Orbital Sidekick GHOSt Orbital Debris Assessment Report (ODAR)

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

Prepared By:

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DAS Software Version Used: v3.1.2

Orbital Sidekick GHOSt Orbital Debris Assessment Report
ASTRO-DIGITAL-DEMO9-ODAR-1.0

Orbital Sidekick GHOSt ODAR

Revision:	Date:	Changes:	Author(s):
1.0	2/18/2021	Initial	D. Thorne
1.1	4/30/2021	Mission parameters and DAS update	D. Thorne

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

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

Section	Status	Comment
4.3-1, Mission-Related Debris Passing Through LEO	Compliant	
4.3-2, Mission-Related Debris Passing Near GEO	Compliant	
4.4-1, Limiting the risk to other space systems from accidental explosions during deployment and mission operations while in orbit about Earth or the Moon	Compliant	
4.4-2, Design for passivation after completion of mission operations while in orbit about Earth or the Moon	Compliant	
4.4-3, Limiting the long-term risk to other space systems from planned breakup	Compliant	
4.4-4, Limiting the short-term risk to other space systems from planned breakup	Compliant	
4.5-2, Probability of Damage from Small Objects	Compliant	
4.6-1, Disposal for space structures passing through LEO	N/A	
4.6-2, Disposal for space structures passing through GEO	N/A	
4.6-3, Disposal for space structures between LEO and GEOs	N/A	
4.6-4, Reliability of post-mission disposal operations	Compliant	
4.7-1, Limit the risk of human casualty	Compliant	
4.8-1, Collision Hazards of Space Tether	N/A	

Assessment Report Format:

ODAR Technical Sections Format Requirements:

This ODAR follows the format in NASA-STD-8719.14, Appendix A.1 and includes the content indicated as a minimum, in each of sections 2 through 8 below for the GHOSt satellite. Sections 9 through 14 apply to the launch vehicle ODAR and are not covered here.

Orbital Sidekick GHOSt Space Mission Program:

1. Program Management and Mission Overview

Mission Manager: Peter Friedhoff
Senior Management: Daniel Katz

Foreign government or space agency participation: None.

Summary of NASA's responsibility under the governing agreement(s): N/A

1.1 Schedule of upcoming mission milestones:

- Shipment of spacecraft: NET Q1 2022
- First Launch: NET Q1 2022

1.2 Mission Overview:

GHOSt is a remote sensing mission with an optical payload. The GHOSt payload is manufactured by Orbital Sidekick (OSK) and consists of a hyperspectral imager. The spacecraft bus is the Corvus-XL design. This standardized satellite bus uses reaction wheels, magnetic torque coils, star trackers, magnetometers, sun sensors, and gyroscopes to enable precision 3-axis pointing without the use of propellant.

1.3 Launch Vehicles and Launch Sites:

SpaceX Falcon 9 rideshare mission, launch sites: Vandenberg AFB, CA and Cape Canaveral, FL.

1.4 Proposed Initial Launch Date:

NET Q1 2022

1.5 Mission Duration:

The design lifetime of the spacecraft hardware is a minimum of 3 years with the goal of reaching 5 years in LEO.

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

The selected launch vehicle will deliver GHOSt directly to its operational circular sun synchronous orbit at an altitude of 525+75/-25 km. The spacecraft will operate for 3-5 years from an orbit with the following parameters:

- Average Orbital Altitude: 525+75/-25 km
- Eccentricity: 0.0000 to 0.0033
- Inclination: 97.4° to 97.8°

OSK will use all design and operational strategies available to minimize the potential for in-orbit collision with crewed spacecraft and all other objects. These strategies include working closely with its launch providers to ensure successful deployment and, making orbital adjustments, and performing collision avoidance maneuvers by utilizing differential drag. After the spacecraft has demonstrated all relevant technologies and completed payload operations, the spacecraft will be left to deorbit in the given period to comply with regulation requirements.

2. Spacecraft Description

2.1 Physical description of the spacecraft:

A total of four Main Solar Panels (MSPs) are used as the primary source of power generation. These MSPs are fixed to the body in the -Z and +Y axis and have dimensions of 56 cm x 0.057 cm x 56 cm. In addition, two Smart Solar Panels (SSP) are placed in the +Z and -Y axis. These panels have dimensions of 18.0 cm x 0.057 cm x 45.4 cm. The Smart Solar Panels (SSPs) have additional electronics embedded in them such as a sun sensor, coil and magnetometer.

The satellite avionics is enclosed inside the Data Power Module (DPM) which consists of a flight computer with integrated GPS and IMU, a secondary GPS, two TT&C transceivers, two battery packs, charging module, and two power distribution modules. An additional battery pack containing two Direct Energy Packs (DEP) is also used to further supply power to the payload and regulate the high loads which the MSPs generate. All the avionics components have previously flown in different Astro Digital missions.

