Blackwing Space, Inc.

Orbital Debris Assessment Report (ODAR)

Baby Bird Mission

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This document is formatted for an Orbital Debris Assessment Report prepared in support of U.S. regulatory review, using the NASA-STD-8719.14 ODAR appendix as the organizing structure.

Review and Approval

I have reviewed the contents of this document and find them satisfactory for submission in support of the Baby Bird FCC application.

Paul Anderson Digitally signed by Paul Anderson
Date: 2026.04.27 23:41:14 -05'00'

04/28/2026

Paul Anderson
CEO and CTO
Blackwing Space

Date

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1 Purpose and Scope

This Orbital Debris Assessment Report (ODAR) provides the orbital debris related mission description, analyses, and controls for the **Baby Bird** spacecraft in support of the Federal Communications Commission (FCC) license application. The report is organized to align with the ODAR format in NASA-STD-8719.14 and is intended to provide a concise, traceable narrative that can be cross-checked against NASA Debris Assessment Software (DAS) outputs, mission design data, and operator procedures.

This report addresses only the Baby Bird spacecraft mission and is not a launch vehicle ODAR. Supporting evidence files, detailed NASA DAS exports, and additional integration materials are available upon request.

2 Compliance Summary

Table 1 cross-references each ODAR requirement to the relevant report section and the corresponding NASA DAS evidence or not-applicable basis.

Table 1: Compliance Matrix

Requirement	Section	Evidence	Basis / Note
4.3-1a	3.1	Req. 4.3-1 image	NASA DAS normal-operations compliance evidence
4.3-1b	3.2	Req. 4.3-2 image	NASA DAS no-release compliance evidence
4.4-1	4.2	N/A	Supported by spacecraft design and passivation controls
4.4-2	4.3	N/A	Supported by end-of-mission passivation sequence
4.4-3	4.4	N/A	No intentional breakup capability
4.4-4	4.5	N/A	Supported by non-propulsive, non-pressurized design basis
4.5-1	5.2	Req. 4.5-1 image	NASA DAS collision-risk compliance evidence
4.5-2	5.3	Req. 4.5-2 image	NASA DAS small-object collision compliance evidence
4.6-1a	6.2	Req. 4.6-1 image	NASA DAS disposal compliance screenshot
4.6-1b	6.3	Orbit lifetime image	NASA DAS orbital lifetime result
4.6-1c	6.4	Altitude history image	NASA DAS altitude history and geometry basis

Requirement	Section	Evidence	Basis / Note
4.6-2	6.5	N/A	No propulsion-based disposal maneuver; retained passive deorbit device provides drag augmentation
4.6-3	6.6	N/A	No alternate disposal treatment requested
4.6-4	6.7	N/A	Supported by operator procedures and tracking support
4.7-1	7.2	Req. 4.7-1 image	NASA DAS casualty-risk and demise screenshot
4.8-1	8.1	N/A	Mission orbit is outside ISS regime

3 System Description

3.1 Mission Overview

Baby Bird is a technology demonstration mission sponsored by Blackwing Space and planned for launch on the SpaceX Transporter-18 rideshare mission no earlier than October 1, 2026, aboard a Falcon 9 launch vehicle. The mission consists of a single 1.5U CubeSat built on Blackwing Space's Sparrow platform. The primary mission objective is to demonstrate a compact optical identification payload for space situational awareness.

The primary payload is a Manifest Space optical beacon module designed to evaluate compact optical identification systems in low Earth orbit. After deployment into the rideshare insertion orbit, Baby Bird will execute initial checkout, enter a planned six-month on-orbit technology demonstration phase, and then transition into a commanded end-of-mission deorbit sequence. That sequence begins with deployment of a retained passive deorbit device that releases a containerized drag sail, followed by spacecraft passivation, subsystem shutdown, and abandonment. The spacecraft is non-propulsive and non-maneuverable, so orbital debris compliance depends on elimination of release events, minimization of breakup risk, conjunction monitoring, and prompt passive decay after drag-sail deployment.

3.2 Spacecraft Physical Description

Baby Bird is a compact 1.5U CubeSat built on Blackwing Space's Sparrow platform. The spacecraft dry mass is 2 kg. Its external dimensions in launch and mission configuration are 17.0 cm $\times$ 12.9 cm $\times$ 11.5 cm. The spacecraft includes a containerized passive deorbit device that remains stowed during the six-month mission and, upon ground command at end of mission, deploys a retained drag sail. This increases the spacecraft area-to-mass ratio from 0.0061 m^2/kg during operations to 0.0842 m^2/kg postmission while keeping the spacecraft as a single attached object.

The spacecraft physical description relevant to orbital debris mitigation is summarized by the following characteristics:

- Total on-orbit mass is approximately 2 kg, with no fuel mass because the spacecraft carries no

Table 2: Mission Summary

Item	**Value**
Mission name	Baby Bird
Operator / applicant	Blackwing Space
Spacecraft type	Single 1.5U CubeSat built on Blackwing Space's Sparrow platform
Mission purpose	Technology demonstration of a compact optical identification beacon for SSA applications
Launch mission	SpaceX Transporter-18 rideshare on Falcon 9
Launch date	No earlier than October 1, 2026
Planned operational life	6 months
Orbital regime	Low Earth Orbit, Sun-synchronous orbit
Disposal concept	Ground-commanded deployment of retained passive deorbit device, followed by passivation and passive orbital decay
Maneuver capability	None

propulsion system.

- Operational bus dimensions are 17.0 cm $\times$ 12.9 cm $\times$ 11.5 cm.
- A retained passive deorbit device deploys only at end of mission and does not release a separate object.
- No deployable solar arrays, booms, or separable subsystems are planned.
- The spacecraft includes an internal rechargeable lithium-ion battery pack and avionics hardware, which are the principal stored energy elements considered in the breakup prevention assessment.

The spacecraft is compatible with the rideshare deployment concept and is designed to remain a single intact object after release from the deployer. No component is intended to detach or be discarded during the mission or during the end-of-mission drag-sail deployment sequence.

3.3 Mission Profile and Orbit Description

Baby Bird is planned for launch on SpaceX Transporter-18, with a launch date no earlier than October 1, 2026. The insertion orbit for this mission is a circular 510 km by 510 km Sun-synchronous orbit at 98 degrees inclination. As a rideshare payload, the spacecraft will deploy from a slot in an Equalizer Flex railed CubeSat dispenser provided by the launch integrator SEOPS Space, then begin operations without any transfer or orbit-raising maneuvers.

Following deployment, the mission profile includes:

1. Separation from the launch vehicle and deployer.

Figure 1: Baby Bird Spacecraft Overview Graphic

Table 3: Mass Properties and Geometric Characteristics

Parameter	Value
Dry mass	2 kg
Propellant mass	0 kg
Stowed dimensions	17.0 cm × 12.9 cm × 11.5 cm
Deployed dimensions	Bus dimensions unchanged; retained drag sail deployed at end of mission
Spacecraft configuration	Single attached spacecraft object
Deployable hardware	Containerized passive deorbit device with retained drag sail
Intentional release hardware	None
Operational area-to-mass ratio	0.0061 m^2/kg
Postmission area-to-mass ratio	0.0842 m^2/kg after drag-sail deployment
Pressure vessels	None identified

2. Initial spacecraft health checkout.
3. Commissioning of power, communications, and mission subsystems.
4. Routine technology demonstration operations for the six-month planned mission lifetime.
5. Ground-commanded deployment of the retained passive deorbit device at end of mission.
6. Deorbit sequence execution, including battery passivation, shutdown of nonessential functions, and abandonment.

