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Supernova-Beta

Orbital Debris Assessment Report

Revision E • 22 July 2015

Prepared for Pumpkin, Inc. in compliance with NASA-STD-8719.14 by Southern Stars Group, LLC.
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NASA Debris Analysis Software (DAS) version 2.02 was used in preparing this report.

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Submitted by:

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Approval and Risk accepted by:

NASA HQ Office of Safety and Mission Assurance Orbital Debris Manager

Mission Directorate Associate Administrator.

NASA Chief, Safety and Mission Assurance.

Record of Revisions

Revision	Date	Affected Pages	Description of Change	Authors
A	1 May 2015	All	Initial Revision.	Tim DeBenedictis
B	5 May 2015	1, 20-28	Added DAS Re-Entry Analysis. Minor edits.	Tim DeBenedictis
C	7 May 2015	All	Applied Pumpkin styles. Corrected launch date.	Tim DeBenedictis
D	14 May 2015	15, 17-19	Corrected error in CSA calculation, orbit lifetime	Tim DeBenedictis
E	22 July 2015	6, 8	Discussion of collision avoidance; added Rob Call as JSpOC POC.	Tim DeBenedictis

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Self-Assessment and OSMA Assessment of the ODAR

A self assessment is provided below, in accordance with the assessment format provided in Appendix A.2 of NASA-STD-8719.14. In the final ODAR document, this assessment will reflect any inputs received from OSMA as well.

Req. #	Launch Vehicle				Spacecraft		
	Compliant	Not Compliant	Incomplete	Standard Non Compliant	Compliant	Not Compliant	Incomplete
4.3-1.a			x		x		
4.3-1.b			x		x		
4.3-2			x		x		
4.4-1			x		x		
4.4-2			x		x		
4.4-3			x		x		
4.4-4			x		x		
4.5-1			x		x		
4.5-2			x		x		
4.6-1(a)			x		x		
4.6-1(b)			x		x		
4.6-1(c)			x		x		
4.6-2			x		x		
4.6-3			x		x		
4.6-4			x		x		
4.6-5			x		x		
4.7-1			x		x		
4.8-1			x		x		

Note:

The primary payload belongs to the University of Hawaii. This is not a Pumpkin, Inc. primary mission. All of the other portions of the launch stack are non-Pumpkin, and Supernova-Beta is not the lead.

Assessment Report Format

ODAR Technical Sections Format Requiremnents:

- This ODAR follows the format in NASA-STD-8719.14, Appendix A.1, and include the content indicated at a minimum in each section 2 through 8 below for the Supernova-Beta satellite. Sections 9 through 14 apply to the launch vehicle ODAR, and are not covered here.

ODAR Section 1: Program Management and Mission Overview

Supernova-Beta is a privately funded mission owned and operated by Pumpkin, Inc., a California limited liability corporation with its principal place of business at 750 Naples St., San Francisco, CA 94112.

Senior Manager and Program Management:

- Andrew Kalman, aek@pumpkininc.com, (415) 584-6360
- Rob Call, rob@pumpkininc.com (415) 385-4370
- Kevin Stein, kevin@pumpkininc.com, (408) 506-7587

The mission point-of-contact for JSpoC collision/conjunction warnings is Rob Call, above.

Key engineering personnel:

- Andrew Kalman, Pumpkin, aek@pumpkininc.com, (415) 584-6360
- Shaun Houlihan, Pumpkin, shaunh@pumpkininc.com, (415) 584-6360

Foreign government or space agency participation:

- No foreign agency is participating in this mission. All personnel are United States citizens.

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

- Not Applicable.

Schedule of upcoming mission milestones:

15 August 2015	Spacecraft delivery to Launch Service Provider.
29 October 2015	Earliest possible launch.

Mission Overview

Supernova-Beta is a 6U CubeSat that will be launched as a secondary payload on a Super Strypi LV into a 430 x 505 km orbit at 94.8° inclination. It is a space test flight of multiple subsystems of Pumpkin's SUPERNOVA bus, developed for the Navy SPAWAR and Air Force ORS office.

Launch Vehicle and Launch Site:

- The launch vehicle is a Super Strypi (ORS-4), scheduled for launch from the Pacific Missile Range Facility, Kauai, Hawaii, USA. The ORS-4 mission will deploy a variety of different CubeSats, including Supernova-Beta.

Proposed Launch Date:

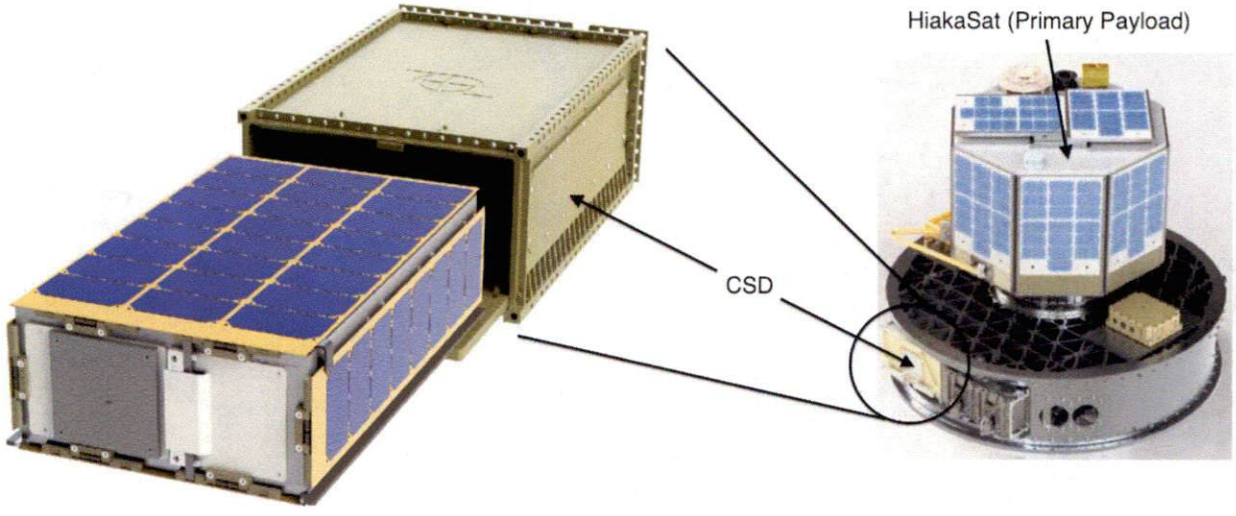
- No earlier than 29 October 2015.

