Alpha Orbital Debris Assessment Report

Firefly Document:	RPT_MSS_0001
Department & Type:	Systems Safety | Report
Revision & Date:	Rev. D, 4/9/2020
	REDACTED

NASA Debris Assessment Software (DAS) Version used in Analysis: v2.1.1

Document Data is Restricted.

APPROVAL

The following individual(s) certify the information included within this file is true, complete, and accurate.

John Lawton

John Lawton
Systems Safety

REVISION HISTORY

Revision	Date	Author	Approved By	Notes
-		E. Billman		
002	11/01/2019	E. Billman		Revised for 300km post-deployment altitude and potential relight before passive deorbit.
C	01/10/2020	R. Lindberg		Revision format switched to alphabetical reflect Firefly's Revision Control System. Revised for launch date.
D	04/09/2020	R. Lindberg		Revised section numbering. Added Chapter 10 to address Safety at End of Launch

TABLE OF CONTENTS

TABLE OF FIGURES

TABLE OF TABLES

Acronyms

Acronym	Definition
DAS	NASA Debris Assessment Software
LEO	Low Earth Orbit
ODAR	Orbital Debris Assessment Report
SSO	Sun-Synchronous Orbit

VAFB	Vandenberg Air Force Base

1 SUPPORTING DOCUMENTS

1.1 GOVERNMENT DOCUMENTS

14 CFR 417.129	FAA Launch License Requirements – Safety at End of Launch
NASA STD 8719.14B	Process for Limiting Orbital Debris

1.2 FIREFLY DOCUMENTS

TBD	Firefly Alpha Hazard Analysis

2 Orbital Debris Assessment Report Evaluation: Firefly Alpha

Table 1: ODAR Evaluation

NS 8719.14B Requirement Number	Launch Vehicle				Spacecraft			Comments
	Compliant or N/A	Not Compliant	Incomplete	Standard Non-Compliant	Compliant or N/A	Not Compliant	Incomplete	
4.3-1.a	Compliant						X	
4.3-1.b	Compliant						X	
4.3-2	Compliant						X	
4.4-1	Compliant						X	
4.4-2	Compliant						X	
4.4-3	Compliant						X	
4.4-4	Compliant						X	
4.5-1	Compliant						X	
4.5-2	N/A						X	
4.6-1(a)	Compliant						X	
4.6-1(b)	N/A						X	
4.6-1(c)	N/A						X	
4.6-2	N/A						X	
4.6-3	N/A						X	
4.6-4	Compliant						X	
4.7-1	Compliant						X	
4.8-1	N/A						X	

Note 1: The spacecraft will file its ODAR separately.

3 MISSION OVERVIEW

Firefly Aerospace Inc. (“Firefly”) was founded to provide economical, high-frequency access to space for small payloads through the design, manufacture and operation of reliable launch vehicles. The Firefly team addresses the market’s need for flexible access to space with a “simplest, soonest” approach to technology selection. Firefly’s mission is to make space accessible by providing our customers with reliable, economical, high- frequency launches for orbital services.

Firefly’s first Alpha vehicle launch is planned in 2020. By the first quarter of 2021, Firefly plans to launch approximately one Alpha vehicle per month given planned production capacity.

This first launch will depart from Vandenberg Ari Force Base (VAFB). For the analysis documented here, a nominal trajectory has been used, targeting a sun-synchronous circular orbit, as shown in 1. The trajectory will be updated in the Final ODAR submitted in support of launch approval.

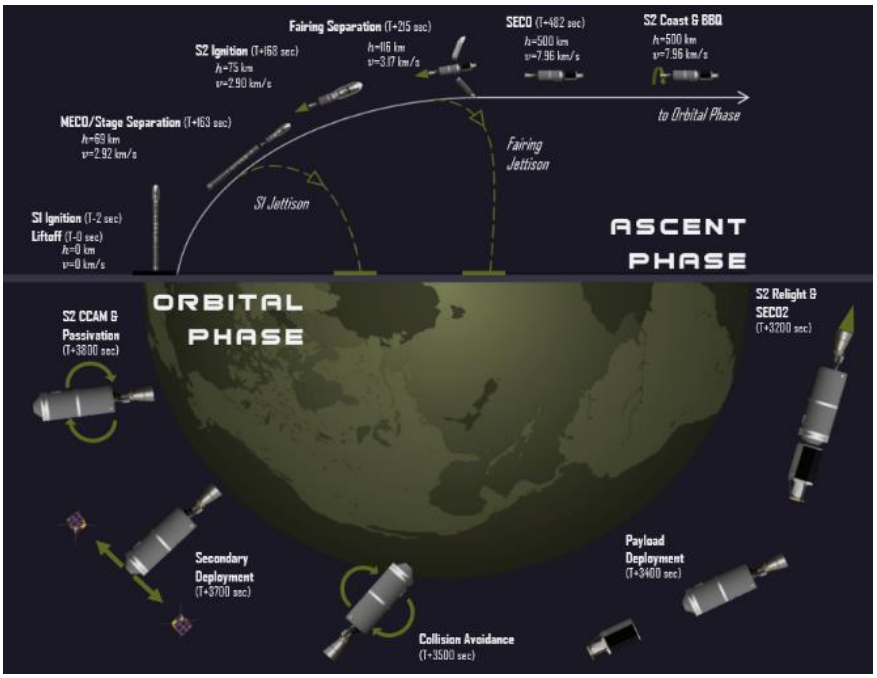


FIGURE 1: FIREFLY ALPHA LAUNCH TRAJECTORY

3.1 PROJECT MANAGEMENT

This mission is managed by Firefly Launch Services, located in Cedar Park, Texas. There is currently no NASA sponsorship for this launch. No foreign government or space agency is involved in this mission.

Launch is planned for [redacted]

4 Firefly Launch Vehicle Overview

Firefly launch vehicles service the small-to-medium-sized satellite market. Alpha delivers 1,000 kg (2,204 lbm) to Low Earth Orbit (LEO), 630 kg (1,388 lbm) to Sun-Synch Orbit (SSO). Firefly vehicles draw on well-established, historically-successful rocket technology, such as LOX/RP-1, pump-fed, regeneratively cooled engines.

In contrast, modern advances in aerospace composite materials enable rapid development of strong, lightweight primary structures such as propellant tanks. Use of Commercial Off-the-Shelf (COTS) components in avionics systems, such as the flight computer and communication system, allows for high-reliability, low-cost, and streamlined development. Proximity to technology centers in Austin, Texas facilitates support operations with all facets of design, testing, and production performed locally.

