generation Probability:** Collision Probability: < 0.000012014

Supporting Deployment and Collision Risk Analysis
The above collision probability is a product of NASA's DAS software.

The HE360 constellation, fully deployed, will consist of 60 operational satellites in 20 clusters of 3 satellites, distributed as follows (from an inclination perspective):[3]

- 40% (8 clusters or 24 spacecraft) in near-polar orbits (97 – 98 degrees)
- 50% (10 clusters or 30 spacecraft) in mid-inclination orbits (35-50 degrees)
- 10% (2 clusters or 6 spacecraft) in low-inclination orbits (0-28.5 degrees)

[3] *See* Letter from Michael Mineiro, HE360, to Merissa Velez, FCC (dated June 1, 2021); *see also* Application of HE360, ICFS File No. SAT-LOA-20190102-00001, at Exhibit A, Narrative (granted October 20, 2022). .

Over the operational life of the constellation, HE360 plans to launch and operate a maximum of 58 clusters (of 3 satellites per cluster) or 174 satellites, following the general distribution described above.

For the purposes of computing the probability of collision with large objects, HE360 has analyzed a single target orbital altitude (556 km) and three distinct representative inclinations (97, 46.5 and 5 degrees). The table below illustrates the probabilities of collision with large objects, computed using DAS, in each of the three representative cases.

	Collision Risk		
Orbital Altitude (km)	97-degree inclination	46.5-degree inclination	5-degree inclination
556	9.9892E-06	6.5046E-06	5.5778E-06

In each case, the satellite meets the 0.001 requirement by nearly two orders of magnitude. Furthermore, aggregating the collision probability for all 174 spacecraft over the life of the constellation, with the orbital inclination distribution described above, results in a total probability of collision with large objects of 0.001357.

The HE360 spacecraft have propulsion systems and will, if possible, conduct collision avoidance maneuvers when warranted. Indeed, the FCC has stated that the large object collision probability should be treated as zero when satellites are capable of propulsive maneuvers.[4] Furthermore, under nominal situations, the remaining propellant at end of mission may be employed to reduce the orbit altitude and orbital life of spacecraft, which will also reduce the probability of collision with large objects due to reduced orbital lifetime. To be clear, no such action is necessary to meet regulatory requirements.

Detailed description and assessment of efficacy of any planned debris avoidance capability intended to help in meeting requirement 4.5-1

There is no significant risk of collision based on orbital parameters and propulsion capability. Furthermore, HE360 will register all HE360 spacecraft with the US Space Force's 18th Space Defense Squadron, which provides active monitoring in conjunction with the Combined Space Operations Center.

HE360 will also work with other spacecraft operators to avoid potential collisions with HE360 satellites, as necessary.

[4] *See* 47 C.F.R. § 25.114(d)(14)(iv)(A)(1)("The collision risk may be assumed zero for a space station during any period in which the space station will be maneuvered effectively to avoid colliding with large objects."); *Mitigation of Orbital Debris in the New Space Age,* Report and Order and Further Notice of Proposed Rulemaking, IB Docket No. 18-313, 35 FCC Rcd 4156, at ¶ 35 (2020)("[F]or purposes of conducting the analysis, and absent evidence to the contrary, the collision risk with large objects should be assumed zero or near zero during the period of the time when the space station is able to conduct collision avoidance maneuvers."); *Space Exploration Holdings, LLC,* Request for Modification of the Authorization for the SpaceX NGSO Satellite System, Memorandum Opinion and Order, 35 FCC Rcd 5649, at ¶ 20 (2020) ("[I]t is the Commission's established licensing practice to consider satellites equipped with propulsion capability to have a collision risk of zero or near zero, absent specific information to the contrary.").

If at any time during the spacecraft's mission or de-orbit phase the spacecraft will operate in or transit through the orbits used by any planned or inhabitable spacecraft, including the International Space Station, describe the design and operational strategies, such as coordination, that will be used to minimize the risk of collision and avoid posing any operational constraints to the spacecraft

Under nominal situations, the remaining propellant at end of mission may be employed to reduce the orbit altitude and orbital life of spacecraft. Under best case scenarios, the orbit altitude will be lowered to just above the ISS orbit and then the spacecraft will be passivated, including venting any remaining propellant.

With respect to the operational strategies to minimize risk to the ISS or any other inhabitable spacecraft in low Earth orbit, HE360 intends to monitor the location of its satellites and work closely with organizations, such as the 18th Space Defense Squadron. To the extent possible, HE360 will be able to conduct collision avoidance maneuvers using differential drag techniques with sufficient advance notice. More generally, HE360 also works with the Space Data Association to coordinate physical operation of its constellation with other operators.[5]

Certify that upon receipt of a space situational awareness conjunction warning, the operator will review and take all possible steps to assess the collision risk, and will mitigate the collision risk if necessary

Upon receipt of a space situational awareness conjunction warning, HE360 certifies that it will attempt to contact the operator of any active spacecraft involved in such a warning, share ephemeris data and other appropriate operational information with any such operator, and modify the spacecraft's attitude, orbit, and/or operations in order to avoid a collision. If the operator of the other spacecraft does not have maneuvering capabilities or is not expedient in response, HE360 will upload potential maneuvers via API to the 18th Space Defense Squadron in order to avoid a collision. High risk events will be mitigated to at least one and a half orders of magnitude below the collision probability mitigated action threshold of 1E-5.