Mission Duration:

- One to two years in LEO operation, until atmospheric reentry via orbital decay.

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

- The Super Strypi is a three-stage, spin-stabilized solid fuel vehicle. The primary payload is HiakaSat; in addition, there are six PPODs and one 6U Canisterized Satellite Dispenser (CSD) flying on the ORS-4 Mission. Once the final stage has burned out, the primary and secondary payloads will be dispensed. A flight sequence diagram provided by the ORS office follows on the next page.



Left: Supernova deploying from Planetary System Corp. Cannisterized Satellite Dispenser (CSD); Right: ORS-4 Integrated Payload Stack, showing location of CSD relative to primary payload (HiakaSat).

- The destination orbit is entirely determined by the primary payload; Supernova-Beta is a secondary payload. Its orbital parameters are defined as follows:

  Apogee: 505 km
  Perigee: 430 km
  Inclination: 94.8 degrees

  Supernova-Beta has no propulsion system and therefore does not actively change orbits. There is no parking or transfer orbit. There is no capability to adjust the orbit by altering the spacecraft's cross-sectional area in the direction of motion, or by any other means.

- The mission point-of-contact for JSpOC collision warnings is Rob Call, rob@pumpkininc.com, +1 (415) 385-4370.

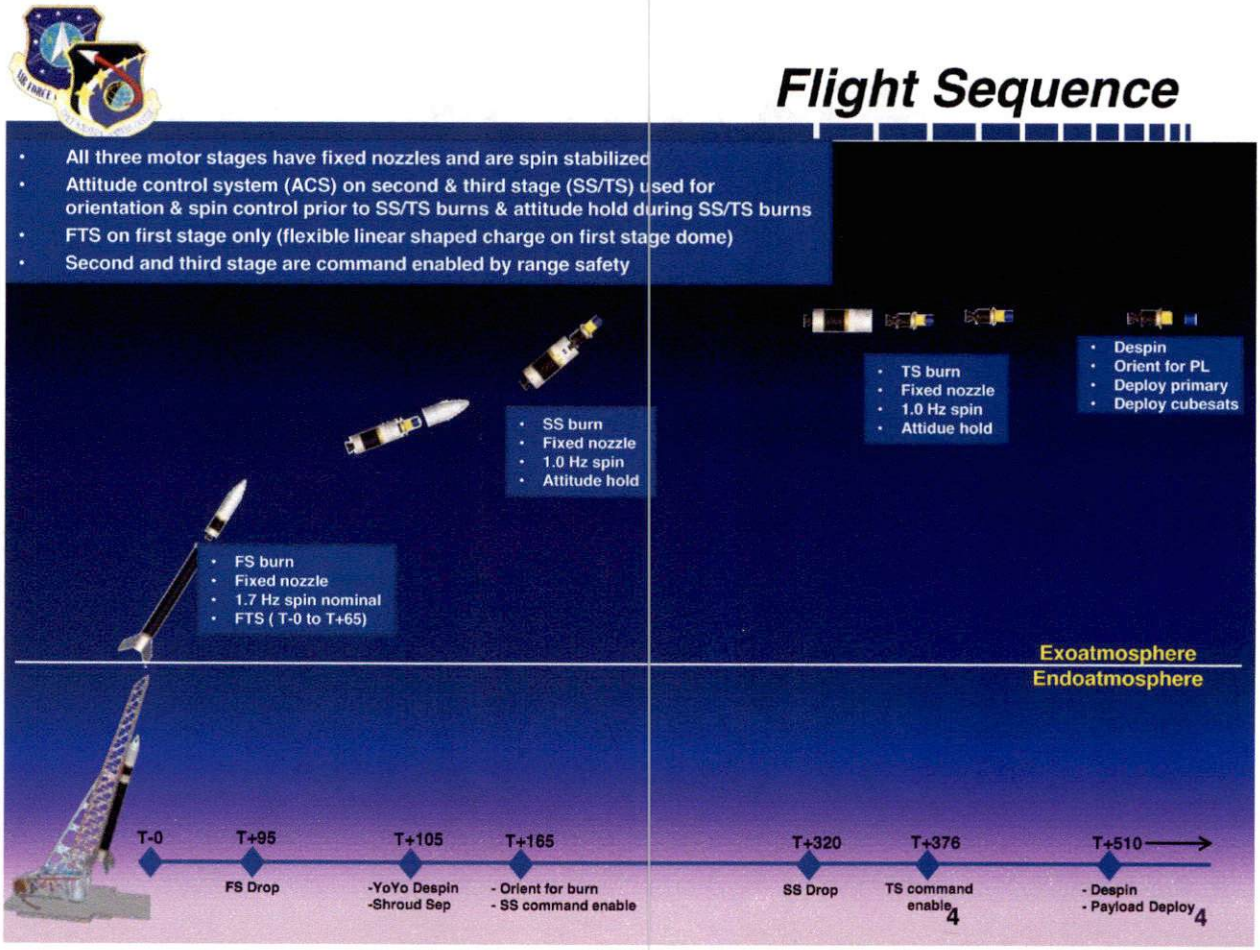


Figure 1. ORS-4 Launch Sequence.