Baby Bird has no propulsion capability or maneuvering capability. During the six-month operational mission, the spacecraft is modeled with an area-to-mass ratio of 0.0061 m^2/kg and remains near the 510 km insertion orbit. At end of mission, the retained passive deorbit device is deployed by ground command, increasing the area-to-mass ratio to 0.0842 m^2/kg. The postmission NASA DAS case then shows orbital decay from approximately 504 km by 505 km to uncontrolled reentry in about 0.531 year, or roughly 6–7 months, after drag-sail deployment.

Table 4: Nominal Orbital Parameters

Parameter	Value
Orbit type	Circular low Earth orbit
Perigee altitude	510 km
Apogee altitude	510 km
Inclination	98 degrees
Orbit classification	Sun-synchronous orbit
Operational area-to-mass ratio	0.0061 m^2/kg
Postmission area-to-mass ratio	0.0842 m^2/kg after drag-sail deployment
Maneuvering capability	None

4 Assessment of Debris Released During Normal Operations

Baby Bird is a self-contained nanosatellite payload that does not intentionally release debris during normal on-orbit operations. No objects are planned to be released after spacecraft separation from the deployer. Any rideshare separation hardware remains associated with the launch deployment system and is not a free object released by the Baby Bird spacecraft.

4.1 Requirement 4.3-1a

Baby Bird limits debris released during normal operations by using a non-separable spacecraft configuration with no disposable covers and no mission concept that requires jettison of hardware or material. The retained passive deorbit device remains stowed throughout normal operations and, when later commanded at end of mission, deploys a drag sail that remains attached to the spacecraft. Operational procedures prohibit intentional release of any object not explicitly incorporated into the licensed spacecraft configuration.

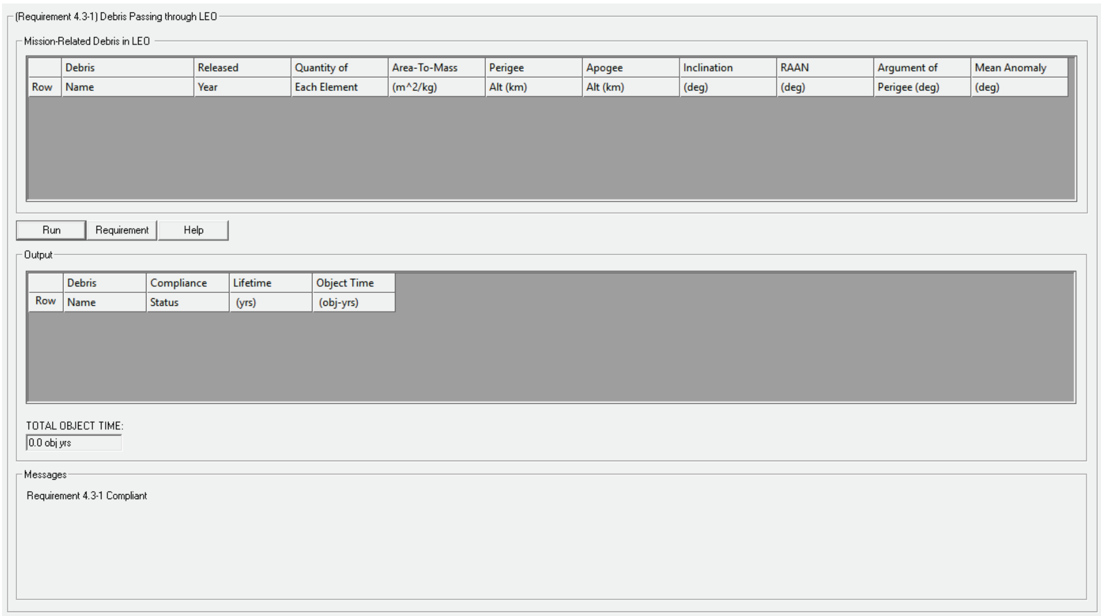


Figure 2: NASA DAS Compliance Evidence for Baby Bird Normal-Operations Debris Release Control

4.2 Requirement 4.3-1b

No planned debris releases during normal operations are identified for Baby Bird. The end-of-mission drag-sail deployment does not create a free-flying object because the sail remains attached to the spacecraft.

Table 5: Objects Released During Normal Operations

Field	**Value**
Planned released objects	None
Release epochs	N/A
Object masses	N/A
Orbital lifetimes of released objects	N/A
Operational justification	N/A

5 Assessment of Accidental Explosions and Intentional Breakups

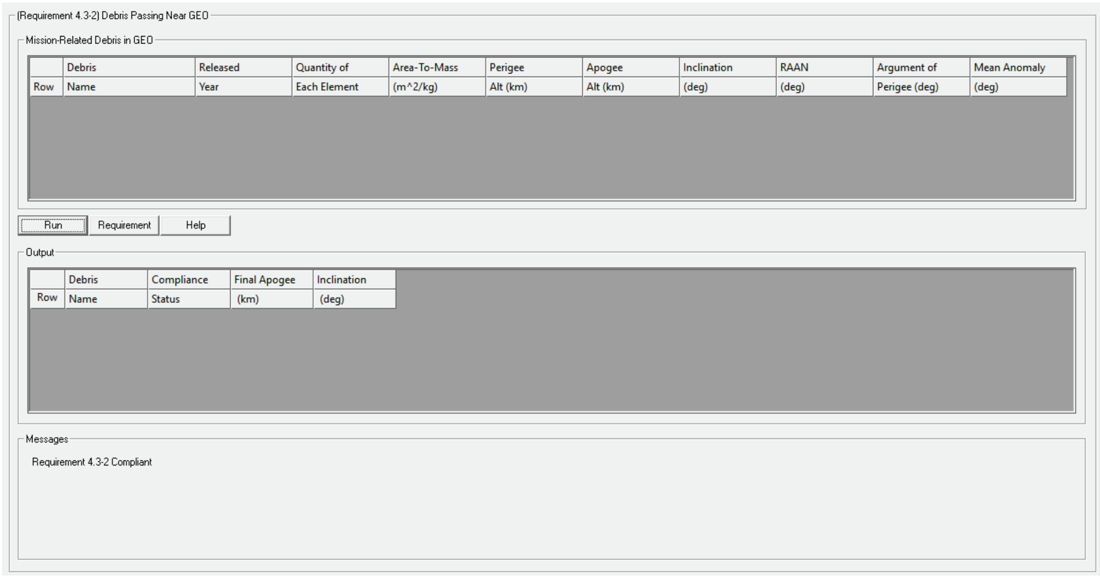


Figure 3: NASA DAS Compliance Evidence Confirming No Planned Debris Releases During Normal Operations

5.1 Energy Sources and Passivation

The principal stored energy source on Baby Bird is a rechargeable lithium-ion battery pack. The spacecraft has no propulsion system and no pressure vessels in the design. No pyrotechnics or intentional breakup devices are identified. The spacecraft does include a retained passive deorbit device with restrained mechanical energy associated with its drag-sail deployment mechanism; that energy is not released during normal operations and is expended only once during the commanded end-of-mission deorbit sequence while the sail remains attached.

The battery system uses LG Chem INR18650 MJ1 cells in a single 2S3P rechargeable pack. The pack contains six cylindrical 18650 lithium-ion cells using INR/NMC chemistry and a non-aqueous liquid electrolyte. The total battery energy is approximately 76.3 Wh. At end of mission, a ground-commanded sequence deploys the retained passive deorbit device and then places the spacecraft into an irreversible passivation mode in which all nonessential loads are disabled, a dedicated battery-depletion sequence is initiated using resistive loads, and charging control is permanently inhibited so that solar generation cannot materially restore stored energy.