Firefly Alpha stage 1 jettison is nominally at 101km. Fairing separation occurs at approximately 143km, which is near-orbit. The secondary stage ends its flight at the target orbital altitude, which is 500km for this mission. The fairing, first and second stages have been included in this assessment. Only the second stage is inserted into Earth orbit.

4.1 Firefly Alpha Architecture

Alpha is a two-stage launch vehicle capable of delivering 1,000 kg (2,204 lbm) of payload to 200 km (125 mile) Low-Earth Orbit. Firefly's entry-to-market vehicle, Alpha provides low-cost launch capabilities for the small satellite market. To learn more about Alpha, please see Table 2 and 2.

CHARACTERISTICS	STAGE ONE	STAGE TWO
Height	29m (95ft) including fairing and stages	
Core Diameter	1.8 m (6.0 ft)	
Fairing Diameter	2.0 m (6.6 ft)	
Material	Carbon composite	
Propellants	LOX/RP-1	LOX/RP-1
Propellant feed system	Turbopump	Turbopump
Engine name	Reaver 1	Lightning 1
Quantity of engines	4	1
Thrust (state total vac)	736 kN (165,459 lbf)	70 kN (15, 737 lbf)
Engine designer/manufacturer	Firefly	Firefly
Restart capability	No	Yes, 1 restart
Max level of throttling	20%	20%

Tank pressurization (No.)	Heated helium (4)	Heated helium (1)
Dry mass	2,895 kg (6,382 lbm)	699.3 kg (1542 lbm)
Max Gross Lift-Off Weight	54,000 kg (119,050 lbm)	
Payload mass	1,000 kg (LEO 28.5°, 200 km), 630 kg (SSO, 500 km)	