ODAR Section 2: Spacecraft Description

Supernova-Beta is a 6U CubeSat, 10 x 20 x 30 cm on a side, with four solar panel "wings" that fold out

to a length of 30 cm after deployment. Superova-Beta is a proof-of-concept flight for SUPERNOVA bus being developed by Pumkin, Inc. for the US Navy SPAWAR office. It will also flight-test two new communication architectures. Finally, the satellite will operate two experimental imaging payloads supplied by commercial mission sponsors (SkyCube and Transparent Sky).

The primary CubeSat structure is made of Aluminum Alloy 6051. It contains all standard commercial off the shelf (COTS) materials, electrical components, PCBs and solar cells. There are no pressure vessels, hazardous or exotic materials. The ClydeSpace electrical power storage system contains lithium polymer batteries with over-charge/current protection circuitry.

Supernova-Beta is built to conform to the overall constraints of the Planetary Systems, Inc. 6U Cannisterized Satellite Dispenser (CSD).

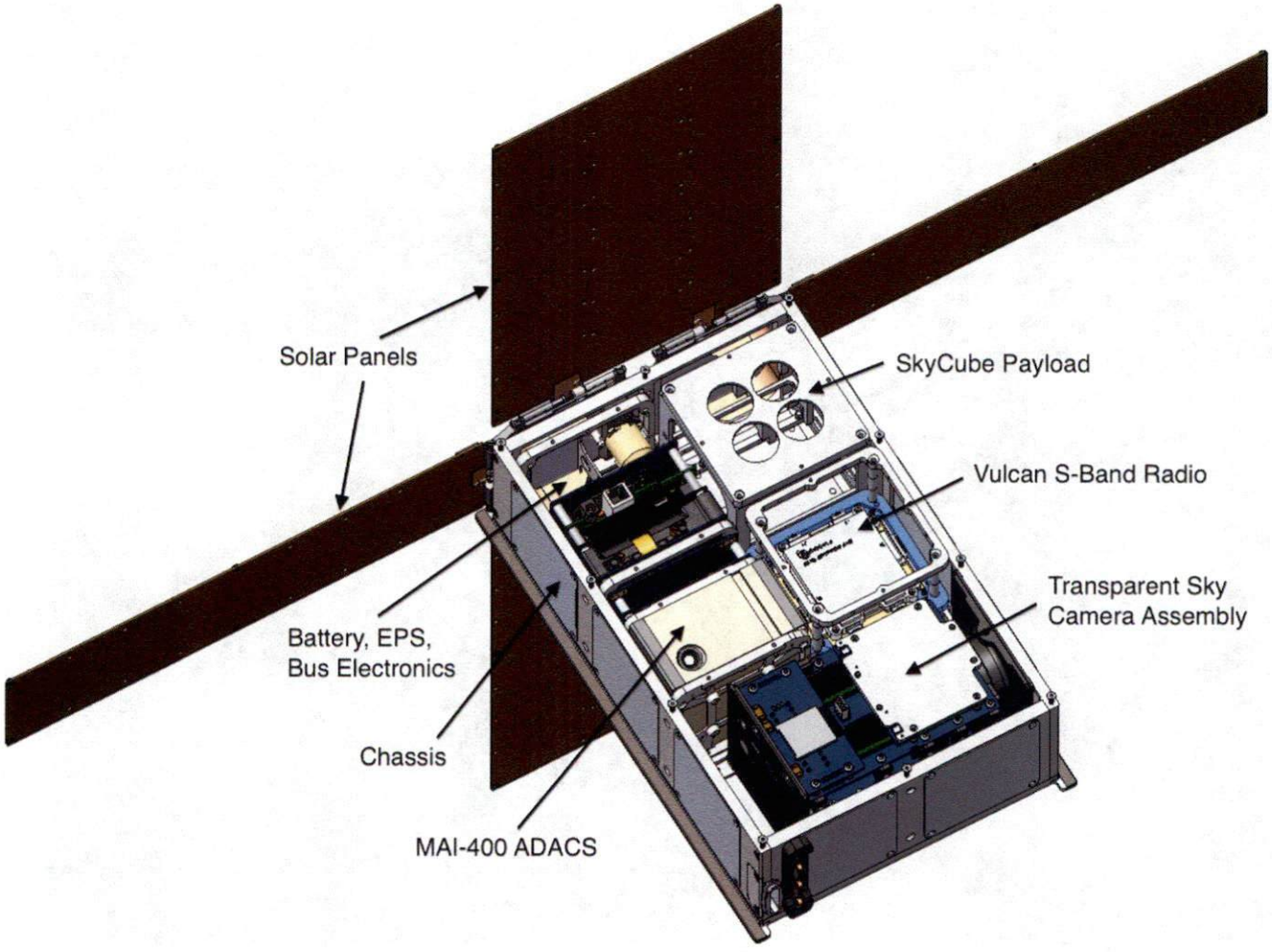


Figure 2. Detailed illustration of Supernova-Beta spacecraft in deployed on-orbit operation configuration, with top cover plate removed to show placement of major internal components.