5.2 Requirement 4.4-1

Baby Bird precludes accidental explosions during deployment and operations by employing a non-propulsive nanosatellite design with no pressure vessels, no pyrotechnic devices, and no intentional breakup mechanisms. The principal accidental breakup hazards are battery-related failure and anomalous deployment behavior of the retained passive deorbit device. Those hazards are controlled through standard battery qualification and handling controls, electrical power system protections, thermal design, retention of the drag sail until commanded end of mission, and mission procedures that maintain the battery and deployment system within their intended operating envelopes.

Table 6: Stored-Energy Sources and Controls

Item	Value
Primary stored-energy source	One rechargeable lithium-ion battery pack
Battery configuration	2S3P, 6 total 18650 cells
Cell model	LG Chem INR18650 MJ1
Battery chemistry	Li-Ion (INR/NMC)
Pack energy	76.3 Wh
Average cell voltage	3.635 V nominal
Passive deorbit device energy	Restrained mechanical deployment energy released once at end of mission
Propulsion / pressure sources	None
End-of-life control	Drag-sail deployment, irreversible passivation, resistive battery depletion, permanent charge inhibition

Compliance Basis: Requirement 4.4-1 is satisfied by the Baby Bird non-propulsive design, absence of pressure systems and pyrotechnics, and the passivation controls described in this section.

5.3 Requirement 4.4-2

At end of mission, Baby Bird will be commanded into an irreversible deorbit and passivation mode. The retained passive deorbit device will be deployed first to release the drag sail and initiate accelerated orbital decay. During the same ground-commanded sequence, all nonessential loads will be disabled, a dedicated resistive battery-depletion sequence will be executed, charging control will be permanently inhibited so that solar generation cannot materially restore stored energy, and remaining nonessential spacecraft functions will be shut down before abandonment. The spacecraft will remain in a low-power safed configuration with residual energy controlled to a level insufficient to cause fragmentation.

Compliance Basis: Requirement 4.4-2 is satisfied by the documented irreversible end-of-life passivation sequence for the Baby Bird battery system.

5.4 Requirement 4.4-3

Baby Bird contains no system intended to fragment, disperse, or destruct the payload on orbit.

Not Applicable: Baby Bird has no intentional breakup capability, no destruct system, and no fragmentation device.

5.5 Requirement 4.4-4

Credible breakup-related failure cases for Baby Bird are limited primarily to battery fault conditions, collision-induced fragmentation, and anomalous behavior of the retained passive deorbit device. Failure cases associated with propulsion, pressurized systems, or pyrotechnics are not present because those systems are not part of the design. Baby Bird addresses its credible failure modes through battery protection and operating controls, conservative power management, qualification and acceptance testing, controlled end-of-mission deployment of the retained drag sail, and elimination of separable hardware that could fragment or detach on orbit.

Compliance Basis: The applicable breakup-prevention controls are described in this section.

6 Assessment of On-Orbit Collisions

6.1 Collision Risk With Large Objects

Baby Bird's on-orbit collision-risk assessment is driven by its 510 km Sun-synchronous insertion orbit, compact physical dimensions, planned six-month operational life, and non-maneuverable mission architecture. The spacecraft cannot perform collision avoidance maneuvers. In lieu of maneuver capability, Blackwing Space will partner with Kayhan Space to monitor conjunction data messages, maintain awareness of the collision environment, and generate detailed ephemeris projections based on downlinked GPS telemetry and high-fidelity orbit propagation.

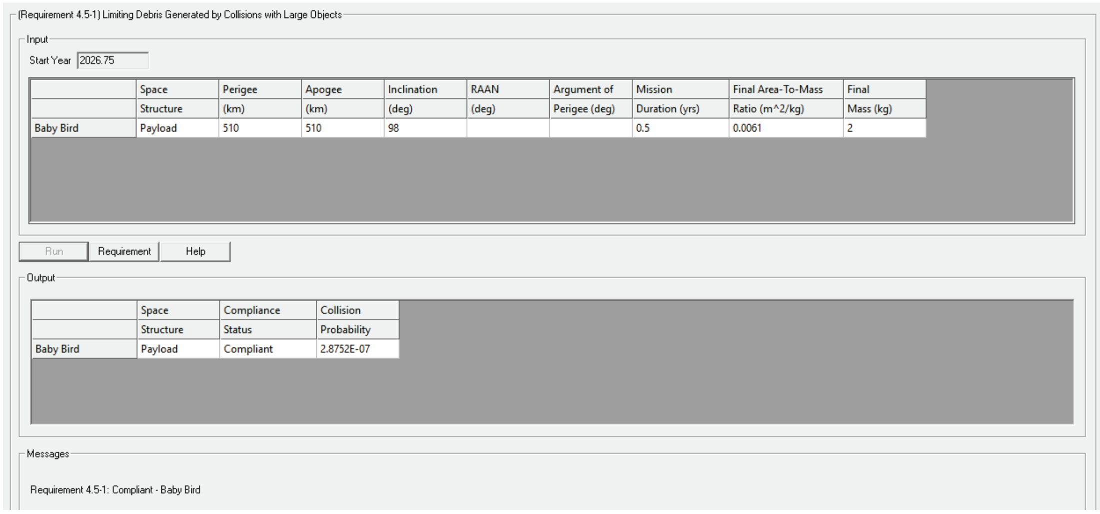
The mission therefore mitigates collision risk through selection of a low Earth orbit that naturally decays on an orbital-debris-compliant timescale, maintenance of high-quality ephemeris knowledge, and use of conjunction screening to support operational awareness even though active maneuvering is not available.

Table 7: Collision Risk Assessment Summary

Parameter	**Value**
Maneuver capability	None
Conjunction monitoring	Planned partnership with Kayhan Space
Ephemeris source	Downlinked GPS telemetry with high-fidelity propagation
Collision mitigation approach	Monitoring, orbit knowledge, compact spacecraft geometry, prompt postmission drag-sail disposal
Quantitative collision probability	2.8752×10^{-7}

6.2 Requirement 4.5-1

The NASA DAS analysis for Baby Bird predicts a probability of collision with tracked objects of 2.8752×10^{-7}. Operationally, Blackwing Space will monitor conjunction data through its partnership with Kayhan Space and will maintain detailed ephemeris projections using GPS-derived


(Requirement 4.5-1) Limiting Debris Generated by Collisions with Large Objects

Input

Start Year 2026.75

	Space Structure	Perigee (km)	Apogee (km)	Inclination (deg)	RAAN (deg)	Argument of Perigee (deg)	Mission Duration (yrs)	Final Area-To-Mass Ratio (m^2/kg)	Final Mass (kg)
Baby Bird	Payload	510	510	98			0.5	0.0061	2

Run Requirement Help

Output

	Space Structure	Compliance Status	Collision Probability
Baby Bird	Payload	Compliant	2.8752E-07

Messages

Requirement 4.5-1: Compliant - Baby Bird

Figure 4: NASA DAS Collision-Risk Compliance Evidence for Baby Bird

orbit knowledge. Because the spacecraft is non-maneuverable, the mission's mitigation basis is not collision avoidance maneuvering but rather conjunction awareness, compact spacecraft size during operations, and prompt postmission disposal after drag-sail deployment.