TABLE 2: ALPHA CHARACTERISTICS

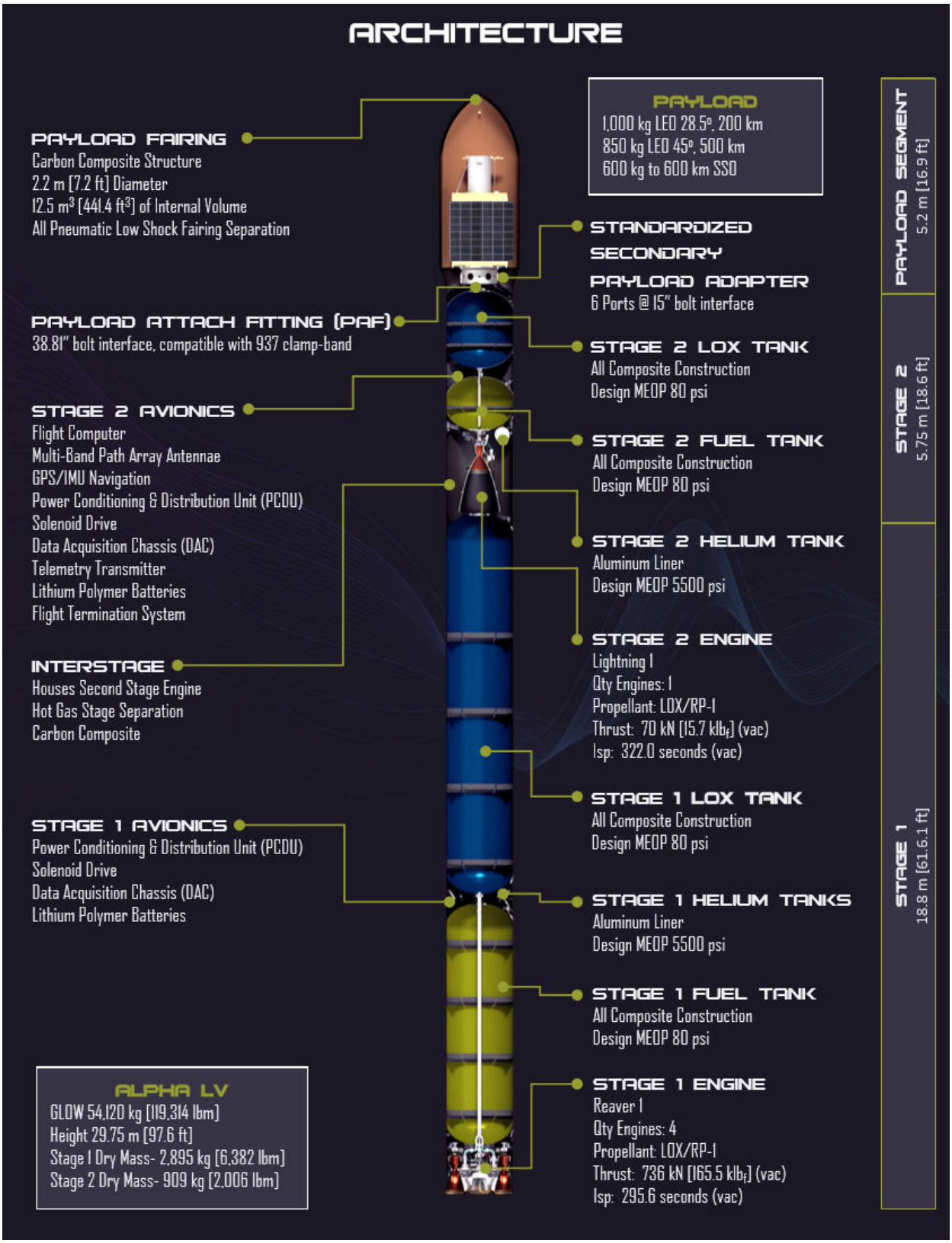


FIGURE 2: ALPHA VEHICLE OVERVIEW

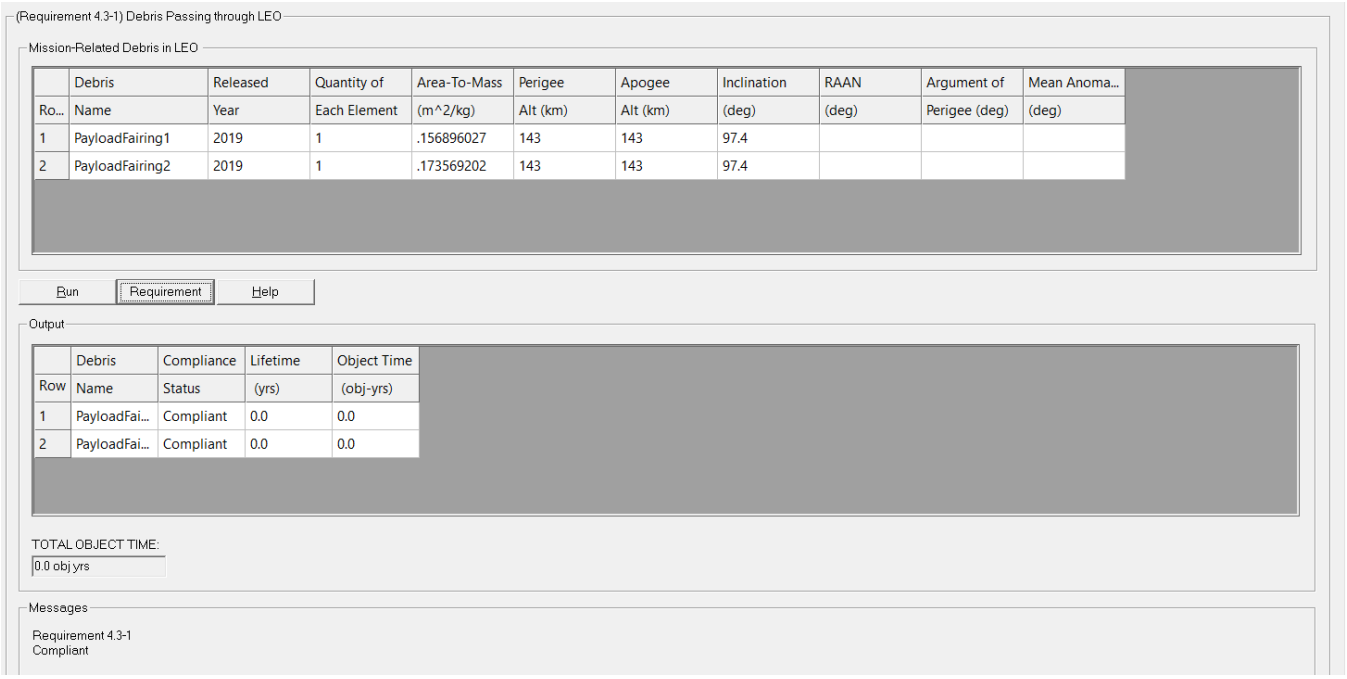
5 FIREFLY ALPHA DEBRIS RELEASED DURING NORMAL OPERATIONS

No objects (>1 mm) are expected to be released from the launch vehicle at any time after launch. Any occurrence of objects greater than 1 mm being released from the launch vehicle would be during an unexpected event.

The launch vehicle is compliant with 4.3-1 (Mission Related Debris Passing Through LEO) and 4.3-2 (Mission Related Debris Passing Near GEO) because no objects will be released from the launch vehicle during normal operations. The only exception to this is the release of the payload, but that will be covered under the separate satellite ODAR.

Out of an abundance of conservatism, the payload fairing was included in the DAS analysis. The two fairing pieces are released at 143km altitude, which is suborbital. The fairings were found to deorbit immediately and are compliant with 4.3-1.

	Debris	Released	Quantity of	Area-To-Mass	Perigee	Apogee	Inclination	RAAN	Argument of	Mean Anoma...
Ro...	Name	Year	Each Element	(m^2/kg)	Alt (km)	Alt (km)	(deg)	(deg)	Perigee (deg)	(deg)
1	PayloadFairing1	2019	1	.156896027	143	143	97.4			
2	PayloadFairing2	2019	1	.173569202	143	143	97.4			



	Debris	Compliance	Lifetime	Object Time
Row	Name	Status	(yrs)	(obj-yrs)
1	PayloadFai...	Compliant	0.0	0.0
2	PayloadFai...	Compliant	0.0	0.0

FIGURE 3: PAYLOAD FAIRING PARAMETERS

6 Firefly Alpha Potential for Explosions and Intentional Breakups

Through the entire mission profile and passivation, there are minimal potential causes of unexpected breakups. Following the completion of flight operations, the second stage will be passivated.

During the mission, there are several potential failure modes. Each one is outlined below with accompanying reasoning.

Failure mode 1: Engine Explosion during engine start, run, or shutdown

Possible causes of engine explosion are inlet conditions, foreign object debris (FOD) or engine defect. This event is mitigated through extensive engine and stage level qualification to ensure the engine is stable for all modes of start, run and shutdown operational conditions. [redacted] Each upper stage engine and stage also undergoes a full acceptance program, including inspection and test to verify proper functionality. Firefly has a FOD and contamination control program that would minimize the possibility of damaging FOD to be introduced into the system. Finally, due to the design elements of the lightning engine, the more likely failure mode is one of a shutdown mode, and less of an explosion mode, as has been demonstrated during hundreds of hot-fire tests. Therefore, engine shutdown is more probable and is not a debris-generating event.

Failure mode 2: Structural failure or compromise of a stage pressure vessel

This failure mode would result in an explosion due to either an overpressure event or a mixing of propellants. Both of these events are mitigated though a series of qualification and acceptance testing in line with SMC-S-016 and compliant with Range Safety requirements. On-orbit loads are benign compared to early flight loads, so the likelihood of failure once on orbit is further minimized by this fact.

6.1 Accidental Explosions

Requirement 4.4-1: Limiting the risk to other space systems from accidental explosions during deployment and mission operations while in orbit around the Earth or the Moon. Probability must be less than 0.001. The only portion of Firefly Alpha to reach orbital altitude is the second stage. Expected probability for the system is 0.000, therefore compliant.

Requirement 4.4-2: Passivate to limit probability of accidental explosion after End of Mission (EOM)

Passivation Plan:

After flight operations, [redacted] the stage will be fully passivated [redacted]

Time-to-orbit from VAFB is approximately 7-8 minutes. The second stage will continue to transmit over 10-12 orbits, ultimately passivating the batteries within a few hours.

6.2 INTENTIONAL BREAKUPS

There are no intentional break-ups planned for Firefly Alpha. Therefore, the system is compliant with Requirements 4.4-3 and 4.4-4:

Requirement 4.4-3: Limit number, size, and orbital lifetime of debris larger than 1mm and 10cm

Requirement 4.4-4: Assess risk to other programs for times immediately after a test when the debris cloud contains regions of high debris density

6.3 FIREFLY ALPHA POTENTIAL FOR ON-ORBIT COLLISIONS

The planned Firefly Alpha trajectory was input into DAS for stage one and stage two.