The satellite is equipped with two TT&C transceivers, Turva S-band / UHF and Lithium UHF. As mentioned, both transceivers are enclosed inside the DPM. Two UHF antennas are placed on the bottom corners of the +X plate. Two S-band patch antennas are placed in the +Z plate. Two Gen4 (Mode1) and a redundant Gen3 (Mode2) Ka-band transceiver are equipped to account for high payload data downlink. These transceivers are mounted in the interior of the satellite's +Z plate with both antennas mounted in that same plate. Two GPS modules are used for redundancy purposes, both mounted inside the DPM and with their corresponding antennas mounted on the -Y plate.

The attitude determination and control system consist of flight proven external hardware with two-star trackers, a gyroscope, reaction wheels and torque rods. In addition to the external hardware a torque rod module and a reaction wheel module are used to regulate the high load required by these components. Both star trackers are placed on the -Y plate.

The optical payload is mounted on the -X plate or payload deck of the satellite and consists of two payload computers, imager, and telescope. Both payload computers are mounted below the payload deck, inside the satellite's bus. The imager is mounted on top of the payload deck with the telescope mounted above on top. The telescope's outer structure is fixed to the satellite bus via six structural support rods.

A 15 inch Planetary Systems Lightband on the +X panel of the satellite is used to deploy the spacecraft from the launch vehicle.

2.2 Detailed illustration of the spacecraft

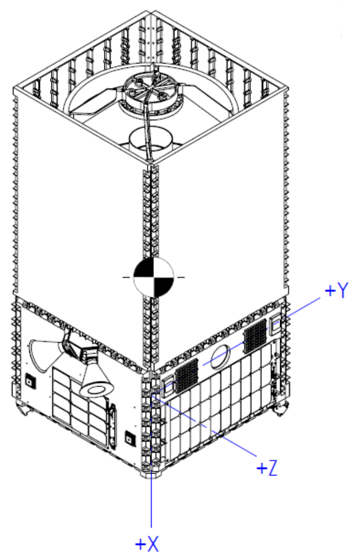

Figure 1: GHOSt Spacecraft

2.3 Total satellite mass at launch, including all propellants and fluids:

85 Kg

2.4 Dry mass of satellites at launch:

N/A

2.5 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:

N/A

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

N/A

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

The GHOSt activity after separation will consist of autonomous de-tumble followed by a safe mode sun tracking mode.

All the following attitude modes use a combination of the following sensors and actuators to perform maneuvers. A magnetometer, sun sensors, gyroscope, reaction wheels, torque rods and star trackers are used to orientate the spacecraft correctly.

- Sun pointing: Is the nominal mode in which the satellite will generate power by pointing both Main Solar Panels (MSPs) in such that the incident angle on each one is approximately 45 degrees in order to fully take advantage of both panels.
- Target Tracking: Is used to communicate with the ground station. This allows the satellite to point towards a fixed reference point while passing through its line of sight.
- Nadir: Used for payload operation when the satellite enters the sun or exits eclipse. Nadir-pointing is the action of pointing directly below the satellite perpendicular to Earth.
- Sun clocking: This mode functions as a complementary mode to the Target Tracking and Nadir modes. This mode is optimized such that while the satellite is performing Nadir or Target Tracking operations the satellite is able to rotate around its fixed inertial axis towards the sun in order to generate additional power.

2.8 Fluids in Pressurized Batteries:

None. Capella uses unpressurized standard Lithium Ion battery cells.

2.9 Description of any range safety or other pyrotechnic devices:

N/A

2.10 Description of the electrical generation and storage system:

Power is generated by the 6 solar panels mounted on the satellite. 4 Main solar Panels (MSPs) and 2 Smart Solar Panels (SSPs). Each MSP is comprised of 12 cells in series with 7 strings for a total of 84 cells per panel. The MSPs ideal power generation comes out to be 85.15 W per panel. The SSP is comprised of 10 cells in series with 3 strings for a total of 30 cells per panel. The SSPs ideal power generation comes out to be 30.41 W per panel. Note that the primary panels for power generation will be the MSPs, with the SSPs functioning as a backup power generation mechanism when detumbling or performing clocking maneuvers.

As previously mentioned, the satellite will have a total of three battery packs, one DPMs and two DEPs. The DPM battery pack is encased inside its own module and then mounted inside the DPM. Both DEP packs are also concealed inside their own casing. The battery packs are all equipped with power regulation ICs which regulate the discharge state of the individual battery cells. All the power required for operating the bus is supplied through the DPM battery pack. The DEP is used to provide power to additional hardware and regulate the power generated by the MSPs. All battery packs are charged through the solar panels.

The satellite bus consumes 18W of power nominally with certain modes reducing or increasing the load. The payload is expected to consume an average of 72W. The charge/discharge cycle is managed by a power management system overseen by the Flight Computer and Electrical Power Subsystem.

2.11 Identification of any other sources of stored energy not noted above:

N/A

2.12 Identification of any radioactive materials on board:

N/A

3. Assessment of Spacecraft Debris Released during Normal Operations

3.1 Identification of any object (>1 mm) expected to be released from the spacecraft any time after launch, including object dimensions, mass, and material:

N/A

3.2 Rationale/necessity for release of each object:

N/A.