6.3 Requirement 4.5-2

Because Baby Bird is a small 1.5U CubeSat with constrained mass and volume, it does not incorporate dedicated debris shielding. The risk from small and untracked debris is mitigated primarily through the limited six-month mission duration, compact operational cross section, robust subsystem design, and prompt postmission drag-sail disposal from low Earth orbit rather than by active protective hardware.

Compliance Basis: NASA DAS evaluates Requirement 4.5-2 as compliant for the Baby Bird mission configuration.

7 Postmission Disposal Assessment

7.1 Disposal Strategy

Baby Bird's disposal strategy is deployment of a retained passive deorbit device immediately following completion of the six-month mission. A ground command deploys the containerized drag sail, increasing the spacecraft area-to-mass ratio from 0.0061 m^2/kg to 0.0842 m^2/kg. During the same end-of-mission sequence, onboard energy is passivated, nonessential systems are shut down, and the spacecraft is abandoned. NASA DAS shows uncontrolled reentry approximately 0.531 year, or about 6–7 months, after drag-sail deployment. This disposal concept is therefore based on passive drag augmentation rather than propulsion.

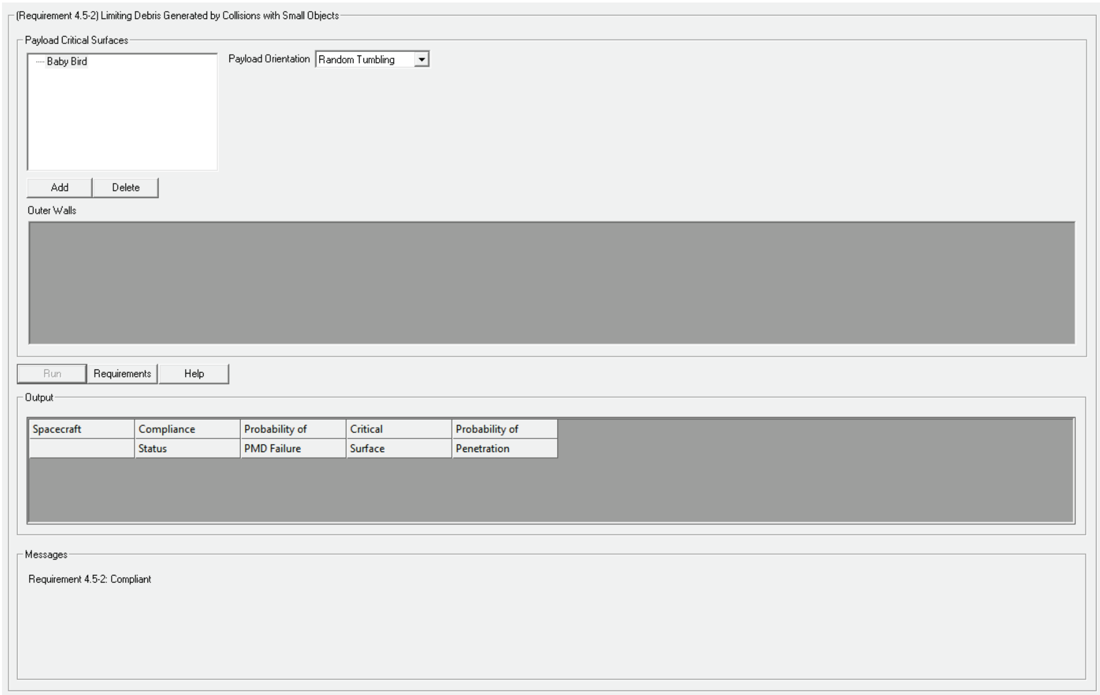


Figure 5: NASA DAS Small-Object Collision Compliance Evidence for Baby Bird

Table 8: Postmission Disposal Strategy Summary

Parameter	**Value**
Disposal method	Ground-commanded deployment of retained passive deorbit device followed by passive orbital decay
Active disposal hardware	No propulsion; retained passive deorbit device with containerized drag sail
End-of-mission action	Drag-sail deployment, irreversible passivation, subsystem shutdown, and abandonment
Initial disposal orbit	Approximately 504 km by 505 km SSO at drag-sail deployment per NASA DAS
Operational area-to-mass ratio	0.0061 m^2/kg
Postmission area-to-mass ratio	0.0842 m^2/kg after drag-sail deployment
Predicted orbital lifetime	Approximately 0.531 year (about 6–7 months) after drag-sail deployment per NASA DAS

7.2 Requirement 4.6-1a

The planned disposal approach for Baby Bird is a ground-commanded transition from the six-month mission phase into a retained drag-sail deployment and passivation sequence. Based on the NASA DAS analyses referenced in this report, the spacecraft exits the operational phase near a 504 km by 505 km Sun-synchronous orbit, deploys the drag sail, passivates onboard energy, and then disposes through uncontrolled atmospheric reentry approximately 6–7 months later.

7.3 Requirement 4.6-1b

The predicted postmission orbital lifetime for Baby Bird is approximately 0.531 year after drag-sail deployment according to the NASA DAS orbit-lifetime analysis for the postmission configuration.

7.4 Requirement 4.6-1c

For disposal compliance analysis, Baby Bird is modeled in two phases: a six-month operational phase at 0.0061 m^2/kg and a postmission phase after drag-sail deployment at 0.0842 m^2/kg. The retained drag sail changes the spacecraft's effective aerodynamic geometry for disposal while remaining physically attached to the spacecraft.