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 post-mission disposal requirements is less than 0.01 (Requirement 56507).
Compliance Statement: COMPLIANT **DAS Analysis for Small Object Impact and Debris Generation Probability:** COMPLIANT. In order to meet the 5-year deorbit requirement, HE360 will lower the orbit altitude (as necessary) if the insertion orbit is above 556km circular during the first 3-month of operation. From an orbit altitude of 556 km or below, the spacecraft will passively deorbit in less than 5-years, following a 5-year mission. Based upon this approach, the probability of collision with small objects has been conducted based upon an operational duration of only 3 months. Given

[5] *See* Letter from Michael Mineiro, HE360, to Merissa Velez, FCC (dated October 21, 2021).

such a short time period, we were able to make extremely conservative assumptions. The critical surface was defined as the largest surface of the spacecraft body. Solar panels were not included due to the inherently parallel nature of solar power generation. Even with the extremely conservative assumption described above, the probability of collision with small objects is still only 4.7165E-03 which is compliant. Details of the DAS analysis of collision with small objects are illustrated in Annex B below.

Because HE360 relies upon a beginning-of-mission propulsive maneuver to ensure compliance with the 5-year post-mission deorbit rule, the reliability of completing this maneuver must be demonstrated to be at least 90% (with a goal of 99%). Given that the propulsion maneuver is planned during the first three months of operation, a 99% reliability translates to a mean time between failure (MTBF) of ~300 months. The HE360 satellites using the water-based propulsion system has >600 spacecraft-months of operation without a failure, suggesting an MTBF >600 months which reflects a 99.5% reliability after the first three months of operation.

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

Description of spacecraft disposal option selected: The HE360 satellites will be disposed of by atmospheric re-entry.

Identification of all systems or components required to accomplish any post-mission disposal operation, including passivation and maneuvering:
Nothing is required for post-mission disposal to meet the 5-year deorbit requirement. However, to meet the post-mission deorbit requirement, the HE360 spacecraft will conduct a beginning-of-mission orbit lowering maneuver if the spacecraft are inserted into an orbit greater than 556 km (circular). In order to achieve this orbit lowering maneuver, all primary bus functionality will be required, including: TT&C, flight, AODC, EPS, and propulsion.

Plan for any spacecraft maneuvers required to accomplish post-mission disposal:
Under nominal situations, any remaining propellant at EOM can be used to further decrease the orbit altitude and significantly reduce the post-operations lifetime. To be clear, no such action is necessary to meet regulatory requirements.

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

The area-to-mass ratio calculations presented below are worst-case with additional mass margin to provide a buffer to address modest changes to satellite design over the life of the constellation which might increase satellite mass. By selecting a worst-case mass, HE360 is over-estimating the orbital lifetime. The cross-sectional areas were computed using the HE360 spacecraft solid model. The operational drag area was estimated using both the spacecraft solid model and an estimate of time distribution of spacecraft orientations based upon downloaded telemetry data from a representative Cluster.

Spacecraft mass: 33 kg
Cross-sectional area:
Maximum Drag Area: 0.48 m^2 (drag area)
Operational Drag Area: 0.417 m^2 (drag area)
Tumbling Drag Area: 0.338 m^2 (drag area)
Minimum Drag Area: 0.155 m^2 (drag area)

Operational area to mass ratio: 0.012652 m^2/kg
Tumbling area to mass ratio: 0.010243

Assessment of spacecraft compliance with Requirements 4.6-1 through 4.6-5 (per DAS and NASA-STD-8719.14 Revision C):

Table 2 below shows results from DAS using the Orbit Lifetime/Dwell Time Science and Engineering Tool. These results use the following common inputs:
Start Year = 2025.0
RAAN = 0
Arg of Perigee = 0

Table 2: DAS Results for Orbit Lifetime

Perigee Altitude (km)	Apogee Altitude (km)	Area-to-Mass Ratio	Inclination (deg)	Orbital Lifetime (yrs)	Object re-entered?
556	556	0.012636	97	9.435	Y
556	556	0.012636	46.5	9.588	Y
556	556	0.012636	5	9.451	Y
530	530	0.012636	45.5	5.552	Y

The last row in the table above illustrates the operational life (assuming no station keeping) from the maximum planned insertion orbit for Cluster 11. The other rows illustrate the worst-case operational lifetime from future HE360 missions assuming a beginning of life orbit reduction maneuver down to 556 km circular.

Requirement 4.6-1: Disposal for space structures passing through LEO:
A spacecraft or orbital stage with a perigee altitude below 2000 km shall be disposed of by one of three methods:
(Requirement 56557)

a) Atmospheric reentry option:
   - Leave the space structure in an orbit in which natural forces will lead to atmospheric reentry within 25 years after the completion of mission but no more

than 30 years after launch; or Maneuver the space structure into a controlled de-orbit trajectory as soon as practical after completion of mission. b) Storage orbit option: Maneuver the space structure into an orbit with perigee altitude greater than 2000 km and apogee less than GEO - 500 km. c) Direct retrieval: Retrieve the space structure and remove it from orbit within 10 years after completion of mission
Compliance Statement: COMPLIANT **DAS Analysis:** The HE360 satellite disposal plan is COMPLIANT using the atmospheric re-entry option. Results from DAS analysis show the following: For Worst-Case Orbit: 600 km x 600 km Post-Mission Lifetime: Less than 12.4 years, if deployed in an inoperable, deployed configuration, and less than 20.8 years, if deployed in an inoperable, stowed configuration.