3.3 Time of release of each object, relative to launch time:

N/A.

3.4 Release velocity of each object with respect to spacecraft:

N/A.

3.5 Expected orbital parameters (apogee, perigee, and inclination) of each object after release:

N/A/.

3.6 Calculated orbital lifetime of each object, including time spent in Low Earth Orbit (LEO):

N/A.

3.7 Assessment of spacecraft compliance with Requirements 4.3-1 and 4.3-2 (per DAS v3.1.2)

N/A.

3.7.1 Mission Related Debris Passing Through LEO:

COMPLIANT

3.7.2 Mission Related Debris Passing Near GEO:

COMPLIANT

4. Assessment of Spacecraft Intentional Breakups and Potential for Explosions

4.1 Identification of all potential causes of spacecraft breakup during deployment and mission operation

N/A.

4.2 Summary of failure modes and effects analyses of all credible failure modes which may lead to an accidental explosion:

N/A.

The in-orbit failure of a battery cell protection circuit could lead to a short circuit resulting in overheating and a very remote possibility of battery cell explosion. The battery safety systems discussed in the FMEA (see requirement 4.4-1 below) describe the combined faults that must occur for any of seven (7) independent, mutually exclusive failure modes to lead to such an explosion.

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

N/A.

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

After the satellite has reached its End of Lifetime (EOL) its 16 Lithium Ion Battery Cells (4 DPM & 12 DEP) will be discharged completely. The solar array charging circuit will be disabled, which will fully discharge all cells within a few days.

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

N/A

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

4.6.1 *Requirement 4.4-1: Limiting the risk to other space systems from accidental explosions during deployment and mission operations while in orbit about Earth or the Moon:*

"For each spacecraft and launch vehicle orbital stage employed for a mission, the program or project shall demonstrate, via failure mode and effects analyses or equivalent analyses, that the integrated probability of explosion for all credible failure modes of each spacecraft and launch vehicle is less than 0.001 (excluding small particle impacts) (Requirement 56449)."

Compliance statement:

- Required Probability: 0.001
- Expected probability, GHOSt: 0.0000

Supporting Rationale and FMEA details:

Battery explosion:

Effect: All failure modes below might result in battery explosion with the possibility of orbital debris generation. However, in the unlikely event that a battery cell does explosively rupture, the small size, mass, and potential energy, of 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 spacecraft due to the lack of penetration energy to the multiple enclosures surrounding the batteries.

Probability: Extremely Low. It is believed to be less than 0.01% given that multiple independent faults must occur for each failure to cause an explosion. Each battery cell is UL/UN certified with individual over-voltage and over-current protection. Identical batteries have been flown on all Astro Digital spacecraft. Even in extreme cases (such as a launch vehicle hydrazine explosion in proximity to the spacecraft), the batteries showed no signs of damage or degradation.

- ***Failure mode 1***: Internal short circuit.

Mitigation: Protoflight level sine burst, sine and random vibration in three axes of both spacecraft, thermal vacuum cycling of both spacecraft and extensive functional testing followed by maximum system rate-limited charge and discharge cycles were performed to prove that no internal short circuit sensitivity exists. Additional environmental and functional testing of the batteries at the power subsystem vendor facilities were also conducted on the batteries at the component level.

Combined faults required for realized failure: Environmental testing **AND** functional charge/discharge tests must both be ineffective in discovery of the failure mode.

- ***Failure Mode 2*****:** Internal thermal rise due to high load discharge rate.

Mitigation**:** Battery cells were tested in the lab for high load discharge rates in a variety of flight-like configurations to determine if the feasibility of an out-of-control thermal rise in the cell. Cells were also tested in a hot, thermal vacuum environment (5 cycles at 50° C, then to -20°C) in order to test the upper limits of the cells capability. No failures were observed or identified via satellite telemetry or via external monitoring circuitry.

Combined faults required for realized failure: Spacecraft thermal design must be incorrect **AND** external over-current detection and disconnect function must fail to enable this failure mode.

- ***Failure Mode 3*****:** Excessive discharge rate or short-circuit due to external device

failure or terminal contact with conductors not at battery voltage levels (due to abrasion or inadequate proximity separation).

Mitigation**:** 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) observation of such other mechanical failures by protoflight level environmental tests (sine burst, random 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 all occur to enable this failure mode.

- ***Failure Mode 4***: Inoperable vents.

Mitigation: Battery venting is not inhibited by the battery holder design or the spacecraft design. The battery is capable of venting gases to the external environment.

Combined faults required for realized failure: The cell manufacturer OR the satellite integrator fails to install proper venting.

- Failure Mode 5: Crushing

Mitigation: This mode is negated by spacecraft design. There are no moving parts in the proximity of the batteries.

Combined faults required for realized failure: A catastrophic failure must occur in an external system **AND** the failure must cause a collision sufficient to crush the batteries leading to an internal short circuit **AND** the satellite must be in a naturally sustained orbit at the time the crushing occurs.