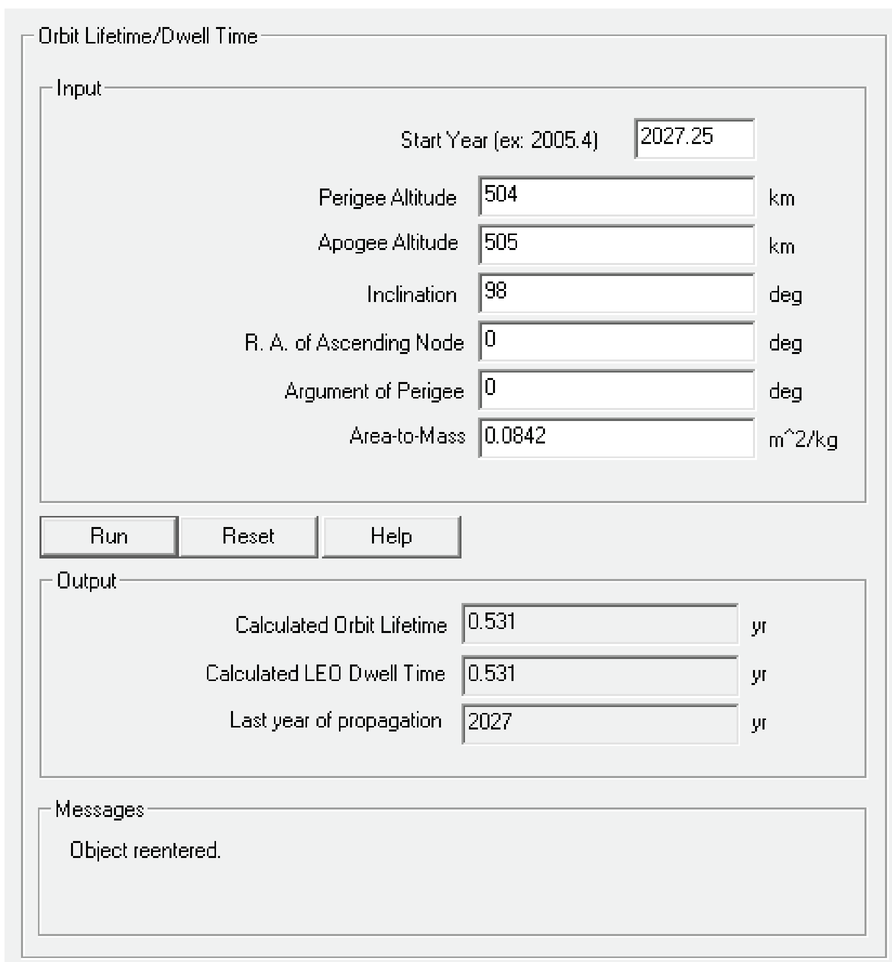
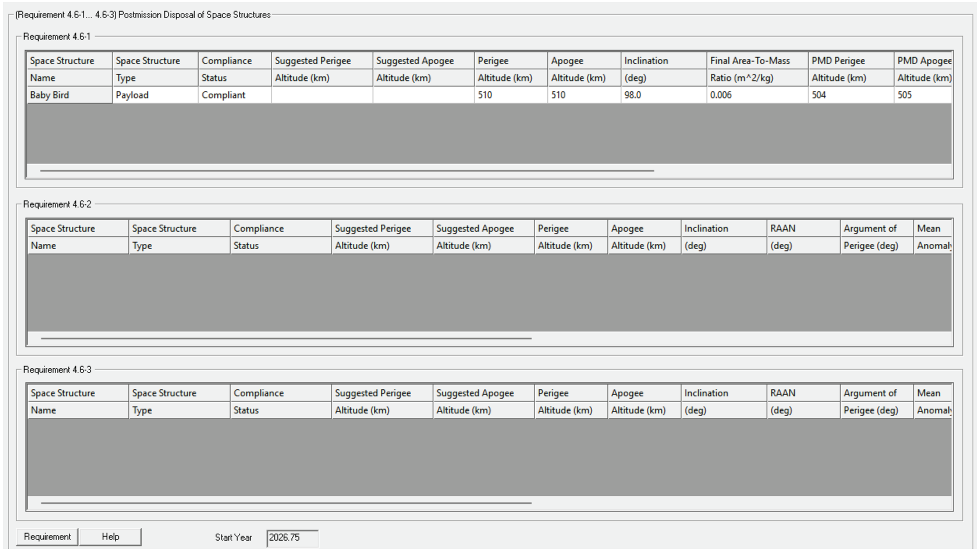


Figure 6: NASA DAS Orbit Lifetime Result for Baby Bird After Drag-Sail Deployment



(Requirement 4.6-1... 4.6-3) Postmission Disposal of Space Structures

Requirement 4.6-1

Space Structure Name	Space Structure Type	Compliance Status	Suggested Perigee Altitude (km)	Suggested Apogee Altitude (km)	Perigee Altitude (km)	Apogee Altitude (km)	Inclination (deg)	Final Area-To-Mass Ratio (m^2/kg)	PMD Perigee Altitude (km)	PMD Apogee Altitude (km)
Baby Bird	Payload	Compliant			510	510	98.0	0.006	504	505

Requirement 4.6-2

Space Structure Name	Space Structure Type	Compliance Status	Suggested Perigee Altitude (km)	Suggested Apogee Altitude (km)	Perigee Altitude (km)	Apogee Altitude (km)	Inclination (deg)	RAAN (deg)	Argument of Perigee (deg)	Mean Anomaly

Requirement 4.6-3

Space Structure Name	Space Structure Type	Compliance Status	Suggested Perigee Altitude (km)	Suggested Apogee Altitude (km)	Perigee Altitude (km)	Apogee Altitude (km)	Inclination (deg)	RAAN (deg)	Argument of Perigee (deg)	Mean Anomaly

Requirement Help Start Year 2026.75

Figure 7: NASA DAS Compliance Evidence for Baby Bird Postmission Disposal

7.5 Requirement 4.6-2

Baby Bird does not rely on propulsion for postmission disposal. Instead, the spacecraft uses a retained passive deorbit device that is deployed by ground command at end of mission and then passively accelerates orbital decay through drag augmentation.

Compliance Basis: Requirement 4.6-2 is satisfied without propulsion because disposal is achieved through deployment of a retained passive deorbit device and subsequent passive atmospheric drag.

7.6 Requirement 4.6-3

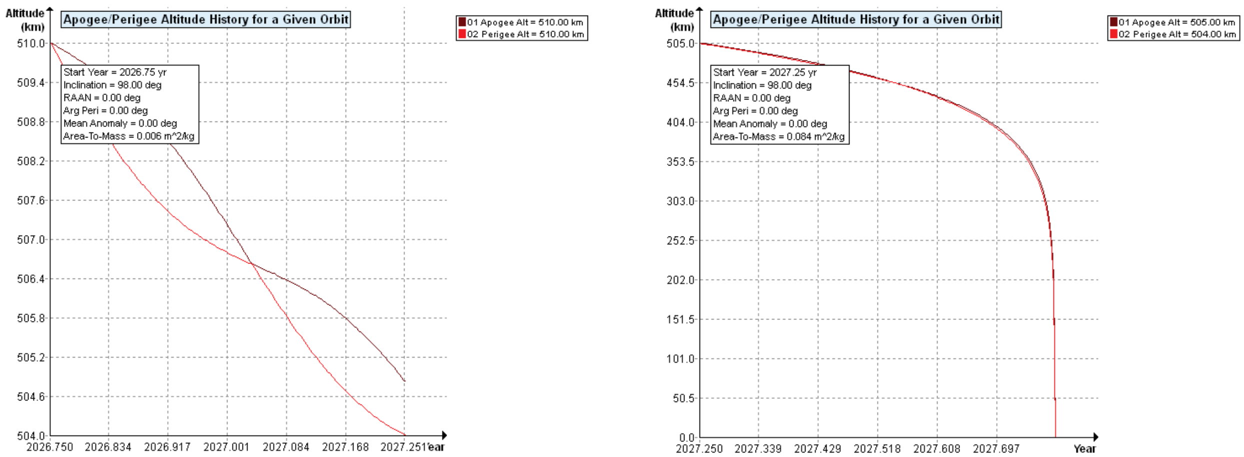
No alternate postmission disposal treatment is requested for Baby Bird. The mission's compliance basis is the standard disposal case in which a ground-commanded retained drag sail increases drag sufficiently to achieve uncontrolled reentry well within 25 years.

Not Applicable: Baby Bird does not request alternate postmission disposal treatment or relief from the standard Compliance Basis.

7.7 Requirement 4.6-4

Baby Bird disposal requires coordination among Blackwing Space mission operations personnel and the ground segment responsible for issuing the end-of-mission drag-sail deployment, safing, and passivation commands. The mission also relies on post-launch orbit knowledge and conjunction monitoring support, including the planned Kayhan Space partnership for tracking awareness, to determine the proper time to initiate the terminal deorbit sequence.

Compliance Basis: Requirement 4.6-4 is satisfied by operator procedures for commanded drag-sail deployment, end-of-life passivation, abandonment, and orbit-monitoring support.



(a) Six-month operational mission phase (b) Postmission decay after drag-sail deployment

Figure 8: NASA DAS apogee/perigee altitude histories for Baby Bird during the operational mission and after end-of-mission drag-sail deployment

8 Reentry Assessment

8.1 Controlled or Uncontrolled Reentry

For a 1.5U CubeSat mission such as Baby Bird, the expected end state is uncontrolled atmospheric reentry following end-of-mission drag-sail deployment and passive orbital decay rather than controlled reentry. The NASA DAS material-component analysis shows 0% reentry survivability risk for the spacecraft configuration. On that basis, the mission expects complete demise with no surviving debris reaching the ground.