Define Rocket Body Properties

	Rocket Body	Perigee	Apogee	Inclination	RAAN	Argument Of	Mean	Final	Final	Planned Brea...
Ro...	Name	Alt (km)	Alt (km)	(deg)	(deg)	Perigee (deg)	Anomaly (deg)	Mass (kg)	Area-To-Mass (m^2/...	(check if yes)
1	Alpha2ndStage	300	300	96.67				699.3	.015172315	☐
2	Alpha1stStage	101	101	97.4				2894.8	.010743402	☐

FIGURE 4: STAGE 1 AND STAGE 2 PARAMETERS

Area calculations for both stages were performed using the DAS 'Calculate Cross-Sectional Area' engineering utility. Both stages were approximated as cylinders with the inputs shown in **Error! Reference source not found.**. Both were calculated using a 'random tumbling' attitude profile.

TABLE 3: AVERAGE CROSS-SECTIONAL AREA CALCULATION INPUTS

Parameter	First Stage Value	Second Stage Value	Units
Final Mass	2894.8	699.3	kg
Diameter	2	2	m
Length	18.8	5.75	m
Avg Cross-Sectional Area	37.6	11.5	m2
Area to Mass Ratio	0.010743402	0.015172315	m2/kg

Using these inputs in DAS, Firefly Alpha is assessed to have a probability of accidental collision with space objects larger than 10 cm in diameter of less than 0.001 and is complaint with Requirement 4.5-1.

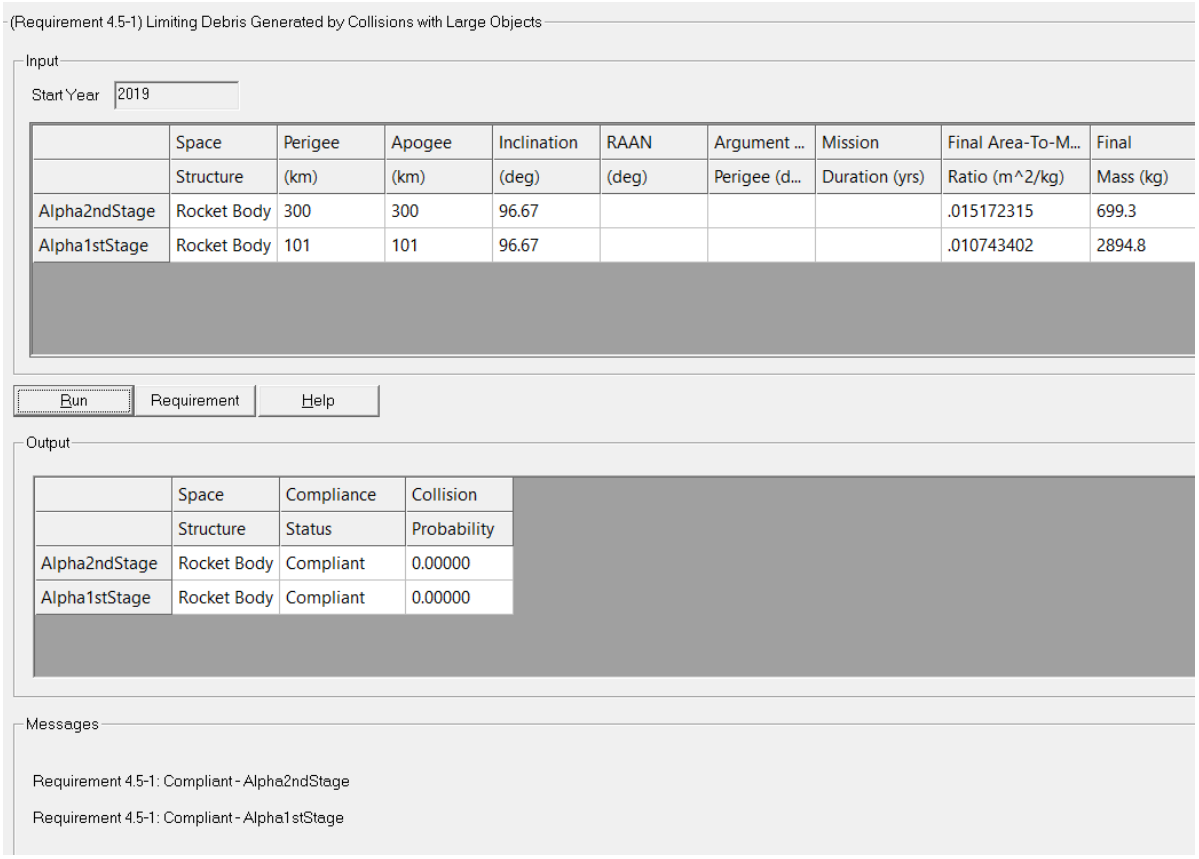


FIGURE 5: PROBABILITY OF ACCIDENTAL COLLISION WITH SPACE OBJECTS LARGER THAN 10CM

```
Processing Requirement 4.5-1:    Return Status:  Passed

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

**INPUT**

      Space Structure Name = Alpha2ndStage
      Space Structure Type = Rocket Body
```

Perigee Altitude = 300.000000 (km)
Apogee Altitude = 300.000000 (km)
Inclination = 96.6700000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Final Area-To-Mass Ratio = 0.015172315 (m^2/kg)
Start Year = 2019.000000 (yr)
Initial Mass = 699.300000 (kg)
Final Mass = 699.300000 (kg)
Duration = 0.000000 (yr)
Station-Kept = False
Abandoned = True
PMD Perigee Altitude = -1.000000 (km)
PMD Apogee Altitude = -1.000000 (km)
PMD Inclination = 0.000000 (deg)
PMD RAAN = 0.000000 (deg)
PMD Argument of Perigee = 0.000000 (deg)
PMD Mean Anomaly = 0.000000 (deg)

OUTPUT

Collision Probability = 0.000000
Returned Error Message: Normal Processing
Date Range Error Message: Normal Date Range
Status = Pass

==========

INPUT

Space Structure Name = Alpha1stStage
Space Structure Type = Rocket Body
Perigee Altitude = 101.000000 (km)
Apogee Altitude = 101.000000 (km)