- ***Failure Mode 6:*** Low level current leakage or short-circuit through battery pack case or due to moisture-based degradation of insulators.

Mitigation: 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 failures in environmental tests must occur to result in this failure mode.

- ***Failure Mode 7:*** Excess temperatures due to orbital environment and high discharge combined.

Mitigation: 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 under a variety of modeled cases, including worst-case orbital scenarios. Analysis shows these temperatures to be 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.

4.6.2 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: GHOSt includes the ability to fully disconnect the Lithium Ion cells from the charging current of the solar arrays. Once the satellite reaches its End of Life (EOL), this feature will be used to completely passivate the batteries by removing all energy from them. 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, the debris from the battery rupture will be contained within the spacecraft due to the lack of penetration energy to the multiple enclosures surrounding the batteries.

4.6.3 Requirement 4.4-3. Limiting the long-term risk to other space systems from planned breakups: Compliance statement:

N/A

4.6.4 Requirement 4.4-4: Limiting the short-term risk to other space systems from planned breakups: Compliance statement:

N/A

5. Assessment of Spacecraft Potential for On-Orbit Collisions

5.1 Assessment of spacecraft compliance with Requirements 4.5-1 and 4.5-2 (per DAS v3.1.2 and calculation methods provided in NASA-STD-8719.14, section 4.5.4):

5.1.1 Requirement 4.5-1. Limiting debris generated by collisions with large objects when operating in Earth orbit:

Status: COMPLIANT

Probability: 9.6217E-06

5.1.2 Requirement 4.5-2. Limiting debris generated by collisions with small objects when operating in Earth or lunar orbit:

Status: COMPLIANT

5.2 Identification of all systems or components required to accomplish any post-mission disposal operation, including passivation and maneuvering:

The Flight Computer, Telemetry Transceiver and Electrical Power Subsystem are needed to complete passivation operations. The spacecraft will passively reenter within 6 years regardless of any orbit lowering maneuver.

6. Assessment of Spacecraft Post-mission Disposal Plans and Procedures

6.1 Description of spacecraft disposal option selected:

The satellite will de-orbit naturally by atmospheric re-entry.

6.2 Plan for any spacecraft maneuvers required to accomplish post-mission disposal:

N/A

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

Spacecraft Mass: 85Kg (worst-case)
Cross-sectional Area: 0.79 m^2 (average RAM)
Area to mass ratio: 0.0092 m^2/kg

6.4 Assessment of spacecraft compliance with Requirements 4.6-1 through 4.6-5 (per DAS v 2.1.1 and NASA-STD-8719.14 section):

6.4.1 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 deorbit 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."

Atmospheric reentry was selected as a viable disposal for the GHOSt satellite in which reentry is estimated to be within 5.979 years post-deployment for nominal initial orbital altitude of 525 km.

This analysis was performed with the NASA Debris Assessment Software v3.1.2. Figure 1 and Figure 2 show the output data from this analysis.