Requirement 4.6-2: Disposal for space structures near GEO. A spacecraft or orbital stage in an orbit near GEO shall be maneuvered at EOM to a disposal orbit above GEO with a predicted minimum perigee of GEO +200 km (35,986 km) or below GEO with an apogee of GEO – 200 km (35,586 km) for a period of at least 100 years after disposal (Requirement 56563).
Compliance Statement: Not applicable; no orbits planned near GEO.

Requirement 4.6-3: Disposal for space structures between LEO and GEO. a. A spacecraft or orbital stage shall be left in an orbit with a perigee greater than 2000 km above the Earth's surface and apogee less than 500 km below GEO (Requirement 56565). b. A spacecraft or orbital stage shall not use nearly circular disposal orbits near regions of high value operational space structures, such as between 19,200 km and 20,700 km (Requirement 56566).
Compliance Statement: Not applicable; no orbits planned between LEO and GEO.

Requirement 4.6-4: Reliability of Post-mission Disposal Operations in Earth orbit. NASA space programs and projects shall ensure that all post mission disposal operations to meet Requirements 4.6-1, 4.6-2, and/or 4.6-3 are designed for a probability of success as follows: (Requirement 56567) a. Be no less than 0.90 at EOM. b. For controlled reentry, the probability of success at the time of reentry burn must be sufficiently high so as not to cause a violation of Requirement 4.7-1 pertaining to limiting the risk of human casualty.
Compliance Statement: N/A; No plans for post-mission disposal operations. However, to meet the post-mission deorbit requirement, the HE360 spacecraft will conduct a beginning-of-mission orbit altitude lowering maneuver if the spacecraft is inserted into an orbit greater than 556 km (circular).

9. ODAR Section 7: Assessment of Spacecraft Reentry Hazards

HE360 has analyzed the demise analysis for the following spacecraft configuration: Cluster 11+.

Results from DAS show that, in both configurations, no components are expected to survive re-entry with an impacting kinetic energy in excess of 15 joules from any of the planned orbits. Details of the DAS analysis are illustrated in Annex A below.

Assessment of spacecraft compliance with Requirement 4.7-1:

Requirement 4.7-1a: Limit the risk of human casualty. The potential for human casualty is assumed for any object with an impacting kinetic energy in excess of 15 joules: a) For uncontrolled reentry, the risk of human casualty from surviving debris shall not exceed 0.0001 (1:10,000) (Requirement 56626).
Compliance Statement: COMPLIANT. Analysis performed using DAS shows that no part of the satellite is expected to have an impacting kinetic energy in excess of 15 joules, and that the risk of human casualty is zero (0) for all planned orbits and inclinations.

Requirement 4.7-1b: For controlled reentry, the selected trajectory shall ensure that no surviving debris impact with a kinetic energy greater than 15 joules is closer than 370 km from foreign landmasses, or is within 50 km from the continental U.S., territories of the U.S., and the permanent ice pack of Antarctica (Requirement 56627).
Compliance Statement: Not Applicable; no plans to use controlled re-entry.

Requirement 4.7-1c: For controlled reentries, the product of the probability of failure of the reentry burn (from Requirement 4.6-4.b) and the risk of human casualty assuming uncontrolled reentry shall not exceed 0.0001 (1:10,000) (Requirement 56628).
Compliance Statement: Not Applicable; no plans to use controlled re-entry.

10. ODAR Section 7A: Assessment of Spacecraft Hazardous Materials

HE360 spacecraft do not contain any hazardous materials.

11. ODAR Section 8: Special Classes of Space Missions

Requirement 4.8-1: Mitigate the collision hazards of space tethers in Earth or Lunar orbits. Intact and remnants of severed tether systems in Earth and lunar orbit shall meet the requirements limiting the generation of orbital debris from on-orbit collisions (Requirements

4.5-1 and 4.5-2) and the requirements governing post-mission disposal (Requirements 4.6-1 through 4.6-4) to the limits specified in those paragraphs (Requirement 56652).
Compliance Statement: Not Applicable; there are no tethers in the HE360 mission.