Inclination = 97.400000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Final Area-To-Mass Ratio = 0.010743402(m^2/kg)
Start Year = 2019.000000 (yr)
Initial Mass = 2894.800000 (kg)
Final Mass = 2894.800000 (kg)
Duration = 0.000000 (yr)
Station-Kept = False
Abandoned = True
PMD Perigee Altitude = -1.000000 (km)
PMD Apogee Altitude = -1.000000 (km)
PMD Inclination = 0.000000 (deg)
PMD RAAN = 0.000000 (deg)
PMD Argument of Perigee = 0.000000 (deg)
PMD Mean Anomaly = 0.000000 (deg)

OUTPUT

Collision Probability = 0.000000
Returned Error Message: Normal Processing
Date Range Error Message: Normal Date Range
Status = Pass

==========

7 FIREFLY ALPHA POSTMISSION DISPOSAL PLANS AND PROCEDURES

Area calculations for both stages were performed using the DAS 'Calculate Cross-Sectional Area' engineering utility. Both stages were approximated as cylinders with the inputs shown in **Error! Reference source not found.**. Both were calculated using a 'random tumbling' attitude profile. The DAS cross-sectional area amount was then divided by the mass.

Requirement 4.6-1 states that "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:

(1) 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; …."

Reentry option 1 is the only one listed as it is applicable to Firefly Alpha. The passivation timeline is included in Section 6.1.

Firefly Alpha is compliant with Requirement 4.6.1, as demonstrated in the DAS log results shown below. Firefly Alpha is also compliant with 4.6-4 (Reliability of Postmission Disposal Operations) because the passive reentry of the rocket body is chosen as the postmission disposal plan.

```
Processing Requirement 4.6 Return Status:  Passed

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

**INPUT**

      Space Structure Name = Alpha2ndStage
      Space Structure Type = Rocket Body

      Perigee Altitude = 300.000000 (km)
      Apogee Altitude = 300.000000 (km)
      Inclination = 96.6700000 (deg)
      RAAN = 0.000000 (deg)
      Argument of Perigee = 0.000000 (deg)
      Mean Anomaly = 0.000000 (deg)
```

Area-To-Mass Ratio = 0.015172315 (m^2/kg)
Start Year = 2019.000000 (yr)
Initial Mass = 699.300000 (kg)
Final Mass = 699.300000 (kg)
Duration = 1.000000 (yr)
Station Kept = False
Abandoned = True
PMD Perigee Altitude = -1.000000 (km)
PMD Apogee Altitude = -1.000000 (km)
PMD Inclination = 0.000000 (deg)
PMD RAAN = 0.000000 (deg)
PMD Argument of Perigee = 0.000000 (deg)
PMD Mean Anomaly = 0.000000 (deg)

OUTPUT

Suggested Perigee Altitude = 300.000000 (km)
Suggested Apogee Altitude = 300.000000 (km)
Returned Error Message = Reentry during mission (no PMD req.).

Released Year = 2019 (yr)
Requirement = 61
Compliance Status = Pass

==========

INPUT

Space Structure Name = Alpha1stStage
Space Structure Type = Rocket Body

Perigee Altitude = 101.000000 (km)
Apogee Altitude = 101.000000 (km)
Inclination = 96.6700000 (deg)
RAAN = 0.000000 (deg)

```
      Argument of Perigee = 0.000000 (deg)
      Mean Anomaly = 0.000000 (deg)
      Area-To-Mass Ratio = 0.010743402 (m^2/kg)
      Start Year = 2019.000000 (yr)
      Initial Mass = 2894.800000 (kg)
      Final Mass = 2894.800000 (kg)
      Duration = 1.000000 (yr)
      Station Kept = False
      Abandoned = True
      PMD Perigee Altitude = -1.000000 (km)
      PMD Apogee Altitude = -1.000000 (km)
      PMD Inclination = 0.000000 (deg)
      PMD RAAN = 0.000000 (deg)
      PMD Argument of Perigee = 0.000000 (deg)
      PMD Mean Anomaly = 0.000000 (deg)

**OUTPUT**

      Suggested Perigee Altitude = 101.000000 (km)
      Suggested Apogee Altitude = 101.000000 (km)
      Returned Error Message = Reentry during mission (no PMD req.).

      Released Year = 2019 (yr)
      Requirement = 61
      Compliance Status = Pass

=============== End of Requirement 4.6 ===============
```

8 FIREFLY ALPHA REENTRY HAZARDS

Requirement 4.7-1 is concerned with limiting the risk of human casualty: "*The potential for human casualty is assumed for any object with an impacting kinetic energy in excess of 15 Joules:*

a) For uncontrolled reentry, the risk of human casualty from surviving debris shall not exceed 0.0001 (1:10,000)."

Due to its length, the full DAS activity log, which includes the detailed vehicle configuration, has been included as Appendix B. Only the return status is included in this section, showing that Firefly Alpha passes requirement 4.7-1.

```
*********Processing Requirement 4.7-1
     Return Status:  Passed
```

9 FIREFLY ALPHA HAZARDOUS MATERIALS

A summary of the hazardous materials contained on the launch vehicle is documented in the Firefly Alpha Hazard Assessment.

10 SAFETY AT END OF LAUNCH – RECONTACT ANALYSIS

Firefly's DREAM payload deployment sequence has been designed to introduce secular drift between each payload and the *Alpha* second stage, as well as between the payloads themselves. This is accomplished by imparting varying amounts of delta-velocity to the payloads projected along the second stage's inertial velocity vector. It is a well-known result of the Clohessy-Wiltshire equations of relative orbital motion that an initial velocity relative to a nearby object (or "chief," in this case, the *Alpha* second stage) along this direction results in a drift that grows without bound.

Error! Reference source not found. illustrates the physical layout of the 3 DREAM payload deployment mechanisms relative to the vehicle body axes. Payloads BSS1 and FOSSACON-1 are deployed at the same time—during deployment #1—and are oriented anti-parallel. BSS1 will be deployed along the vehicle +Y axis, and FOSSACON-1 will be deployed along the vehicle -Y axis. The QuadPack payloads, which will be deployed together during deployment signal #2, will be deployed along the +Y axis. For the purposes of this analysis, the payloads deployed from the QuadPack are treated as a single object. The Spinnaker-3 payload is a non-separating payload.