The NASA DAS reentry model was constructed from a component-level material inventory for the Baby Bird spacecraft. Table 10 summarizes the component set used in the demise analysis.

Table 9: Reentry and Demise Assessment Summary

Parameter	Value
Reentry type	Uncontrolled reentry after drag-sail deployment and passive orbital decay
Predicted reentry timing	Approximately 0.531 year (about 6–7 months) after drag-sail deployment
Reentry survivability result	0% survivability risk per NASA DAS component analysis
Expected surviving debris	None identified

Table 10: Baby Bird Reentry Component Inventory From NASA DAS Input File

Row	Component	Qty	Material	Body Type	Thermal Mass [kg]	Demise Altitude [km]
1	Baby Bird	1	Aluminum 6061-T6	Box	2	–
2	Chassis Plate -X	1	Aluminum 6061-T6	Flat Plate	0.0685	77.7
3	Chassis Plate XY	2	Aluminum 6061-T6	Flat Plate	0.0730	77.6
4	Chassis Plate +X	1	Aluminum 6061-T6	Flat Plate	0.0730	77.6
5	Chassis Structure +Z	1	Aluminum 6061-T6	Flat Plate	0.0565	77.6
6	Chassis Structure -Z	1	Aluminum 6061-T6	Flat Plate	0.0500	77.7
7	Chassis Structure Y	2	Aluminum 6061-T6	Flat Plate	0.0605	77.7
8	Capsule Pod Cover	2	Aluminum 6061-T6	Flat Plate	0.0650	77.7
9	Capsule Pod	2	Aluminum 6061-T6	Box	0.111	77.5
10	Rook Enclosure Top	1	Aluminum 6061-T6	Box	0.0300	77.8
11	Rook Enclosure Middle	1	Aluminum 6061-T6	Box	0.0360	77.8
12	Rook Enclosure Bottom	1	Aluminum 6061-T6	Box	0.0560	77.7
13	Rook Board	1	Fiberglass	Flat Plate	0.0235	77.5
14	UHF Antenna Cover	1	Aluminum 6061-T6	Box	0.0320	77.8
15	UHF Antenna Board	1	Fiberglass	Flat Plate	0.0265	77.5
16	Battery Board	1	Fiberglass	Flat Plate	0.0225	77.6
17	Battery Cells	6	Stainless Steel (generic)	Cylinder	0.0460	74.2
18	Payload Enclosure Bottom	1	Aluminum 6061-T6	Box	0.0370	77.7
19	Payload Enclosure Top	1	Aluminum 6061-T6	Flat Plate	0.1800	76.7
20	Payload Base Board	1	Fiberglass	Flat Plate	0.0240	77.5
21	Payload LED Board	1	Fiberglass	Flat Plate	0.0105	77.6
22	GPS Antenna Board	1	Fiberglass	Flat Plate	0.0080	77.7
23	Deorbit Device	1	Aluminum 6061-T6	Box	0.040	77.4
24	Deorbit Device Enclosure Top	1	Aluminum 6061-T6	Flat Plate	0.025	77.8
25	Deorbit Device Enclosure Bottom	1	Aluminum 6061-T6	Box	0.102	77.4
26	Solar Panel PCB	3	Fiberglass	Flat Plate	0.037	77.5
27	Solar Cell	9	Fiberglass	Flat Plate	0.002	77.9

8.2 Requirement 4.7-1

The NASA DAS component-level demise analysis for Baby Bird indicates 0% reentry survivability risk, which implies no expected surviving debris and a human casualty expectation below the applicable threshold.

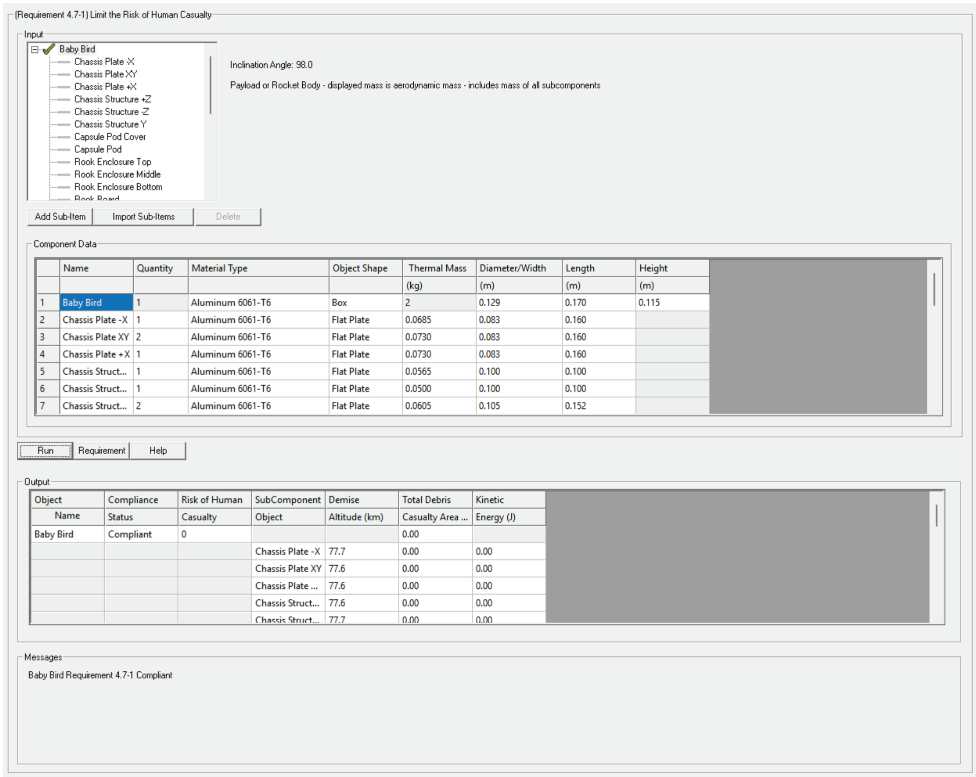


Figure 9: NASA DAS Reentry Survivability and Casualty-Risk Compliance Evidence for Baby Bird

9 Collision Risk With the International Space Station

Baby Bird is planned for a 510 km circular Sun-synchronous orbit at 98 degrees inclination. This orbit is distinct from the International Space Station operating orbit and inclination regime. On that basis, a dedicated ISS collision-risk case is not applicable for this mission.

9.1 Requirement 4.8-1

Based on the mission orbit of 510 km circular Sun-synchronous orbit at 98 degrees inclination, Requirement 4.8-1 is not applicable because the mission does not operate in the ISS orbital regime.

Not Applicable: The Baby Bird mission orbit does not overlap the ISS operating regime.

10 References

1. NASA-STD-8719.14, *Process for Limiting Orbital Debris*, revision used for the application.
2. NASA Debris Assessment Software (DAS), version **3.2.6**, used for Baby Bird mission compliance analyses.
3. FCC orbital debris mitigation rules and application guidance applicable to the mission.
4. Mission-specific analyses, procedures, and design documents cited throughout this report.