Annex A – DAS Log Results

03 29 2024; 06:38:07AM Project Data Saved To File
03 29 2024; 06:38:11AM Processing Requirement 4.3-1: Return Status : Not Run

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

=============== End of Requirement 4.3-1 ===============
03 29 2024; 06:38:13AM Processing Requirement 4.3-2: Return Status : Passed

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

=============== End of Requirement 4.3-2 ===============
03 29 2024; 07:02:17AM Processing Requirement 4.5-1: Return Status : Passed

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

INPUT

Space Structure Name = Orbit1
Space Structure Type = Payload
Perigee Altitude = 556.000 (km)
Apogee Altitude = 556.000 (km)
Inclination = 46.500 (deg)
RAAN = 0.000 (deg)
Argument of Perigee = 0.000 (deg)
Mean Anomaly = 0.000 (deg)
Final Area-To-Mass Ratio = 0.0126 (m^2/kg)
Start Year = 2025.000 (yr)
Initial Mass = 33.000 (kg)
Final Mass = 32.260 (kg)
Duration = 5.000 (yr)
Station-Kept = False
Abandoned = True
Long-Term Reentry = False

OUTPUT

Collision Probability = 6.5046E-06

Returned Message: Normal Processing
Date Range Message: Normal Date Range
Status = Pass

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

INPUT

Space Structure Name = Orbit2
Space Structure Type = Payload
Perigee Altitude = 556.000 (km)
Apogee Altitude = 556.000 (km)
Inclination = 97.000 (deg)
RAAN = 0.000 (deg)
Argument of Perigee = 0.000 (deg)
Mean Anomaly = 0.000 (deg)
Final Area-To-Mass Ratio = 0.0126 (m^2/kg)
Start Year = 2025.000 (yr)
Initial Mass = 33.000 (kg)
Final Mass = 32.260 (kg)
Duration = 5.000 (yr)
Station-Kept = False
Abandoned = True
Long-Term Reentry = False

OUTPUT

Collision Probability = 9.9892E-06
Returned Message: Normal Processing
Date Range Message: Normal Date Range
Status = Pass

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

INPUT

Space Structure Name = Orbit3
Space Structure Type = Payload
Perigee Altitude = 556.000 (km)
Apogee Altitude = 556.000 (km)
Inclination = 5.000 (deg)
RAAN = 0.000 (deg)
Argument of Perigee = 0.000 (deg)
Mean Anomaly = 0.000 (deg)
Final Area-To-Mass Ratio = 0.0126 (m^2/kg)
Start Year = 2025.000 (yr)

Initial Mass = 33.000 (kg)
Final Mass = 32.260 (kg)
Duration = 5.000 (yr)
Station-Kept = False
Abandoned = True
Long-Term Reentry = False

OUTPUT

Collision Probability = 5.5778E-06
Returned Message: Normal Processing
Date Range Message: Normal Date Range
Status = Pass

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

=============== End of Requirement 4.5-1 ===============

03 29 2024; 07:05:34AM Project Data Saved To File
03 29 2024; 07:06:29AM Requirement 4.5-2: Compliant

=============== End of Requirement 4.5-2 ===============

03 29 2024; 07:06:32AM Processing Requirement 4.6 Return Status : Passed

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

INPUT

Space Structure Name = Orbit1
Space Structure Type = Payload

Perigee Altitude = 556.000000 (km)
Apogee Altitude = 556.000000 (km)
Inclination = 46.500000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Area-To-Mass Ratio = 0.012636 (m^2/kg)
Start Year = 2025.000000 (yr)
Initial Mass = 33.000000 (kg)
Final Mass = 32.260000 (kg)
Duration = 5.000000 (yr)
Station Kept = False

Abandoned = True
PMD Perigee Altitude = 503.277350 (km)
PMD Apogee Altitude = 503.767288 (km)
PMD Inclination = 46.491740 (deg)
PMD RAAN = 210.248872 (deg)
PMD Argument of Perigee = 354.527516 (deg)
PMD Mean Anomaly = 0.000000 (deg)
Long-Term Reentry = False

OUTPUT

Suggested Perigee Altitude = 503.277350 (km)
Suggested Apogee Altitude = 503.767288 (km)
Returned Error Message = Passes LEO reentry orbit criteria.

Released Year = 2034 (yr)
Requirement = 61
Compliance Status = Pass

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

INPUT

Space Structure Name = Orbit2
Space Structure Type = Payload

Perigee Altitude = 556.000000 (km)
Apogee Altitude = 556.000000 (km)
Inclination = 97.000000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Area-To-Mass Ratio = 0.012636 (m^2/kg)
Start Year = 2025.000000 (yr)
Initial Mass = 33.000000 (kg)
Final Mass = 32.260000 (kg)
Duration = 5.000000 (yr)
Station Kept = False
Abandoned = True
PMD Perigee Altitude = 499.261712 (km)
PMD Apogee Altitude = 499.836456 (km)
PMD Inclination = 97.056379 (deg)
PMD RAAN = 250.547297 (deg)
PMD Argument of Perigee = 156.056697 (deg)
PMD Mean Anomaly = 0.000000 (deg)
Long-Term Reentry = False

OUTPUT

Suggested Perigee Altitude = 499.261712 (km)
Suggested Apogee Altitude = 499.836456 (km)
Returned Error Message = Passes LEO reentry orbit criteria.