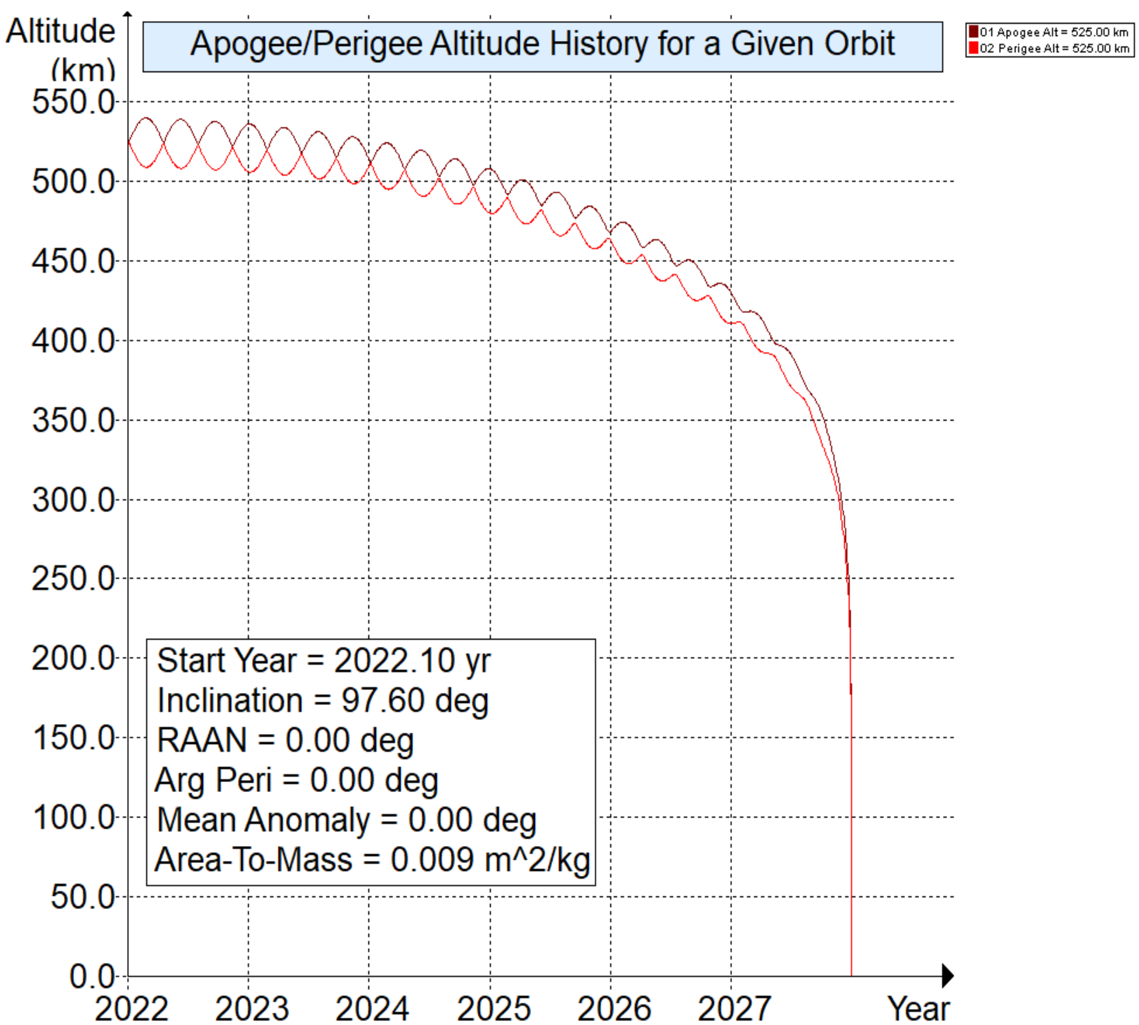

Figure 1: GHOSt Orbital History

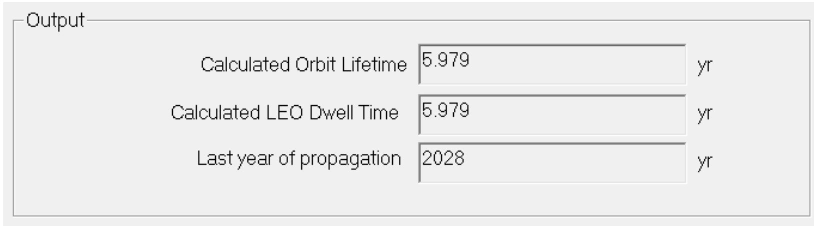

Figure 2: GHOSt DAS analysis output

6.4.2 Requirement 4.6-2. Disposal for space structures near GEO:

N/A

6.4.3 Requirement 4.6-3. Disposal for space structures between LEO and GEO:

N/A

6.4.4 Requirement 4.6-4. Reliability of Post-mission Disposal Operations:

The GHOSt spacecraft will satisfy the requirement to deorbit within the 6 years after the spacecraft has been launched without the use of any additional subsystem as previously discussed above.

Reliability of passive deorbit has been validated through different missions in which the accuracy of the orbit's dwell time has a small variation of a couple of months. Taking this into consideration and given the wide margin of the mission, the post mission disposal can be considered reliable.

7. Assessment of Spacecraft Reentry Hazards

7.1 Assessment of spacecraft compliance with Requirement 4.7-1: Requirement 4.7-1. Limit the risk of human casualty:

"The potential for human casualty is assumed for any object with an impacting kinetic energy in excess of 15 joules: For uncontrolled reentry, the risk of human casualty from surviving debris shall not exceed 0.0001 (1:10,000) (Requirement 56626)."

COMPLIANT

Risk of Human Casualty (1:100000000). This is the lowest output the DAS software will report. Considering 0 energy makes it to the ground during reentry, the risk of human casualty is 0.

For additional information on each subcomponent please refer to Appendix A.

7.1.1 Requirements 4.7-1b, and 4.7-1c:

N/A

APPENDIX A

DAS output log

Processing Requirement 4.3-1: Return Status : Not Run
======================
No Project Data Available
======================
============== End of Requirement 4.3-1 ===============

Processing Requirement 4.3-2: Return Status : Passed
======================
No Project Data Available
======================
============== End of Requirement 4.3-2 ===============

Processing Requirement 4.5-1: Return Status : Passed
==============
Run Data
==============
INPUT
Space Structure Name = GHOSt
Space Structure Type = Payload
Perigee Altitude = 525.000 (km)
Apogee Altitude = 525.000 (km)
Inclination = 97.600 (deg)
RAAN = 0.000 (deg)
Argument of Perigee = 0.000 (deg)
Mean Anomaly = 0.000 (deg)
Final Area-To-Mass Ratio = 0.0100 (m^2/kg)
Start Year = 2022.100 (yr)
Initial Mass = 85.000 (kg)
Final Mass = 85.000 (kg)
Duration = 5.000 (yr)
Station-Kept = False
Abandoned = True
OUTPUT
Collision Probability = 9.6217E-06
Returned Message: Normal Processing
Date Range Message: Normal Date Range
Status = Pass
==============
=============== End of Requirement 4.5-1 ===============