A Supporting Data: reentry.csv

```
Reentry Data
Row Num,Name,Parent,Qty,Material,Body Type,Thermal Mass,Diameter/Width,Length,Height,Status,Risk,Demise Alt,
    Total DCA,KE
1,Baby Bird,0,1,Aluminum 6061-T6,Box,2,0.129,0.170,0.115,Compliant,'0',,0.00,
2,Chassis Plate -X,1,1,Aluminum 6061-T6,Flat Plate,0.0685,0.083,0.160,,,,77.7,0.00,0.00
3,Chassis Plate XY,1,2,Aluminum 6061-T6,Flat Plate,0.0730,0.083,0.160,,,,77.6,0.00,0.00
4,Chassis Plate +X,1,1,Aluminum 6061-T6,Flat Plate,0.0730,0.083,0.160,,,,77.6,0.00,0.00
5,Chassis Structure +Z,1,1,Aluminum 6061-T6,Flat Plate,0.0565,0.100,0.100,,,,77.6,0.00,0.00
6,Chassis Structure -Z,1,1,Aluminum 6061-T6,Flat Plate,0.0500,0.100,0.100,,,,77.7,0.00,0.00
7,Chassis Structure Y,1,2,Aluminum 6061-T6,Flat Plate,0.0605,0.105,0.152,,,,77.7,0.00,0.00
8,Capsule Pod Cover,1,2,Aluminum 6061-T6,Flat Plate,0.0650,0.0830,0.152,,,,77.7,0.00,0.00
9,Capsule Pod,1,2,Aluminum 6061-T6,Box,0.111,0.0830,0.152,0.0080,,,77.5,0.00,0.00
10,Rook Enclosure Top,1,1,Aluminum 6061-T6,Box,0.0300,0.0900,0.0960,0.0075,,,77.8,0.00,0.00
11,Rook Enclosure Middle,1,1,Aluminum 6061-T6,Box,0.0360,0.0900,0.0960,0.0230,,,77.8,0.00,0.00
12,Rook Enclosure Bottom,1,1,Aluminum 6061-T6,Box,0.0560,0.0900,0.0960,0.0230,,,77.7,0.00,0.00
13,Rook Board,1,1,Fiberglass,Flat Plate,0.0235,0.0900,0.0950,,,,77.5,0.00,0.00
14,UHF Antenna Cover,1,1,Aluminum 6061-T6,Box,0.0320,0.1000,0.1000,0.0041,,,77.8,0.00,0.00
15,UHF Antenna Board,1,1,Fiberglass,Flat Plate,0.0265,0.1000,0.1000,,,,77.5,0.00,0.00
16,Battery Board,1,1,Fiberglass,Flat Plate,0.0225,0.0900,0.0950,,,,77.6,0.00,0.00
17,Battery Cells,1,6,Stainless Steel (generic),Cylinder,0.0460,0.0180,0.0650,,,,74.2,0.00,0.00
18,Payload Enclosure Bottom,1,1,Aluminum 6061-T6,Box,0.0370,0.0900,0.0950,0.0046,,,77.7,0.00,0.00
19,Payload Enclosure Top,1,1,Aluminum 6061-T6,Flat Plate,0.1800,0.0900,0.0950,,,,76.7,0.00,0.00
20,Payload Base Board,1,1,Fiberglass,Flat Plate,0.0240,0.0900,0.0950,,,,77.5,0.00,0.00
21,Payload LED Board,1,1,Fiberglass,Flat Plate,0.0105,0.0450,0.0800,,,,77.6,0.00,0.00
22,GPS Antenna Board,1,1,Fiberglass,Flat Plate,0.0080,0.0520,0.0700,,,,77.7,0.00,0.00
23,Deorbit Device,1,1,Aluminum 6061-T6,Box,0.040,0.050,0.059,0.009,,,77.4,0.00,0.00
24,Deorbit Device Enclosure Top,1,1,Aluminum 6061-T6,Flat Plate,0.025,0.090,0.095,,,,77.8,0.00,0.00
25,Deorbit Device Enclosure Bottom,1,1,Aluminum 6061-T6,Box,0.102,0.090,0.095,0.015,,,77.4,0.00,0.00
26,Solar Panel PCB,1,3,Fiberglass,Flat Plate,0.037,0.083,0.152,,,,77.5,0.00,0.00
27,Solar Cell,1,9,Fiberglass,Flat Plate,0.002,0.040,0.080,,,,77.9,0.00,0.00
```