Released Year = 2034 (yr)
Requirement = 61
Compliance Status = Pass

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

INPUT

Space Structure Name = Orbit3
Space Structure Type = Payload

Perigee Altitude = 556.000000 (km)
Apogee Altitude = 556.000000 (km)
Inclination = 5.000000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Area-To-Mass Ratio = 0.012636 (m^2/kg)
Start Year = 2025.000000 (yr)
Initial Mass = 33.000000 (kg)
Final Mass = 32.260000 (kg)
Duration = 5.000000 (yr)
Station Kept = False
Abandoned = True
PMD Perigee Altitude = 500.430642 (km)
PMD Apogee Altitude = 500.659730 (km)
PMD Inclination = 4.995756 (deg)
PMD RAAN = 182.671201 (deg)
PMD Argument of Perigee = 356.856741 (deg)
PMD Mean Anomaly = 0.000000 (deg)
Long-Term Reentry = False

OUTPUT

Suggested Perigee Altitude = 500.430642 (km)
Suggested Apogee Altitude = 500.659730 (km)
Returned Error Message = Passes LEO reentry orbit criteria.

Released Year = 2034 (yr)

Requirement = 61
Compliance Status = Pass

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

=============== End of Requirement 4.6 ===============
03 29 2024; 07:06:41AM *********Processing Requirement 4.7-1
Return Status : Passed

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

name = Orbit1
quantity = 1
parent = 0
materialID = 5
type = Box
Aero Mass = 32.259998
Thermal Mass = 32.259998
Diameter/Width = 0.300000
Length = 0.450000
Height = 0.300000

name = C10-GPS Antenna 1
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.187000
Thermal Mass = 0.187000
Diameter/Width = 0.068000
Length = 0.070000
Height = 0.053000

name = C10-GPS Antenna 2
quantity = 1
parent = 1
materialID = 8
type = Cylinder
Aero Mass = 0.126000
Thermal Mass = 0.126000
Diameter/Width = 0.070000
Length = 0.022000

name = C10-GPS Filter
quantity = 1

parent = 1
materialID = 8
type = Box
Aero Mass = 0.040000
Thermal Mass = 0.040000
Diameter/Width = 0.050000
Length = 0.068000
Height = 0.008500

name = C10-Solar Wings
quantity = 2
parent = 1
materialID = 8
type = Box
Aero Mass = 0.906000
Thermal Mass = 0.906000
Diameter/Width = 0.330000
Length = 0.360000
Height = 0.060000

name = C10-Z panels
quantity = 2
parent = 1
materialID = 8
type = Flat Plate
Aero Mass = 0.871000
Thermal Mass = 0.871000
Diameter/Width = 0.300000
Length = 0.300000

name = C10-Wing Deployer
quantity = 2
parent = 1
materialID = 54
type = Cylinder
Aero Mass = 0.325000
Thermal Mass = 0.325000
Diameter/Width = 0.350000
Length = 0.200000

name = C10-X Panels
quantity = 2
parent = 1
materialID = 8
type = Flat Plate
Aero Mass = 1.093000

Thermal Mass = 1.093000
Diameter/Width = 0.300000
Length = 0.450000

name = C10-Y Panels
quantity = 2
parent = 1
materialID = 8
type = Box
Aero Mass = 1.609500
Thermal Mass = 1.609500
Diameter/Width = 0.300000
Length = 0.450000
Height = 0.062000

name = C10-Radio Enclosures
quantity = 2
parent = 1
materialID = 8
type = Box
Aero Mass = 0.538000
Thermal Mass = 0.538000
Diameter/Width = 0.120000
Length = 0.160000
Height = 0.067000

name = C10-Tray X
quantity = 2
parent = 1
materialID = 9
type = Flat Plate
Aero Mass = 0.836000
Thermal Mass = 0.836000
Diameter/Width = 0.300000
Length = 0.300000

name = C10-Tray -Z
quantity = 1
parent = 1
materialID = 9
type = Flat Plate
Aero Mass = 0.970000
Thermal Mass = 0.970000
Diameter/Width = 0.300000
Length = 0.300000

name = C10-Wheel Assembly
quantity = 1
parent = 1
materialID = 54
type = Box
Aero Mass = 1.261000
Thermal Mass = 1.261000
Diameter/Width = 0.140000
Length = 0.170000
Height = 0.077000

name = C10-Battery
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 1.775000
Thermal Mass = 1.775000
Diameter/Width = 0.083000
Length = 0.181000
Height = 0.080000

name = C10-Power Supply
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.928000
Thermal Mass = 0.928000
Diameter/Width = 0.082000
Length = 0.240000
Height = 0.071000

name = C10-GPS Receiver
quantity = 2
parent = 1
materialID = 8
type = Flat Plate
Aero Mass = 0.125000
Thermal Mass = 0.125000
Diameter/Width = 0.072000
Length = 0.120000

name = C10-Propulsion Assembly
quantity = 1
parent = 1

materialID = 8
type = Box
Aero Mass = 2.051000
Thermal Mass = 2.051000
Diameter/Width = 0.130000
Length = 0.260000
Height = 0.094000

name = C10-Rate Sensor Assembly
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.134000
Thermal Mass = 0.134000
Diameter/Width = 0.098000
Length = 0.110000
Height = 0.041000

name = C10-Computer Assembly
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.384000
Thermal Mass = 0.384000
Diameter/Width = 0.090000
Length = 0.200000
Height = 0.080000

name = C10-Startracker
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.185000
Thermal Mass = 0.185000
Diameter/Width = 0.062000
Length = 0.067000
Height = 0.056000