Total spacecraft mass at launch:

- 12 kg

Dry mass of spacecraft at launch:

- 12 kg

Propulsion systems:

- None.

On-board fluids:

- None.

Attitude control:

- Active attitude will be provided by a Maryland Aerospace, Inc. MAI-400 Attitude Determination and Control System. The MAI-400 includes three reaction wheels, a three-axis magnetometer, three torque rods, a two-camera Earth Horizon Sensor, and a stand-alone ADACS computer.

Range safety or other pyrotechnic devices:

- None.

Electrical generation and storage system:

- Solar cells charging a 30 Watt-Hour Li-Ion battery pack. The battery pack has been pre-qualified by ClydeSpace for use in spaceflight applications. An extensive discussion of the battery system follows in section 4.4.

Other sources of stored energy:

- The solar panel release mechanism is an electrically activated pin-puller supplied by TiNi aerospace. Nickel-Titanium (Nitinol) wire triggers energy release stored in a loaded compression spring. The pin puller applies a pull force of 22 N across a stroke distance of 6.3 mm, implying a one-time discharge of 0.14 Joules of stored mechanical energy over a time duration of 35 ms. Since their debut aboard the Mars Global Surveyor spacecraft in November 1996, TiNi Pinpullers have been qualified and used successfully in numerous other space applications.

Radioactive materials:

- None.

ODAR Section 3: Assessment of Spacecraft Debris Released during Normal Operations

No objects (>1 mm) are expected to be released from the spacecraft any time after launch. Therefore Supenova-Beta is COMPLIANT with requirements 4.3-1 and 4.3-2.

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

- None.

Rationale/necessity for release of each object:

- N/A.

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

- N/A.

Release velocity of each object with respect to spacecraft:

- N/A.

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

- N/A.

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

- N/A.

Assessment of spacecraft compliance with Requirements 4.3-1 and 4.3-2 (per DAS v2.0.2):

- 4.3-1, Mission Related Debris Passing Through LEO: COMPLIANT
- 4.3-2, Mission Related Debris Passing Near GEO: COMPLIANT

ODAR Section 4: Assessment of Spacecraft Intentional Breakups and Potential for Explosions

There are no intentional breakups scheduled during on orbit operations. We are aware of no known potential causes of spacecraft breakup during deployment and mission operations.

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:

- The battery safety systems are discussed in requirement 4.4-1 below. If the Li-Po batteries fail, they are expected to vent gas, rather than explode.

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

- There are no plans for any intentional spacecraft breakup by explosion, collision, nor by any other means.

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

- Supernova-Beta contains no components which are passivated at EOM. The spacecraft will be destroyed by atmospheric reentry. There is no plan to passivate the batteries, but even in the event of mechanical damage or short-circuit they will not explode.

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

- N/A.

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

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

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

  Compliance statement:

  Required Probability: 0.001.
  Expected probability: 0.000.

  Supporting Rationale:

  The primary electrical energy storage system aboard Supernova-Beta is a 30 Watt-hour Lithium polymer battery module supplied by Clyde Space, Ltd. of Glasgow, Scotland, UK. Clyde Space has performed analysis and qualification of our battery under an ESA contract. In addition, NASA Goddard has tested and passed our battery for manned space flight on the shuttle. These tests include:

  - Capacity at C/10 under vacuum
  - Radiation testing to 500 kRad following ECSS guidelines.
  - Capacity at -10°C, 0°C, 20°C and 40°C
  - Cycling Tests at reduced pressure (15-20mbars) - 30% DoD, C/2 Charge/Discharge >5000 cycles
  - Vibration and shock to NASA GEVS.

  All batteries have an integrated, thermostatically controlled battery heater, and built-in over-charge, over-discharge, and over-current protection. There is no credible failure mode known which might result in battery explosion with possible orbital debris generation.

- ***Requirement 4.4-2:*** Design for passivation after completion of mission operations while in orbit about Earth or the Moon:

  Design of all spacecraft and launch vehicle orbital stages shall include the ability to deplete all onboard sources of stored energy and disconnect all energy generation sources when they are no longer required for mission operations or postmission disposal or control to a level which can not cause an explosion or deflagration large enough to release orbital debris or break up the spacecraft (Requirement 56450).

  Compliance statement:

  Supernova-Beta's 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 batteries is such that while the spacecraft could be expected to vent gases, most debris from the battery rupture should be contained within the vessel due to the lack of penetration energy.

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

  Compliance statement:

  This requirement is not applicable. There are no planned breakups.

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

  Compliance statement:

  This requirement is not applicable. There are no planned breakups.

ODAR Section 5. Assessment of Spacecraft Potential for On-Orbit Collisions

Calculation of spacecraft probability of collision with space objects larger than 10 cm in diameter during the orbital lifetime of the spacecraft takes into account both the mean cross sectional area and orbital lifetime. A summary of the cross sectional area computation follows.