Requirement 4.5-2: Compliant
=============== End of Requirement 4.5-2 ===============

Processing Requirement 4.6 Return Status : Passed
==============
Project Data
==============
INPUT
Space Structure Name = GHOSt
Space Structure Type = Payload
Perigee Altitude = 525.000000 (km)
Apogee Altitude = 525.000000 (km)
Inclination = 97.600000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Area-To-Mass Ratio = 0.010000 (m^2/kg)
Start Year = 2022.100000 (yr)
Initial Mass = 85.000000 (kg)
Final Mass = 85.000000 (kg)
Duration = 5.000000 (yr)
Station Kept = False
Abandoned = True
PMD Perigee Altitude = 384.428488 (km)
PMD Apogee Altitude = 401.178963 (km)
PMD Inclination = 97.701300 (deg)
PMD RAAN = 71.517188 (deg)
PMD Argument of Perigee = 67.678474 (deg)
PMD Mean Anomaly = 0.000000 (deg)
OUTPUT
Suggested Perigee Altitude = 384.428488 (km)
Suggested Apogee Altitude = 401.178963 (km)
Returned Error Message = Passes LEO reentry orbit criteria.
Released Year = 2027 (yr)
Requirement = 61
Compliance Status = Pass
==============
=============== End of Requirement 4.6 ===============

Processing Requirement 4.6 Return Status : Passed
==============
Project Data
==============
INPUT
Space Structure Name = GHOSt
Space Structure Type = Payload
Perigee Altitude = 525.000000 (km)
Apogee Altitude = 525.000000 (km)
Inclination = 97.600000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Area-To-Mass Ratio = 0.010000 (m^2/kg)

Start Year = 2022.100000 (yr)
Initial Mass = 85.000000 (kg)
Final Mass = 85.000000 (kg)
Duration = 5.000000 (yr)
Station Kept = False
Abandoned = True
PMD Perigee Altitude = 384.428009 (km)
PMD Apogee Altitude = 401.178421 (km)
PMD Inclination = 97.701300 (deg)
PMD RAAN = 71.517298 (deg)
PMD Argument of Perigee = 67.678479 (deg)
PMD Mean Anomaly = 0.000000 (deg)
OUTPUT
Suggested Perigee Altitude = 384.428009 (km)
Suggested Apogee Altitude = 401.178421 (km)
Returned Error Message = Passes LEO reentry orbit criteria.
Released Year = 2027 (yr)
Requirement = 61
Compliance Status = Pass
==============
=============== End of Requirement 4.6 ===============
04 30 2021; 12:32:50PM *********Processing Requirement 4.7-1
Return Status : Passed
***********INPUT****
Item Number = 1
name = GHOSt
quantity = 1
parent = 0
DAS Activity Log
materialID = 9
type = Box
Aero Mass = 85.000000
Thermal Mass = 85.000000
Diameter/Width = 0.580000
Length = 1.060000
Height = 0.580000
name = DPM
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 2.300000
Thermal Mass = 2.300000
Diameter/Width = 0.100000
Length = 0.189000
Height = 0.090000
name = DEP
quantity = 1
parent = 1
materialID = 8

type = Box
Aero Mass = 2.200000
Thermal Mass = 2.200000
Diameter/Width = 0.170000
Length = 0.194000
Height = 0.124000
name = RW
quantity = 3
parent = 1
materialID = 8
type = Box
Aero Mass = 1.380000
Thermal Mass = 1.380000
Diameter/Width = 0.146000
Length = 0.146000
Height = 0.039000
name = TRQ
quantity = 3
parent = 1
materialID = 46
type = Cylinder
Aero Mass = 0.490000
Thermal Mass = 0.490000
Diameter/Width = 0.020000
Length = 0.300000
name = Ka Gen3
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 1.000000
Thermal Mass = 1.000000
DAS Activity Log
Diameter/Width = 0.093000
Length = 0.102000
Height = 0.089000
name = Ka Gen4
quantity = 2
parent = 1
materialID = 8
type = Box
Aero Mass = 1.500000
Thermal Mass = 1.500000
Diameter/Width = 0.100000
Length = 0.125000
Height = 0.070000
name = NX
quantity = 1
parent = 1
materialID = 8

type = Box
Aero Mass = 0.300000
Thermal Mass = 0.300000
Diameter/Width = 0.085000
Length = 0.105000
Height = 0.030000
name = TX2
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.300000
Thermal Mass = 0.300000
Diameter/Width = 0.085000
Length = 0.105000
Height = 0.030000
name = AGX
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.300000
Thermal Mass = 0.300000
Diameter/Width = 0.105000
Length = 0.105000
Height = 0.030000
name = Star tracker
quantity = 2
parent = 1
materialID = 8
type = Cylinder
Aero Mass = 1.000000
Thermal Mass = 1.000000
Diameter/Width = 0.075000
Length = 0.120000
DAS Activity Log
name = Yquantity
= 1
parent = 1
materialID = 9
type = Flat Plate
Aero Mass = 1.940000
Thermal Mass = 1.940000
Diameter/Width = 0.349000
Length = 0.520000
name = X+
quantity = 1
parent = 1
materialID = 9
type = Flat Plate