name = C10-GNSS Antenna
quantity = 1
parent = 1
materialID = 8
type = Cylinder

Aero Mass = 0.255000
Thermal Mass = 0.255000
Diameter/Width = 0.078000
Length = 0.030000

name = C10-Horn Antenna
quantity = 1
parent = 1
materialID = 5
type = Cylinder
Aero Mass = 0.120000
Thermal Mass = 0.120000
Diameter/Width = 0.070000
Length = 0.081000

name = C10-CBS Antenna
quantity = 1
parent = 1
materialID = 5
type = Cylinder
Aero Mass = 0.714000
Thermal Mass = 0.714000
Diameter/Width = 0.140000
Length = 0.070000

name = C10-Discone Antenna
quantity = 8
parent = 1
materialID = 54
type = Flat Plate
Aero Mass = 0.005000
Thermal Mass = 0.005000
Diameter/Width = 0.013000
Length = 0.715000

name = C10-Discone Bracket
quantity = 1
parent = 1
materialID = -1
type = Cylinder
Aero Mass = 0.034000
Thermal Mass = 0.034000
Diameter/Width = 0.112000
Length = 0.065000

name = C10-Transceiver

quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 1.100000
Thermal Mass = 1.100000
Diameter/Width = 0.094000
Length = 0.123000
Height = 0.070000

name = C10-Transmitter
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.400000
Thermal Mass = 0.400000
Diameter/Width = 0.090000
Length = 0.095000
Height = 0.029000

name = C10-LNA Subassembly
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.934000
Thermal Mass = 0.934000
Diameter/Width = 0.125000
Length = 0.140000
Height = 0.058000

name = C10-MUX Subassembly
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 1.570000
Thermal Mass = 1.570000
Diameter/Width = 0.125000
Length = 0.150000
Height = 0.080000

name = C10-SDR1 Subassembly
quantity = 1
parent = 1

materialID = 8
type = Box
Aero Mass = 0.335000
Thermal Mass = 0.335000
Diameter/Width = 0.094000
Length = 0.110000
Height = 0.044000

name = C10-SDR2 Subassembly
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 1.030000
Thermal Mass = 1.030000
Diameter/Width = 0.108000
Length = 0.166000
Height = 0.079000

name = C10-LNB Subassembly
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.335000
Thermal Mass = 0.335000
Diameter/Width = 0.097000
Length = 0.110000
Height = 0.046000

name = C10-Sband Antenna
quantity = 1
parent = 1
materialID = 5
type = Flat Plate
Aero Mass = 0.100000
Thermal Mass = 0.100000
Diameter/Width = 0.098000
Length = 0.098000

name = C10-Lband Antenna
quantity = 1
parent = 1
materialID = 5
type = Flat Plate
Aero Mass = 0.100000

Thermal Mass = 0.100000
Diameter/Width = 0.098000
Length = 0.098000

name = C10-UHF Antenna
quantity = 1
parent = 1
materialID = 54
type = Flat Plate
Aero Mass = 0.021000
Thermal Mass = 0.021000
Diameter/Width = 0.013000
Length = 0.177000

name = C10-VHF Antenna
quantity = 1
parent = 1
materialID = 54
type = Flat Plate
Aero Mass = 0.054000
Thermal Mass = 0.054000
Diameter/Width = 0.013000
Length = 0.460000

name = C10-Whip Antenna
quantity = 1
parent = 1
materialID = 54
type = Flat Plate
Aero Mass = 0.029000
Thermal Mass = 0.029000
Diameter/Width = 0.013000
Length = 0.250000

name = C10-S-Band Uplink Antenna
quantity = 1
parent = 1
materialID = 5
type = Flat Plate
Aero Mass = 0.030000
Thermal Mass = 0.030000
Diameter/Width = 0.055000
Length = 0.055000

name = C10-X-Band Antenna
quantity = 2

parent = 1
materialID = 5
type = Flat Plate
Aero Mass = 0.080000
Thermal Mass = 0.080000
Diameter/Width = 0.060000
Length = 0.120000

name = C10-Self-imager
quantity = 1
parent = 1
materialID = 5
type = Box
Aero Mass = 0.200000
Thermal Mass = 0.200000
Diameter/Width = 0.080000
Length = 0.080000
Height = 0.040000

name = C10-Separation Ring
quantity = 1
parent = 1
materialID = 5
type = Cylinder
Aero Mass = 0.444000
Thermal Mass = 0.444000
Diameter/Width = 0.252000
Length = 0.100000

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

name = Orbit1
Demise Altitude = 77.996915
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = C10-GPS Antenna 1
Demise Altitude = 77.210163
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = C10-GPS Antenna 2
Demise Altitude = 76.572468

Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = C10-GPS Filter
Demise Altitude = 77.645375
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = C10-Solar Wings
Demise Altitude = 77.477320
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = C10-Z panels
Demise Altitude = 77.210743
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = C10-Wing Deployer
Demise Altitude = 0.000000
Debris Casualty Area = 1.430400
Impact Kinetic Energy = 12.125870