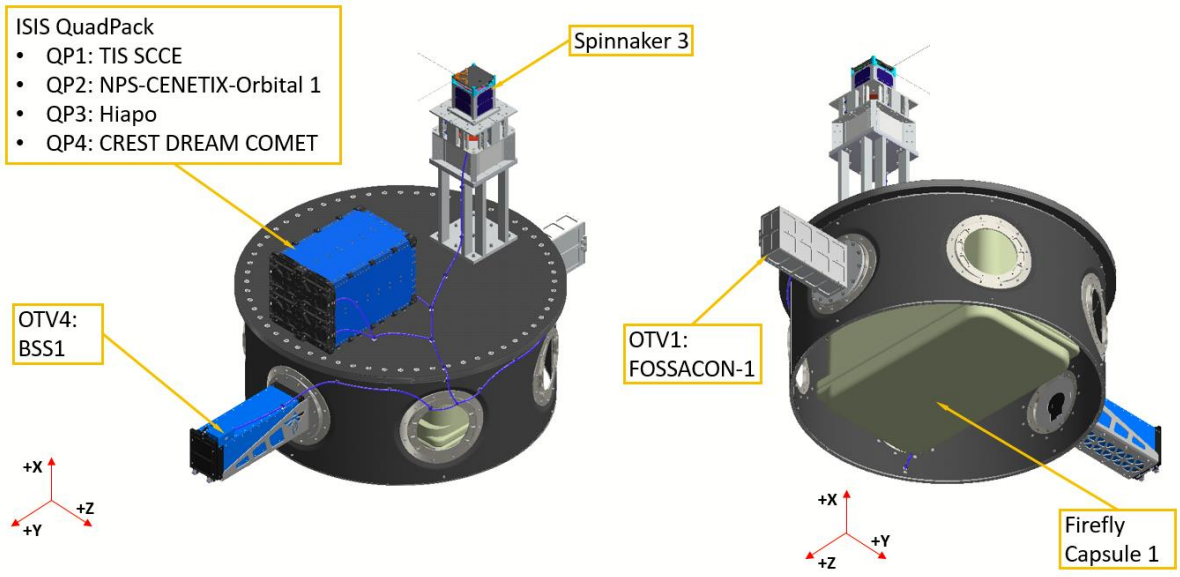


FIGURE 6: PHYSICAL DREAM PAYLOAD CONFIGURATION

Motion under the Clohessy-Wiltshire model of relative orbital dynamics is a function of initial position and velocity vectors with respect to the chief object. These values are known in the case of the DREAM payloads, and in the case of the relative velocity vector, are parameters that can be controlled in flight by the attitude control system. Table 4 lists the primary factors affecting deployment dynamics. The roll angle, or angle between the vehicle -Y axis and inertial velocity vector, can be configured in the mission planning phase via a flight software configuration file. To impart a meaningful drift between the QuadPack payload and both the second stage and BSS1 payload, a roll angle of 30° is commanded prior to deployment #2.

TABLE 4: DREAM PAYLOAD DEPLOYMENT PROPERTIES

Payload Name	Deployment Δv (m/s)	Roll Angle (°)	Deployment No.
BSS1	1.2	0	1
FOSSACON-1	1.2	0	1
QuadPack	1.12	30	2

Figures 7 and 8 illustrate the orientation of the vehicle axes (red) to the flight path and orbital velocity vector (yellow) during each deployment. Note that the vehicle X-axis is held parallel to the radial direction (local "up") during both deployments.

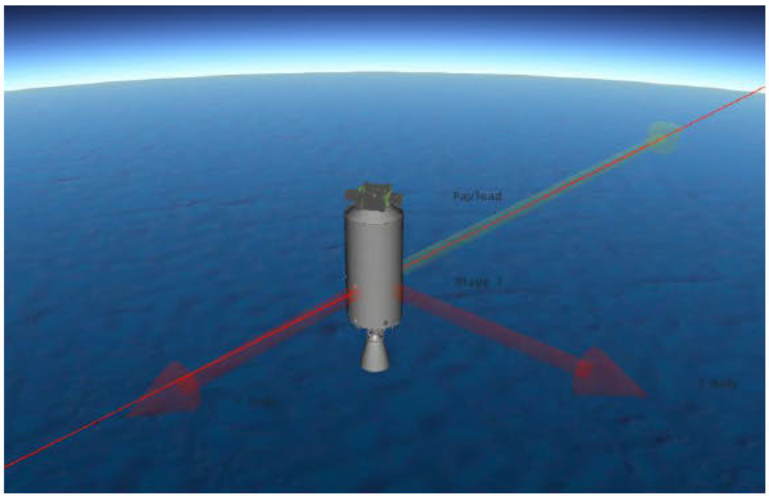


FIGURE 7 –DEPLOYMENT ORIENTATION #1

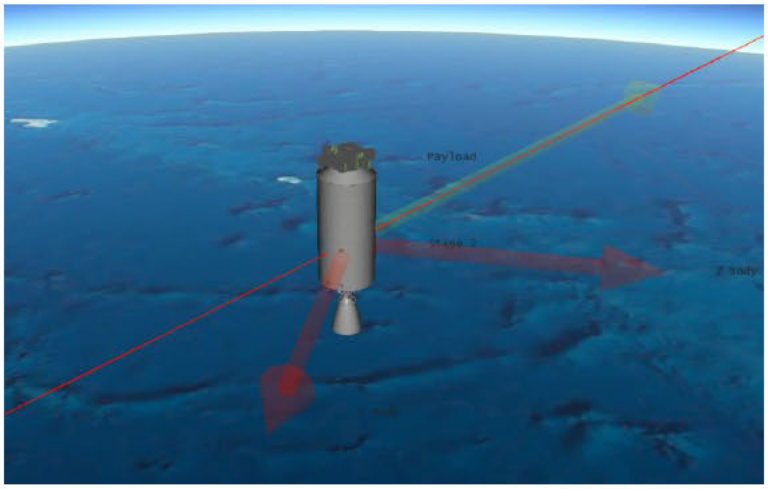


FIGURE 8 - DEPLOYMENT ORIENTATION #2

Assuming a circular orbit of the second stage of 300 km altitude, equations of relative motion may be integrated to calculate separation between the payloads and second stage at desired points of time. Three separate times were chosen for inspection in this analysis: 1 minute following deployment #1, 1 minute following deployment #2, and 45 minutes following deployment #1. Deployment #2 is initiated 5 minutes after deployment #1, allowing for the vehicle to carry out the deployment and required roll maneuver prior to QuadPack deployment. The third time was chosen to inspect the distance of the payloads from the vehicle at the time of the experimental relight of the second stage engine approximately half an orbit after SECO1.