Aero Mass = 7.100000
Thermal Mass = 7.100000
Diameter/Width = 0.558000
Length = 0.558000
name = Xquantity
= 1
parent = 1
materialID = 9
type = Flat Plate
Aero Mass = 5.000000
Thermal Mass = 5.000000
Diameter/Width = 0.520000
Length = 0.520000
name = Z+
quantity = 1
parent = 1
materialID = 9
type = Flat Plate
Aero Mass = 2.100000
Thermal Mass = 2.100000
Diameter/Width = 0.340000
Length = 0.520000
name = Y+
quantity = 1
parent = 1
materialID = 9
type = Flat Plate
Aero Mass = 4.140000
Thermal Mass = 4.140000
Diameter/Width = 0.340000
Length = 1.060000
name = Zquantity
= 1
parent = 1
materialID = 9
type = Flat Plate
Aero Mass = 4.140000
Thermal Mass = 4.140000
Diameter/Width = 0.340000
DAS Activity Log
Length = 1.060000
name = MLB
quantity = 1
parent = 1
materialID = 9
type = Cylinder
Aero Mass = 3.000000
Thermal Mass = 3.000000
Diameter/Width = 0.400000
Length = 0.150000

name = Shadow panel
quantity = 2
parent = 1
materialID = 9
type = Flat Plate
Aero Mass = 1.990000
Thermal Mass = 1.990000
Diameter/Width = 0.540000
Length = 0.730000
name = Cell array
quantity = 4
parent = 1
materialID = 23
type = Flat Plate
Aero Mass = 1.500000
Thermal Mass = 1.500000
Diameter/Width = 0.503000
Length = 0.520000
name = Bipod base
quantity = 3
parent = 1
materialID = 8
type = Box
Aero Mass = 0.500000
Thermal Mass = 0.500000
Diameter/Width = 0.064000
Length = 0.281000
Height = 0.049000
name = Spectrometer
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 3.000000
Thermal Mass = 3.000000
Diameter/Width = 0.273000
Length = 0.315000
Height = 0.179000
name = Optical bench
quantity = 1
parent = 1
materialID = 8
DAS Activity Log
type = Cylinder
Aero Mass = 7.000000
Thermal Mass = 7.000000
Diameter/Width = 0.166000
Length = 0.498000
name = Primary mirror
quantity = 1

parent = 1
materialID = 8
type = Cylinder
Aero Mass = 7.500000
Thermal Mass = 7.500000
Diameter/Width = 0.150000
Length = 0.498000
name = Secondary mirror
quantity = 1
parent = 1
materialID = 8
type = Cylinder
Aero Mass = 1.000000
Thermal Mass = 1.000000
Diameter/Width = 0.085000
Length = 0.181000
name = Spider
quantity = 1
parent = 1
materialID = 8
type = Cylinder
Aero Mass = 2.000000
Thermal Mass = 2.000000
Diameter/Width = 0.090000
Length = 0.498000
name = Spider base
quantity = 1
parent = 1
materialID = 8
type = Cylinder
Aero Mass = 2.500000
Thermal Mass = 2.500000
Diameter/Width = 0.263000
Length = 0.498000
name = Lens stack
quantity = 1
parent = 1
materialID = -1
type = Cylinder
Aero Mass = 1.000000
Thermal Mass = 1.000000
Diameter/Width = 0.050000
Length = 0.291000
name = Mirror base
quantity = 1
DAS Activity Log
parent = 1
materialID = 8
type = Box
Aero Mass = 2.500000

Thermal Mass = 2.500000
Diameter/Width = 0.100000
Length = 0.273000
Height = 0.050000
name = Baffle
quantity = 1
parent = 1
materialID = 8
type = Cylinder
Aero Mass = 0.500000
Thermal Mass = 0.500000
Diameter/Width = 0.123000
Length = 0.200000
name = Bipod flexure
quantity = 12
parent = 1
materialID = 65
type = Cylinder
Aero Mass = 0.133000
Thermal Mass = 0.133000
Diameter/Width = 0.035000
Length = 0.062000
name = Bipod tube
quantity = 6
parent = 1
materialID = 23
type = Cylinder
Aero Mass = 0.064000
Thermal Mass = 0.064000
Diameter/Width = 0.042000
Length = 0.138000
**************OUTPUT****
Item Number = 1
name = GHOSt
Demise Altitude = 77.998215
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
****
name = DPM
Demise Altitude = 68.003548
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
****
name = DEP
Demise Altitude = 69.922852
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
DAS Activity Log
****
name = RW