****
name = C10-X Panels
Demise Altitude = 77.338924
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = C10-Y Panels
Demise Altitude = 77.232899
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = C10-Radio Enclosures
Demise Altitude = 77.157998
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****

name = C10-Tray X
Demise Altitude = 76.113942
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = C10-Tray -Z
Demise Altitude = 75.806373
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = C10-Wheel Assembly
Demise Altitude = 71.211727
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = C10-Battery
Demise Altitude = 75.547302
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = C10-Power Supply
Demise Altitude = 76.859314
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = C10-GPS Receiver
Demise Altitude = 77.392232
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = C10-Propulsion Assembly
Demise Altitude = 76.233582
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = C10-Rate Sensor Assembly
Demise Altitude = 77.617142
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = C10-Computer Assembly
Demise Altitude = 77.501005
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = C10-Startracker
Demise Altitude = 77.198116
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = C10-GNSS Antenna
Demise Altitude = 76.022583
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = C10-Horn Antenna
Demise Altitude = 76.413061
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = C10-CBS Antenna
Demise Altitude = 72.947022
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = C10-Discone Antenna
Demise Altitude = 77.948182
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = C10-Discone Bracket
Demise Altitude = 77.806992
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = C10-Transceiver
Demise Altitude = 75.814440

Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = C10-Transmitter
Demise Altitude = 76.534840
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = C10-LNA Subassembly
Demise Altitude = 76.302397
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = C10-MUX Subassembly
Demise Altitude = 75.681872
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = C10-SDR1 Subassembly
Demise Altitude = 77.075069
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = C10-SDR2 Subassembly
Demise Altitude = 76.540204
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = C10-LNB Subassembly
Demise Altitude = 77.092958
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = C10-Sband Antenna
Demise Altitude = 76.725464
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****

name = C10-Lband Antenna
Demise Altitude = 76.725464
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = C10-UHF Antenna
Demise Altitude = 77.024295
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = C10-VHF Antenna
Demise Altitude = 77.036046
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = C10-Whip Antenna
Demise Altitude = 77.047817
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = C10-S-Band Uplink Antenna
Demise Altitude = 77.033072
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = C10-X-Band Antenna
Demise Altitude = 76.843672
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = C10-Self-imager
Demise Altitude = 75.948290
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = C10-Separation Ring
Demise Altitude = 76.534215
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****

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

name = Orbit2
quantity = 1
parent = 0
materialID = 9
type = Box
Aero Mass = 32.259998
Thermal Mass = 32.259998
Diameter/Width = 0.300000
Length = 0.450000
Height = 0.300000

name = O
quantity = 1
parent = 1
materialID = 9
type = Box
Aero Mass = 32.259998
Thermal Mass = 32.259998
Diameter/Width = 0.300000
Length = 0.450000
Height = 0.300000

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

name = Orbit2
Demise Altitude = 77.999975
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = O
Demise Altitude = 63.094590
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****

***********INPUT****
Item Number = 3

name = Orbit3
quantity = 1
parent = 0
materialID = 8
type = Box
Aero Mass = 32.259998
Thermal Mass = 32.259998
Diameter/Width = 0.300000
Length = 0.450000
Height = 0.300000

name = O
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 32.259998
Thermal Mass = 32.259998
Diameter/Width = 0.300000
Length = 0.450000
Height = 0.300000

**************OUTPUT****
Item Number = 3

name = Orbit3
Demise Altitude = 77.996991
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = O
Demise Altitude = 70.015320
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****

=============== End of Requirement 4.7-1 ===============
03 29 2024; 07:06:41AM Project Data Saved To File

Annex B – DAS Log Results – Small Object Analysis Model

03 29 2024; 07:31:43AM   Requirement 4.5-2: Compliant

===
Spacecraft = Orbit1
Critical Surface = Critical Surface
===

INPUT

Apogee Altitude = 600.000 (km)
Perigee Altitude = 600.000 (km)
Orbital Inclination = 46.500 (deg)
RAAN = 0.000 (deg)
Argument of Perigee = 0.000 (deg)
Mean Anomaly = 0.000 (deg)
Final Area-To-Mass = 0.0126 (m^2/kg)
Initial Mass = 32.260 (kg)
Final Mass = 32.260 (kg)
Station Kept = No
Start Year = 2024.900 (yr)
Duration = 0.250 (yr)
Orientation = Random Tumbling
CS Areal Density = 0.270 (g/cm^2)
CS Surface Area = 0.1920 (m^2)
Vector = (0.000000 (u), 0.000000 (v), 0.000000 (w))
CS Pressurized = No
Outer Wall 1   Density: 0.270 (g/cm^2) Separation: 1.000 (cm)

OUTPUT

Probability of Penetration = 4.7165E-03 (4.7277E-03)
Returned Error Message: Normal Processing
Date Range Error Message: Normal Date Range

===
Spacecraft = Orbit4
Critical Surface = New Critical Surface
===

INPUT

Apogee Altitude = 530.000 (km)
Perigee Altitude = 530.000 (km)