Supernova-Beta is stowed in a convex configuration, meaning that no element of the CubeSat obscures another element of the same CubeSat from view. Thus, the stowed mean CSA was calculated using Equation 1. Once Supernova-Beta has been ejected from the dispenser, and solar panels have been deployed, Equation 2 is utilized to determine the mean CSA. A_{max} is the view that yields the maximum cross-sectional area. A_1 and A_2 are the two cross-sectional areas orthogonal to A_{max}.

$$MeanCSA = \frac{\sum SurfaceArea}{4} = \frac{2 \cdot \left[(w \cdot l) + (w \cdot h) + (l \cdot h) \right]}{4}$$

Equation 1: Mean Cross Sectional Area for Convex Objects

$$MeanCSA = \frac{(A_{max} + A_1 + A_2)}{2}$$

Equation 2: Mean Cross Sectional Area for Complex Objects

In a stowed configuration, Supernova-Beta is 10 x 20 x 30 cm. With solar panels deployed, the dimensions are approximately 20 x 30 x 40 cm. Thus, the convex mean CSA for ORS Squared is 500 cm^2. The complex mean CSA is 1200 cm^2.

$$ConvexMeanCSA = \frac{2 \cdot \left[(10 \cdot 20) + (10 \cdot 30) + (20 \cdot 30) \right]}{4} = 550 cm^2$$

Equation 3: Mean Cross Sectional Area for Stowed Spacecraft

$$ComplexMeanCSA = \frac{\left[\left(2 \cdot \left((20 \cdot 30) + (10 \cdot 30) \right) + (10 \cdot 20) \right) + (20 \cdot 30) + (10 \cdot 30) \right]}{2} = \frac{\left[2000 + 600 + 300 \right]}{2} = 1450 cm^2$$

Equation 4: Mean Cross Sectional Area for Deployed Spacecraft

Requirement 4.5-1 asks to compute probability of collision with large space objects (> 10 cm diameter). Using DAS 2.0.2 sofware, we computed the probability of spacecraft collision with space objects larger than 10 cm in diameter during the orbital lifetime of the spacecraft (assumptions: 430 x 505 km altitude, 94.8° inclination, 0.12 m^2 area), as 0.00000.

Requirement 4.5-2 asks to compute probability of collision with space objects, including orbital debris and meteoroids, of sufficient size to prevent postmission disposal. However, as there is no post-mission disposal operation, requirement 4.5-2 is not applicable to this mission.

Assessment of spacecraft compliance with Requirements 4.5-1 and 4.5-2 (per DAS v2.0, and calculation methods provided in NASA-STD-8719.14, section 4.5.4):

- *Requirement 4.5-1. Limiting debris generated by collisions with large objects when operating in Earth orbit:* For each spacecraft and launch vehicle orbital stage in or passing through LEO, the program or project shall demonstrate that, during the orbital lifetime of each spacecraft and orbital stage, the probability of accidental collision with space objects larger than 10 cm in diameter is less than 0.001 (Requirement 56506).

  Large Object Impact and Debris Generation Probability: 0.00000; COMPLIANT.

- *Requirement 4.5-2. Limiting debris generated by collisions with small objects when operating in Earth or lunar orbit:* For each spacecraft, the program or project shall demonstrate that, during the mission of the spacecraft, the probability of accidental collision with orbital debris and meteoroids sufficient to prevent compliance with the applicable postmission disposal requirements is less than 0.01 (Requirement 56507).

  Small Object Impact and Debris Generation Probability: NOT APPLICABLE.

ODAR Section 6: Assessment of Spacecraft Postmission Disposal Plans and Procedures

Disposal is achieved via passive atmospheric reentry. There will be no post-mission disposal operation. The spacecraft will naturally decay from orbit within 25 years after end of the mission, satisfying requirement 4.6-1a (spacecraft disposal option).

6.1 Description of spacecraft disposal option selected:

- The spacecraft has no capability or plan for end-of-mission disposal. Any discussion of systems and components required to accomplish post-mission disposal operation, including passivation and maneuvering, is not applicable.

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

- Not applicable.

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

- **Spacecraft Mass:** 12 kg
  Cross-sectional Area: 0.12 m^2 (see calculation in section 5)
  Area to mass ratio: 0.12/12 = 0.01 m^2/kg

6.4 Assessment of spacecraft compliance with Requirements 4.6-1 through 4.6-5 (per DAS v 2.0 .2 and NASA-STD-8719.14 section):

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

  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.

  Analysis: The Supernova-Beta satellite reentry is COMPLIANT using Method "a." Supernova-Beta will re-enter approximately 4.9 years after deployment, with orbit history as shown in Figure 2 (analysis assumes an approximate random tumbling behavior).