B Supporting Data: das_output_log.txt

```
04 24 2026; 17:02:44PM  Project Data Saved To File
04 24 2026; 17:02:46PM  Project Data Saved To File
04 24 2026; 17:03:59PM  Project Data Saved To File
04 24 2026; 17:05:54PM  Processing Requirement 4.3-1:   Return Status :  Not Run

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

=============== End of Requirement 4.3-1 ===============
04 24 2026; 17:06:48PM  Processing Requirement 4.3-2: Return Status : Passed

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

=============== End of Requirement 4.3-2 ===============
04 24 2026; 17:12:05PM  Processing Requirement 4.5-1:   Return Status :  Passed

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

**INPUT**
```

```
        Space Structure Name = Baby Bird
        Space Structure Type = Payload
        Perigee Altitude = 510.000 (km)
        Apogee Altitude = 510.000 (km)
        Inclination = 98.000 (deg)
        RAAN = 0.000 (deg)
        Argument of Perigee = 0.000 (deg)
        Mean Anomaly = 0.000 (deg)
        Final Area-To-Mass Ratio = 0.0061 (m^2/kg)
        Start Year = 2026.750 (yr)
        Initial Mass = 2.000 (kg)
        Final Mass = 2.000 (kg)
        Duration = 0.500 (yr)
        Station-Kept = False
        Abandoned = True
        Long-Term Reentry = False

**OUTPUT**

        Collision Probability = 2.8752E-07
        Returned Message: Normal Processing
        Date Range Message: Normal Date Range
        Status = Pass

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

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

04 24 2026; 17:12:44PM  Project Data Saved To File
04 24 2026; 17:12:55PM  Requirement 4.5-2:  Compliant

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

04 24 2026; 17:13:22PM  Processing Requirement 4.6      Return Status :  Passed

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

**INPUT**

        Space Structure Name = Baby Bird
        Space Structure Type = Payload

        Perigee Altitude = 510.000000 (km)
        Apogee Altitude = 510.000000 (km)
        Inclination = 98.000000 (deg)
        RAAN = 0.000000 (deg)
        Argument of Perigee = 0.000000 (deg)
        Mean Anomaly = 0.000000 (deg)
        Area-To-Mass Ratio = 0.006100 (m^2/kg)
        Start Year = 2026.750000 (yr)
        Initial Mass = 2.000000 (kg)
        Final Mass = 2.000000 (kg)
        Duration = 0.500000 (yr)
        Station Kept = False
        Abandoned = True
        PMD Perigee Altitude = 504.013788 (km)
        PMD Apogee Altitude = 504.831307 (km)
        PMD Inclination = 97.993325 (deg)
        PMD RAAN = 192.963056 (deg)
        PMD Argument of Perigee = 133.435064 (deg)
        PMD Mean Anomaly = 0.000000 (deg)
```

```
        Long-Term Reentry = False

**OUTPUT**

        Suggested Perigee Altitude = 504.013788 (km)
        Suggested Apogee Altitude = 504.831307 (km)
        Returned Error Message = Passes LEO reentry orbit criteria.

        Released Year = 2035 (yr)
        Requirement = 61
        Compliance Status = Pass

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

=============== End of Requirement 4.6 ===============
04 24 2026; 17:14:19PM  *********Processing Requirement 4.7-1
        Return Status :  Passed

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

name = Baby Bird
quantity = 1
parent = 0
materialID = 8
type = Box
Aero Mass = 2.000000
Thermal Mass = 2.000000
Diameter/Width = 0.129000
Length = 0.170000
Height = 0.115000

name = Chassis Plate -X
quantity = 1
parent = 1
materialID = 8
type = Flat Plate
Aero Mass = 0.068500
Thermal Mass = 0.068500
Diameter/Width = 0.083000
Length = 0.160000

name = Chassis Plate XY
quantity = 2
parent = 1
materialID = 8
type = Flat Plate
Aero Mass = 0.073000
Thermal Mass = 0.073000
Diameter/Width = 0.083000
Length = 0.160000

name = Chassis Plate +X
quantity = 1
parent = 1
materialID = 8
type = Flat Plate
Aero Mass = 0.073000
Thermal Mass = 0.073000
Diameter/Width = 0.083000
Length = 0.160000

name = Chassis Structure +Z
```

```
quantity = 1
parent = 1
materialID = 8
type = Flat Plate
Aero Mass = 0.056500
Thermal Mass = 0.056500
Diameter/Width = 0.100000
Length = 0.100000

name = Chassis Structure -Z
quantity = 1
parent = 1
materialID = 8
type = Flat Plate
Aero Mass = 0.050000
Thermal Mass = 0.050000
Diameter/Width = 0.100000
Length = 0.100000

name = Chassis Structure Y
quantity = 2
parent = 1
materialID = 8
type = Flat Plate
Aero Mass = 0.060500
Thermal Mass = 0.060500
Diameter/Width = 0.105000
Length = 0.152000

name = Capsule Pod Cover
quantity = 2
parent = 1
materialID = 8
type = Flat Plate
Aero Mass = 0.065000
Thermal Mass = 0.065000
Diameter/Width = 0.083000
Length = 0.152000

name = Capsule Pod
quantity = 2
parent = 1
materialID = 8
type = Box
Aero Mass = 0.111000
Thermal Mass = 0.111000
Diameter/Width = 0.083000
Length = 0.152000
Height = 0.008000

name = Rook Enclosure Top
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.030000
Thermal Mass = 0.030000
Diameter/Width = 0.090000
Length = 0.096000
Height = 0.007500

name = Rook Enclosure Middle
quantity = 1
```

```
parent = 1
materialID = 8
type = Box
Aero Mass = 0.036000
Thermal Mass = 0.036000
Diameter/Width = 0.090000
Length = 0.096000
Height = 0.023000

name = Rook Enclosure Bottom
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.056000
Thermal Mass = 0.056000
Diameter/Width = 0.090000
Length = 0.096000
Height = 0.023000

name = Rook Board
quantity = 1
parent = 1
materialID = 23
type = Flat Plate
Aero Mass = 0.023500
Thermal Mass = 0.023500
Diameter/Width = 0.090000
Length = 0.095000

name = UHF Antenna Cover
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.032000
Thermal Mass = 0.032000
Diameter/Width = 0.100000
Length = 0.100000
Height = 0.004100

name = UHF Antenna Board
quantity = 1
parent = 1
materialID = 23
type = Flat Plate
Aero Mass = 0.026500
Thermal Mass = 0.026500
Diameter/Width = 0.100000
Length = 0.100000

name = Battery Board
quantity = 1
parent = 1
materialID = 23
type = Flat Plate
Aero Mass = 0.022500
Thermal Mass = 0.022500
Diameter/Width = 0.090000
Length = 0.095000

name = Battery Cells
quantity = 6
```

```
parent = 1
materialID = 54
type = Cylinder
Aero Mass = 0.046000
Thermal Mass = 0.046000
Diameter/Width = 0.018000
Length = 0.065000

name = Payload Enclosure Bottom
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.037000
Thermal Mass = 0.037000
Diameter/Width = 0.090000
Length = 0.095000
Height = 0.004600

name = Payload Enclosure Top
quantity = 1
parent = 1
materialID = 8
type = Flat Plate
Aero Mass = 0.180000
Thermal Mass = 0.180000
Diameter/Width = 0.090000
Length = 0.095000

name = Payload Base Board
quantity = 1
parent = 1
materialID = 23
type = Flat Plate
Aero Mass = 0.024000
Thermal Mass = 0.024000
Diameter/Width = 0.090000
Length = 0.095000

name = Payload LED Board
quantity = 1
parent = 1
materialID = 23
type = Flat Plate
Aero Mass = 0.010500
Thermal Mass = 0.010500
Diameter/Width = 0.045000
Length = 0.080000

name = GPS Antenna Board
quantity = 1
parent = 1
materialID = 23
type = Flat Plate
Aero Mass = 0.008000
Thermal Mass = 0.008000
Diameter/Width = 0.052000
Length = 0.070000

name = Deorbit Device
quantity = 1
parent = 1
materialID = 8
```

```
type = Box
Aero Mass = 0.040000
Thermal Mass = 0.040000
Diameter/Width = 0.050000
Length = 0.059000
Height = 0.009000

name = Deorbit Device Enclosure Top
quantity = 1
parent = 1
materialID = 8
type = Flat Plate
Aero Mass = 0.025000
Thermal Mass = 0.025000
Diameter/Width = 0.090000
Length = 0.095000

name = Deorbit Device Enclosure Bottom
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 0.102000
Thermal Mass = 0.102000
Diameter/Width = 0.090000
Length = 0.095000
Height = 0.015000

name = Solar Panel PCB
quantity = 3
parent = 1
materialID = 23
type = Flat Plate
Aero Mass = 0.037000
Thermal Mass = 0.037000
Diameter/Width = 0.083000
Length = 0.152000

name = Solar Cell
quantity = 9
parent = 1
materialID = 23
type = Flat Plate
Aero Mass = 0.002000
Thermal Mass = 0.002000
Diameter/Width = 0.040000
Length = 0.080000

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

name = Baby Bird
Demise Altitude = 77.997062
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Chassis Plate -X
Demise Altitude = 77.663848
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

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

```
name = Chassis Plate XY
Demise Altitude = 77.646966
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Chassis Plate +X
Demise Altitude = 77.646966
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Chassis Structure +Z
Demise Altitude = 77.613480
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Chassis Structure -Z
Demise Altitude = 77.663885
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Chassis Structure Y
Demise Altitude = 77.739425
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Capsule Pod Cover
Demise Altitude = 77.672153
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Capsule Pod
Demise Altitude = 77.494556
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Rook Enclosure Top
Demise Altitude = 77.797723
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Rook Enclosure Middle
Demise Altitude = 77.797621
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Rook Enclosure Bottom
Demise Altitude = 77.688670
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Rook Board
Demise Altitude = 77.537842
Debris Casualty Area = 0.000000
```

```
Impact Kinetic Energy = 0.000000

*************************************
name = UHF Antenna Cover
Demise Altitude = 77.797808
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = UHF Antenna Board
Demise Altitude = 77.538194
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Battery Board
Demise Altitude = 77.562615
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Battery Cells
Demise Altitude = 74.211595
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Payload Enclosure Bottom
Demise Altitude = 77.739205
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Payload Enclosure Top
Demise Altitude = 76.654340
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Payload Base Board
Demise Altitude = 77.529477
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Payload LED Board
Demise Altitude = 77.619247
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = GPS Antenna Board
Demise Altitude = 77.702180
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Deorbit Device
Demise Altitude = 77.425754
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

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

```
name = Deorbit Device Enclosure Top
Demise Altitude = 77.806200
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Deorbit Device Enclosure Bottom
Demise Altitude = 77.366875
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Solar Panel PCB
Demise Altitude = 77.512842
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

*************************************
name = Solar Cell
Demise Altitude = 77.928683
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

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

=============== End of Requirement 4.7-1 ===============
04 24 2026; 17:14:19PM  Project Data Saved To File
```