Demise Altitude = 67.637184
Debris Casualty Area = 0.000000
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name = TRQ
Demise Altitude = 66.809738
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
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name = Ka Gen3
Demise Altitude = 70.141327
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name = Ka Gen4
Demise Altitude = 67.452446
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name = NX
Demise Altitude = 73.974701
Debris Casualty Area = 0.000000
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name = TX2
Demise Altitude = 73.974701
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name = AGX
Demise Altitude = 74.162285
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name = Star tracker
Demise Altitude = 68.334930
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name = YDemise
Altitude = 73.941360
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
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name = X+
Demise Altitude = 64.079460
DAS Activity Log
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Impact Kinetic Energy = 0.000000
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name = XDemise
Altitude = 67.751709
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
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name = Z+
Demise Altitude = 73.561859
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Impact Kinetic Energy = 0.000000
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name = Y+
Demise Altitude = 72.528358
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
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name = ZDemise
Altitude = 72.528358
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
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name = MLB
Demise Altitude = 73.597000
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
****
name = Shadow panel
Demise Altitude = 75.285988
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
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name = Cell array
Demise Altitude = 75.686417
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
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name = Bipod base
Demise Altitude = 75.066124
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
****
name = Spectrometer
Demise Altitude = 71.855125
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
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DAS Activity Log
name = Optical bench
Demise Altitude = 67.320892
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

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name = Primary mirror
Demise Altitude = 66.142044
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
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name = Secondary mirror
Demise Altitude = 71.196892
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
****
name = Spider
Demise Altitude = 72.397278
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
****
name = Spider base
Demise Altitude = 74.561562
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
****
name = Lens stack
Demise Altitude = 69.852608
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
****
name = Mirror base
Demise Altitude = 67.092873
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
****
name = Baffle
Demise Altitude = 75.426537
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
****
name = Bipod flexure
Demise Altitude = 64.511101
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
****
name = Bipod tube
Demise Altitude = 77.108971
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
DAS Activity Log
****
=============== End of Requirement 4.7-1 ===============

APPENDIX B
Requirement 4.7-1

Name	Qty	Material	Body Type	Thermal Mass	Diameter/ Width	Length	Height
GHOSt	1	Aluminum 7075-T6	Box	85	0.58	1.06	0.58
DPM	1	Aluminum 6061-T6	Box	2.3	0.1	0.189	0.09
DEP	1	Aluminum 6061-T6	Box	2.2	0.17	0.194	0.124
RW	3	Aluminum 6061-T6	Box	1.38	0.146	0.146	0.039
TRQ	3	Nickel	Cylinder	0.49	0.02	0.3	
Ka Gen3	1	Aluminum 6061-T6	Box	1	0.093	0.102	0.089
Ka Gen4	2	Aluminum 6061-T6	Box	1.5	0.1	0.125	0.07
NX	1	Aluminum 6061-T6	Box	0.3	0.085	0.105	0.03
TX2	1	Aluminum 6061-T6	Box	0.3	0.085	0.105	0.03
AGX	1	Aluminum 6061-T6	Box	0.3	0.105	0.105	0.03
Star tracker	2	Aluminum 6061-T6	Cylinder	1	0.075	0.12	
Y-	1	Aluminum 7075-T6	Flat Plate	1.94	0.349	0.52	
X+	1	Aluminum 7075-T6	Flat Plate	7.1	0.558	0.558	
X-	1	Aluminum 7075-T6	Flat Plate	5	0.52	0.52	
Z+	1	Aluminum 7075-T6	Flat Plate	2.1	0.34	0.52	
Y+	1	Aluminum 7075-T6	Flat Plate	4.14	0.34	1.06	
Z-	1	Aluminum 7075-T6	Flat Plate	4.14	0.34	1.06	
MLB	1	Aluminum 7075-T6	Cylinder	3	0.4	0.15	
Shadow panel	2	Aluminum 7075-T6	Flat Plate	1.99	0.54	0.73	
Cell array	4	Fiberglass	Flat Plate	1.5	0.503	0.52	
Bipod base	3	Aluminum 6061-T6	Box	0.5	0.064	0.281	0.049
Spectrometer	1	Aluminum 6061-T6	Box	3	0.273	0.315	0.179
Optical bench	1	Aluminum 6061-T6	Cylinder	7	0.166	0.498	
Primary mirror	1	Aluminum 6061-T6	Cylinder	7.5	0.15	0.498	
Secondary mirror	1	Aluminum 6061-T6	Cylinder	1	0.085	0.181	
Spider	1	Aluminum 6061-T6	Cylinder	2	0.09	0.498	
Spider base	1	Aluminum 6061-T6	Cylinder	2.5	0.263	0.498	
Lens stack	1	Glass	Cylinder	1	0.05	0.291	
Mirror base	1	Aluminum 6061-T6	Box	2.5	0.1	0.273	0.05
Baffle	1	Aluminum 6061-T6	Cylinder	0.5	0.123	0.2	
Bipod flexure	12	Titanium (6 Al-4 V)	Cylinder	0.133	0.035	0.062	
Bipod tube	6	Fiberglass	Cylinder	0.064	0.042	0.138	