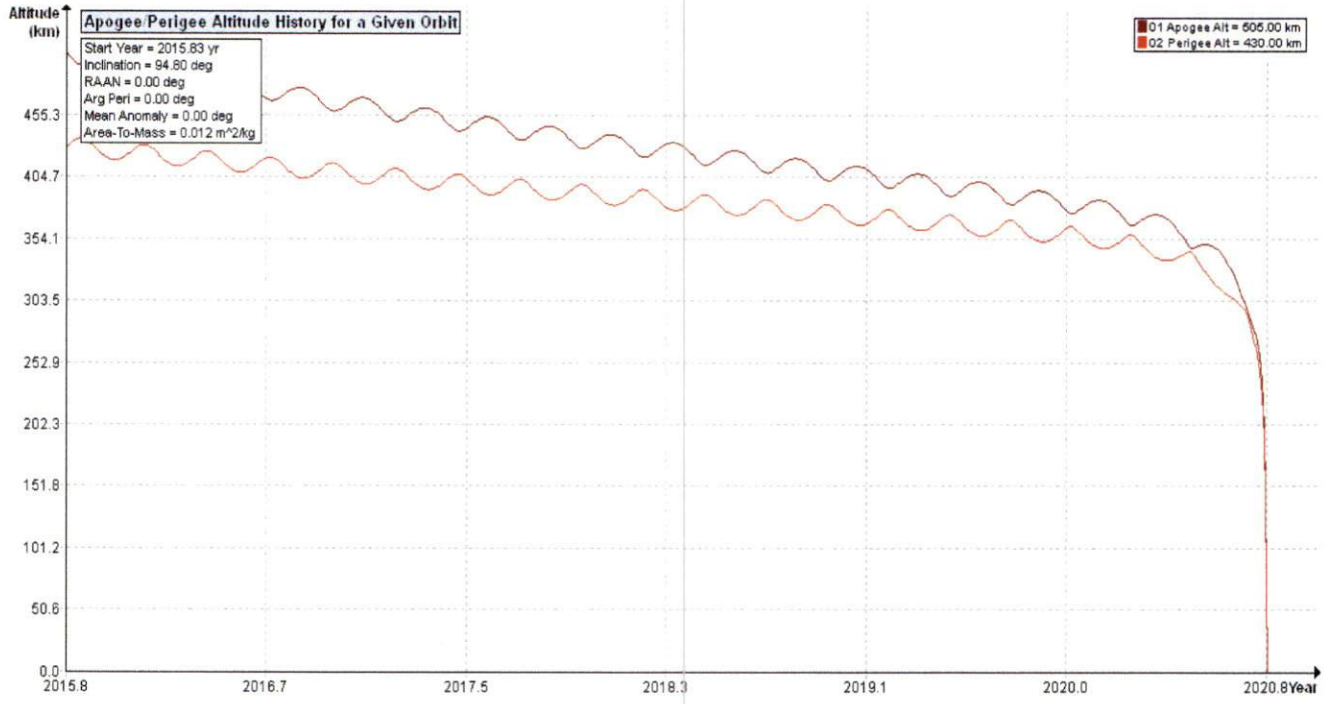


Figure 3. Supernova-Beta orbit history, assuming successful solar panel deployment immediately upon orbit insertion at T=2015.83

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

- **Analysis:** Not applicable.

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

- **Analysis:** Not applicable.

Requirement 4.6-4. Reliability of Postmission Disposal Operations

- **Analysis:** Supernova-Beta does not rely on solar panel deployment to ensure post mission disposal within the allowed 25-year timeframe. Even if the solar panel deployment mechanism fails, the satellite will reenter passively approximately 6.8 years after launch, as shown in Figure 4, below.

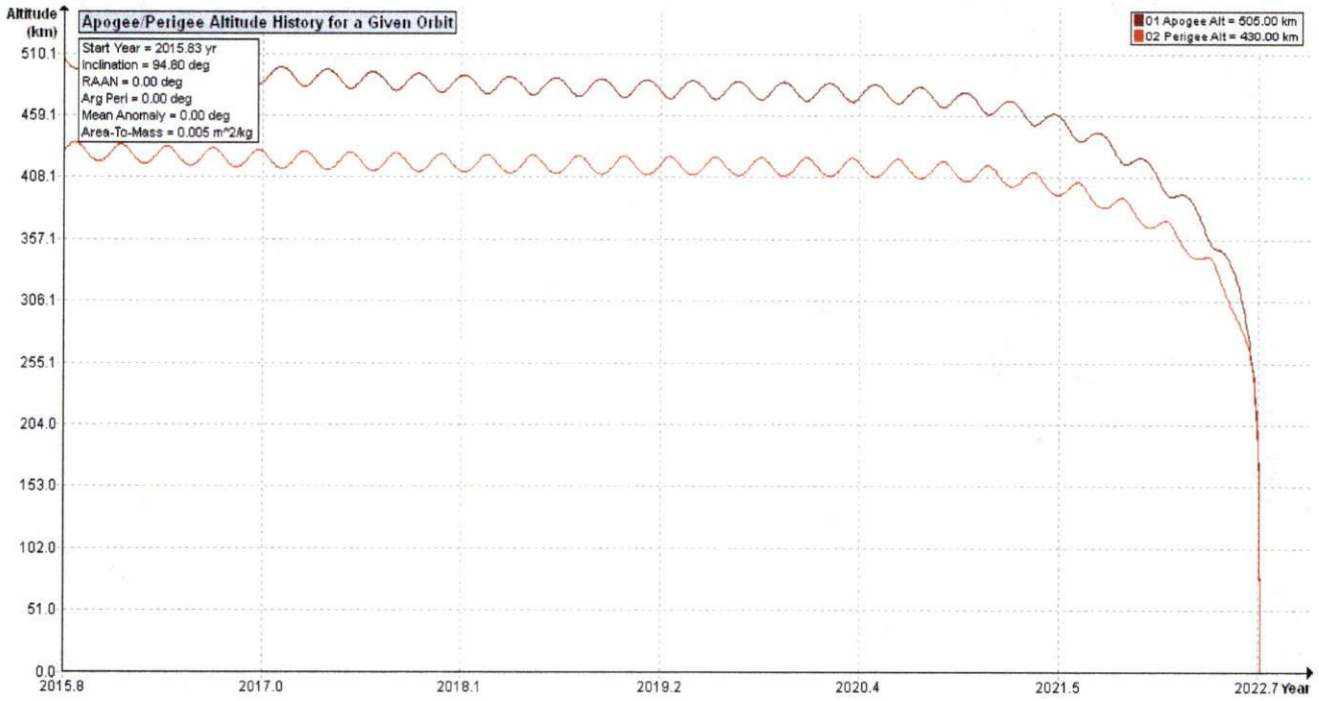


Figure 4. Supernova-Beta orbit history, assuming solar panel non-deployment after orbit insertion at T=2015.83.