Figures 9-11 show the relative trajectories of each payload in the radial-transverse plane at each of the described reference times. Observe how the BSS1 and QuadPack payloads drift below the second stage, having been deployed in the retrograde direction, and the FOSSACON-1 payload drift above the second stage, having been deployed in the prograde direction.

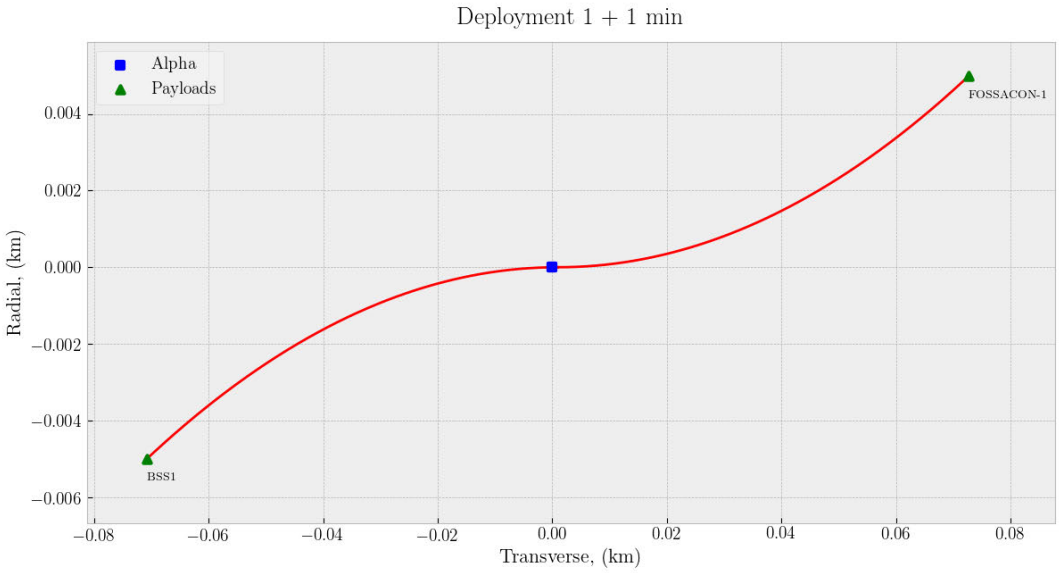


FIGURE 9 – PAYLOAD SEPARATION 1 MINUTE AFTER DEPLOYMENT #1

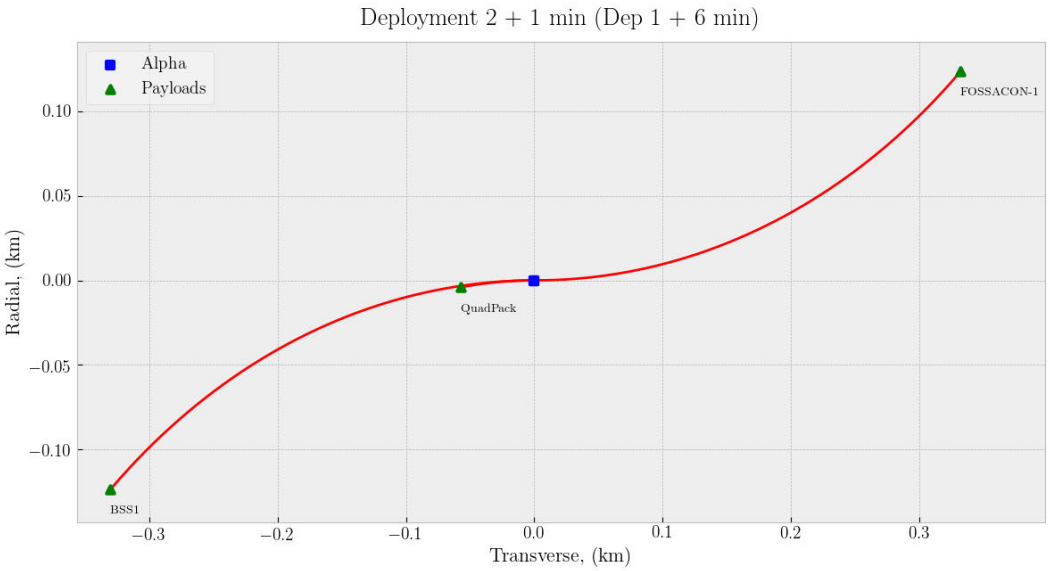


FIGURE 10 - PAYLOAD SEPARATION 1 MINUTE AFTER DEPLOYMENT #2

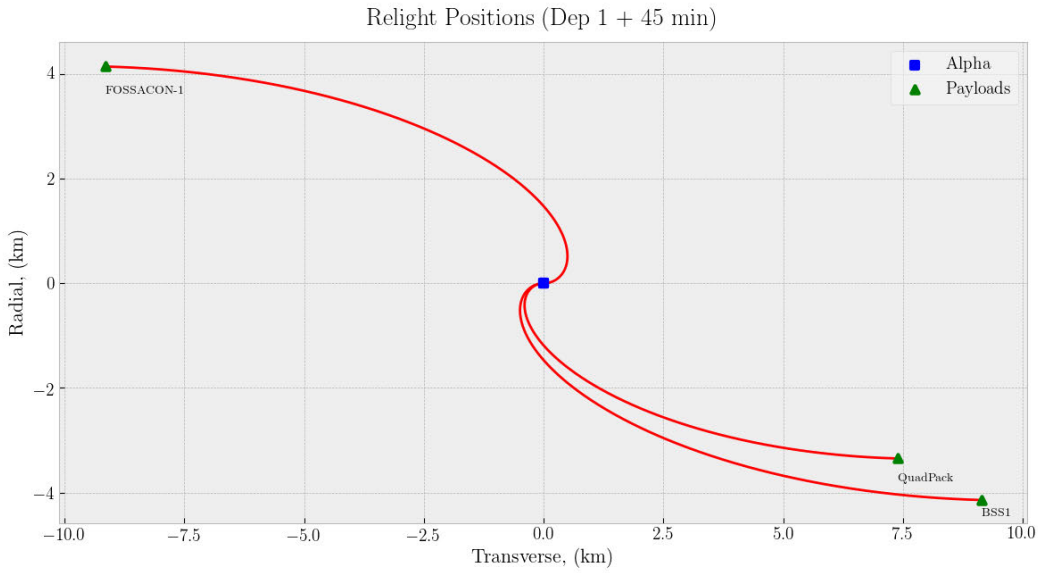


FIGURE 11 - PAYLOAD SEPARATION 45 MINUTES AFTER DEPLOYMENT #1

Table 5 shows the magnitude of displacement between each payload and the second stage at the three reference times. These values have been corroborated using AGI's System Tool Kit (STK) as an independent toolset with close agreement.