Orbital Inclination = 45.500 (deg)
RAAN = 0.000 (deg)
Argument of Perigee = 0.000 (deg)
Mean Anomaly = 0.000 (deg)
Final Area-To-Mass = 0.0126 (m^2/kg)
Initial Mass = 32.260 (kg)
Final Mass = 32.260 (kg)
Station Kept = No
Start Year = 2024.900 (yr)
Duration = 0.250 (yr)
Orientation = Random Tumbling
CS Areal Density = 0.270 (g/cm^2)
CS Surface Area = 0.1920 (m^2)
Vector = (0.000000 (u), 0.000000 (v), 0.000000 (w))
CS Pressurized = No
Outer Wall 1   Density: 0.270 (g/cm^2) Separation: 1.000 (cm)

OUTPUT

Probability of Penetration = 2.2815E-03 (2.2841E-03)
Returned Error Message: Normal Processing
Date Range Error Message: Normal Date Range

=============== End of Requirement 4.5-2 ================

END of ODAR for HawkEye 360

Attachment 5

Technical Certification

I, Ryan Fielder, hereby certify, under penalty of perjury, that I am the technically qualified person responsible for the preparation of the engineering information contained in the technical portions of the foregoing application and the related attachments, that I am familiar with Part 25 of the Commission's rules, and that the technical information is complete and accurate to the best of my knowledge and belief.

/s/ Ryan Fielder
Ryan Fielder
Director, Space Programs
HawkEye 360, Inc.
485 Springpark Place, Suite 400
Herndon, VA 20170
+1 (571) 668-0042

Dated: 03 April 2024

Attachment 6

Ownership Information

Ownership Information

The following individuals are directors of HawkEye 360, Inc. (“HE360”):

Nomi Bergman
Dave DeWalt
Arthur Money
John Serafini
Nick Sinai
Mark Spoto
James “Sandy” Winnefeld
J. Jesse Yeo

The following individuals are officers of HE360:

John Serafini (Chief Executive Officer)
Robert Rainhart – President
Stephanie Widzinski – Assistant Treasurer, SVP Finance/Controller
Dennis Burnett – Secretary, EVP and General Counsel
Alison Cooke – Assistant Secretary and Legal Manager
Alex Fox – Chief Growth Officer
Chris Herndon – Chief Information Officer
Patrick Zeitouni – Chief Strategy Officer

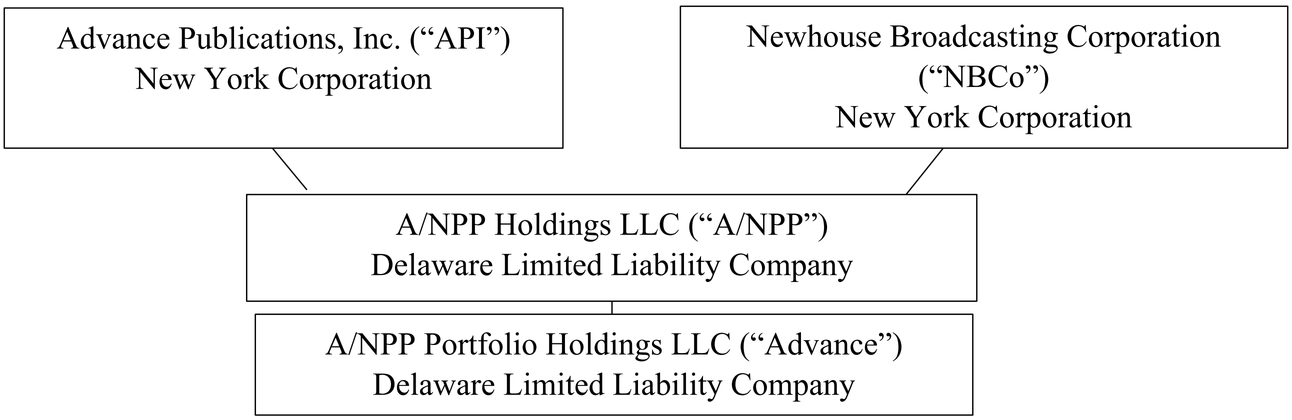
All of the directors and officers of HE360 may be reached at the following address:

HawkEye 360, Inc.
485 Springpark Place
Suite 400
Herndon, VA 20170
USA

The following are shareholders with 10% or more of the voting stock (issued & outstanding) in HE360.

Shareholder	Citizenship/ Country of Incorporation	Percentage (equity and voting)
A/NPP Portfolio Holdings LLC	United States	19.45%

Ownership Information for A/NPP Portfolio Holdings LLC



As of the date of this filing, A/NPP Portfolio Holdings LLC (“Advance”) directly holds approximately a 19.45% equity and voting interest in HawkEye 360, Inc. (“HE360”), on a fully diluted basis. In turn, Advance is wholly owned by A/NPP Holdings LLC (“A/NPP”).

A/NPP is beneficially owned by two entities, Advance Publications, Inc. and Newhouse Broadcasting Corporation (“API” and “NBCo,” respectively). NBCo is the majority shareholder of A/NPP with a 65% equity interest in A/NPP. API owns the remaining 35% equity interest in A/NPP and the board of directors of API makes all voting and investment decisions with respect to the HE360 shares held by Advance.

Taken as whole, Newhouse family members (“Newhouse Family”), each of whom is a U.S. citizen, ultimately own and control API and NBCo. However, no single stockholder or single member of the Newhouse Family, holding an interest in NBCo and/or API, has a 10% or greater attributable interest in HE360.