ODAR Section 7: Assessment of Spacecraft Reentry Hazards

A detailed description of spacecraft components includes small Li-ion batteries; an aluminum framework; cameras and other circuitry; solar cells. All components will vaporize on re-entry.

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).

  Summary Analysis Results: DAS v2.0.2 reports that Supernova-Beta is COMPLIANT with the requirement. No components are predicted by NASA DAS software to survive re-entry. The probability of human casualty due to uncontrolled reentry is 0.000000.

  Analysis (per DAS v2.0.2):

```
05 05 2015; 15:17:01PM  DAS Application Started
05 05 2015; 15:24:53PM  Processing Requirement 4.6    Return Status :  Passed

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

**INPUT**

      Space Structure Name = SUPERNOVA-BETA
      Space Structure Type = Payload

      Perigee Altitude = 430.000000 (km)
      Apogee Altitude = 505.000000 (km)
      Inclination = 94.800000 (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 = 2015.830000 (yr)
      Initial Mass = 12.000000 (kg)
      Final Mass = 12.000000 (kg)
      Duration = 2.000000 (yr)
      Station Kept = False
      Abandoned = True
      PMD Perigee Altitude = 396.097686 (km)
      PMD Apogee Altitude = 462.565628 (km)
      PMD Inclination = 94.784071 (deg)
      PMD RAAN = 118.104405 (deg)
      PMD Argument of Perigee = 101.887116 (deg)
      PMD Mean Anomaly = 0.000000 (deg)

**OUTPUT**
```

```
      Suggested Perigee Altitude = 396.097686 (km)
      Suggested Apogee Altitude = 462.565628 (km)
      Returned Error Message = Passes LEO reentry orbit criteria.

      Released Year = 2021 (yr)
      Requirement = 61
      Compliance Status = Pass

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

=============== End of Requirement 4.6 ===============
05 05 2015; 15:26:28PM *********Processing Requirement 4.7-1
      Return Status :  Passed

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

name = SUPERNOVA-BETA
quantity = 1
parent = 0
materialID = 5
type = Box
Aero Mass = 12.000000
Thermal Mass = 12.000000
Diameter/Width = 0.200000
Length = 0.300000
Height = 0.100000

name = Chassis
quantity = 1
parent = 1
materialID = 5
type = Box
Aero Mass = 5.481000
Thermal Mass = 1.640000
Diameter/Width = 0.200000
Length = 0.300000
Height = 0.100000

name = ADCS
quantity = 1
parent = 2
materialID = 5
type = Box
Aero Mass = 0.690000
Thermal Mass = 0.690000
Diameter/Width = 0.100000
Length = 0.100000
Height = 0.056000

name = TransSky Lens
quantity = 1
parent = 2
materialID = 5
type = Cylinder
Aero Mass = 1.570000
Thermal Mass = 1.570000
```

```
Diameter/Width = 0.102000
Length = 0.125000

name = TransSky Camera
quantity = 1
parent = 2
materialID = 5
type = Box
Aero Mass = 0.250000
Thermal Mass = 0.250000
Diameter/Width = 0.070000
Length = 0.070000
Height = 0.070000

name = TransSky Camera Processor Stack
quantity = 4
parent = 2
materialID = 23
type = Flat Plate
Aero Mass = 0.005000
Thermal Mass = 0.005000
Diameter/Width = 0.055000
Length = 0.084000

name = Vulcan Radio Housing
quantity = 1
parent = 2
materialID = 5
type = Box
Aero Mass = 0.304000
Thermal Mass = 0.148000
Diameter/Width = 0.082000
Length = 0.082000
Height = 0.040000

name = Vulcan Radio Boards
quantity = 3
parent = 7
materialID = 23
type = Flat Plate
Aero Mass = 0.052000
Thermal Mass = 0.052000
Diameter/Width = 0.078000
Length = 0.087000

name = ClydeSpace EPS
quantity = 1
parent = 2
materialID = 5
type = Flat Plate
Aero Mass = 0.148000
Thermal Mass = 0.148000
Diameter/Width = 0.085000
Length = 0.090000

name = ClydeSpace Battery
quantity = 1
parent = 2
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materialID = 5
type = Box
Aero Mass = 0.256000
Thermal Mass = 0.256000
Diameter/Width = 0.090000
Length = 0.095000
Height = 0.020000

name = Globalstar Modem
quantity = 1
parent = 2
materialID = 5
type = Box
Aero Mass = 0.060000
Thermal Mass = 0.060000
Diameter/Width = 0.064000
Length = 0.119000
Height = 0.027000

name = Beagle Boards
quantity = 3
parent = 2
materialID = 23
type = Flat Plate
Aero Mass = 0.037000
Thermal Mass = 0.037000
Diameter/Width = 0.054000
Length = 0.090000

name = SkyCube Structure
quantity = 1
parent = 2
materialID = 5
type = Box
Aero Mass = 0.432000
Thermal Mass = 0.305000
Diameter/Width = 0.100000
Length = 0.100000
Height = 0.100000

name = SkyCube Unity Board
quantity = 1
parent = 13
materialID = 23
type = Flat Plate
Aero Mass = 0.042000
Thermal Mass = 0.042000
Diameter/Width = 0.082000
Length = 0.082000

name = StenSat Radio
quantity = 1
parent = 13
materialID = 5
type = Box
Aero Mass = 0.025000
Thermal Mass = 0.025000
Diameter/Width = 0.044000
```

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Length = 0.078000
Height = 0.008000

name = LinkSprite Camera
quantity = 4
parent = 13
materialID = 5
type = Flat Plate
Aero Mass = 0.005000
Thermal Mass = 0.005000
Diameter/Width = 0.032000
Length = 0.032000

name = Micro Video Lens
quantity = 4
parent = 13
materialID = 5
type = Cylinder
Aero Mass = 0.010000
Thermal Mass = 0.010000
Diameter/Width = 0.032000
Length = 0.032000

name = Chassis Covers
quantity = 6
parent = 1
materialID = 5
type = Flat Plate
Aero Mass = 0.004000
Thermal Mass = 0.004000
Diameter/Width = 0.080000
Length = 0.080000

name = 6U Solar Panel
quantity = 2
parent = 1
materialID = 23
type = Flat Plate
Aero Mass = 0.403000
Thermal Mass = 0.403000
Diameter/Width = 0.200000
Length = 0.300000

name = 3U Solar Panel
quantity = 2
parent = 1
materialID = 23
type = Flat Plate
Aero Mass = 0.202000
Thermal Mass = 0.202000
Diameter/Width = 0.100000
Length = 0.300000

name = Vulcan Antenna Housing
quantity = 1
parent = 1
materialID = 5
type = Box
```

```
Aero Mass = 0.072000
Thermal Mass = 0.024000
Diameter/Width = 0.082000
Length = 0.082000
Height = 0.012000

name = Vulcan Antenna Substrate
quantity = 2
parent = 21
materialID = 64
type = Flat Plate
Aero Mass = 0.024000
Thermal Mass = 0.024000
Diameter/Width = 0.082000
Length = 0.082000

name = Globalstar Antenna
quantity = 1
parent = 1
materialID = 23
type = Box
Aero Mass = 0.030000
Thermal Mass = 0.030000
Diameter/Width = 0.063000
Length = 0.063000
Height = 0.011000

name = UHF Antenna
quantity = 1
parent = 1
materialID = 23
type = Flat Plate
Aero Mass = 0.009000
Thermal Mass = 0.009000
Diameter/Width = 0.021000
Length = 0.115000

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

name = SUPERNOVA-BETA
Demise Altitude = 77.997847
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Chassis
Demise Altitude = 74.265730
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = ADCS
Demise Altitude = 67.051448
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

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

```
name = TransSky Lens
Demise Altitude = 64.081194
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = TransSky Camera
Demise Altitude = 70.939800
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = TransSky Camera Processor Stack
Demise Altitude = 74.179363
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Vulcan Radio Housing
Demise Altitude = 72.239152
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Vulcan Radio Boards
Demise Altitude = 71.316089
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = ClydeSpace EPS
Demise Altitude = 70.881449
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = ClydeSpace Battery
Demise Altitude = 70.094660
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Globalstar Modem
Demise Altitude = 73.480285
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Beagle Boards
Demise Altitude = 73.604824
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = SkyCube Structure
Demise Altitude = 72.007996
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
```

```
************************************
name = SkyCube Unity Board
Demise Altitude = 71.130324
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = StenSat Radio
Demise Altitude = 70.995667
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = LinkSprite Camera
Demise Altitude = 71.319628
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Micro Video Lens
Demise Altitude = 71.286292
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Chassis Covers
Demise Altitude = 77.901699
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = 6U Solar Panel
Demise Altitude = 76.860308
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = 3U Solar Panel
Demise Altitude = 77.094597
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Vulcan Antenna Housing
Demise Altitude = 77.523176
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Vulcan Antenna Substrate
Demise Altitude = 77.374105
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Globalstar Antenna
Demise Altitude = 77.396566
```

```
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = UHF Antenna
Demise Altitude = 77.679168
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

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=============== End of Requirement 4.7-1 ===============
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Requirements 4.7-1b and 4.7-1c below are non-applicable requirements because Supernova-Beta does not use controlled reentry.

4.7-1, b) **NOT APPLICABLE.** 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).

4.7-1 c) **NOT APPLICABLE.** 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).

ODAR Section 7A: Assessment of Spacecraft Hazardous Materials

Not Applicable. There are no hazardous materials contained on the spacecraft.

ODAR Section 8: Assessment for Tether Missions

No tether will be used; this section is not applicable.

END of ODAR for Supernova-Beta

Appendix A: Acronyms

Al	Aluminum
cm	Centimeter
COTS	Commercial Off-The-Shelf
CSD	Cannisterized Satellite Dispenser
DAS	Debris Assessment Software
EOM	End Of Mission
GEO	Geosynchronous Earth Orbit
ITAR	International Traffic In Arms Regulations
kg	Kilogram
km	Kilometer
LEO	Low Earth Orbit
Li-Ion	Lithium Ion
m^2	meters squared
Ml	Milliliter
Mm	Millimeter
N/A	Not Applicable
ODAR	Orbital Debris Assessment Report
OSMA	Office of Safety and Mission Assurance
Ti	Titanium
yr	Year