TABLE 5 – SEPARATION DISTANCE (METERS)

	Deployment 1 + 1m	Deployment 2 + 1m	Deployment 1 + 45m
BSS1	71	353	10,037
FOSSACON-1	73	355	10,035
QuadPack	0	66	8,113

Appendix A FIREFLY ALPHA VEHICLE CALCULATIONS

Input

Random Tumbling Orientation

	Component	Point 1	Point 1	Point 1	Point 2	Point 2	Point 2	Point 3	Point 3	Point 3	Radius 1	Radius 2
Ro...	Shape	U (LU)	V (LU)	W (LU)	U (LU)	V (LU)	W (LU)	U (LU)	V (LU)	W (LU)	(LU)	(LU)
1	Cylinder	0	0	0	0	0	18.8				1	1
*												

Run Reset Help Plot

Output

Cross-Sectional Area 31.10 (LU)^2 LU = Length Unit

FIGURE 12 STAGE ONE CROSS-SECTIONAL AREA CALCULATION

Calculate Cross-Sectional Area

Input

Random Tumbling Orientation

	Component	Point 1	Point 1	Point 1	Point 2	Point 2	Point 2	Point 3	Point 3	Point 3	Radius 1	Radius 2
Ro...	Shape	U (LU)	V (LU)	W (LU)	U (LU)	V (LU)	W (LU)	U (LU)	V (LU)	W (LU)	(LU)	(LU)
1	Cylinder	0	0	0	0	0	5.75				1	1
*												

Run Reset Help Plot

Output

Cross-Sectional Area 10.61 (LU)^2 LU = Length Unit

FIGURE 13 STAGE 2 CROSS-SECTIONAL AREA CALCULATION

Appendix B REQUIREMENT 4.7-1 ACTIVITY LOG

*********Processing Requirement 4.7-1

Return Status : Passed

**********INPUT****

Item Number = 1

name = Alpha2ndStage

quantity = 1

parent = 0

materialID = -1

type = Flat Plate

Aero Mass = 699.299988

Thermal Mass = 699.299988

Diameter/Width = 6.200000

Length = 6.200000

name = Nitrogen Tank Overwrap

quantity = 1

parent = 1

materialID = -1

type = Cylinder

Aero Mass = 10.028000

Thermal Mass = 9.699000

Diameter/Width = 0.397000

Length = 0.537000

name = Nitrogen Tank

quantity = 1

parent = 2

materialID = 8

type = Cylinder

Aero Mass = 0.329000

Thermal Mass = 0.329000

Diameter/Width = 0.376000

Length = 0.478000

name = Fuel Tank

quantity = 1

parent = 1

materialID = -1

type = Sphere

Aero Mass = 35.169998

Thermal Mass = 35.169998

Diameter/Width = 0.913000

name = Helium Tank Overwrap

quantity = 1

parent = 1

materialID = -1

type = Cylinder

Aero Mass = 28.306999

Thermal Mass = 18.990000

Diameter/Width = 0.435900

Length = 0.910800

name = Helium Tank

quantity = 1

parent = 5

materialID = 8

type = Cylinder

Aero Mass = 9.317000

Thermal Mass = 9.317000

Diameter/Width = 0.413000

Length = 0.910800

name = LOX Tank

quantity = 1

parent = 1

materialID = -1

type = Cylinder

Aero Mass = 71.279999

Thermal Mass = 68.000000

Diameter/Width = 1.800000

Length = 2.916500

name = LOx PMD baffle004005

quantity = 2

parent = 7

materialID = 8

type = Flat Plate

Aero Mass = 0.352000

Thermal Mass = 0.352000

Diameter/Width = 0.119000

Length = 0.372000

name = LOx PMD Baffle0006

quantity = 16

parent = 7

materialID = 8

type = Flat Plate

Aero Mass = 0.136000

Thermal Mass = 0.136000

Diameter/Width = 0.100000

Length = 0.151700

name = LOx PMD Base

quantity = 2

parent = 7
materialID = 8
type = Flat Plate
Aero Mass = 0.200000
Thermal Mass = 0.200000
Diameter/Width = 0.139000
Length = 0.200000

name = Intertank Bellows
quantity = 1
parent = 1
materialID = 59
type = Cylinder
Aero Mass = 1.548000
Thermal Mass = 1.548000
Diameter/Width = 0.060000
Length = 0.200000

name = Component Panel
quantity = 3
parent = 1
materialID = -1
type = Box
Aero Mass = 6.700000
Thermal Mass = 4.900000
Diameter/Width = 0.480000
Length = 0.480000
Height = 0.480000

name = panel core
quantity = 3
parent = 12
materialID = 5

type = Box
Aero Mass = 1.800000
Thermal Mass = 1.800000
Diameter/Width = 0.480000
Length = 0.480000
Height = 0.480000

name = Engine
quantity = 1
parent = 1
materialID = 19
type = Cylinder
Aero Mass = 33.262001
Thermal Mass = 33.262001
Diameter/Width = 0.197000
Length = 0.656000

name = Propulsion Lines
quantity = 12
parent = 1
materialID = 54
type = Flat Plate
Aero Mass = 10.580000
Thermal Mass = 10.580000
Diameter/Width = 10.575000
Length = 400.000000

name = Avionics
quantity = 14
parent = 1
materialID = 8
type = Box
Aero Mass = 4.280000

Thermal Mass = 4.280000
Diameter/Width = 0.200000
Length = 0.800000
Height = 0.018000

name = Sump
quantity = 1
parent = 1
materialID = 9
type = Cylinder
Aero Mass = 8.400000
Thermal Mass = 8.400000
Diameter/Width = 0.420000
Length = 0.200000

name = turbopump
quantity = 1
parent = 1
materialID = 59
type = Cylinder
Aero Mass = 6.300000
Thermal Mass = 6.300000
Diameter/Width = 0.320000
Length = 0.360000

name = Nitrogen Tank Support Structure
quantity = 5
parent = 1
materialID = 8
type = Box
Aero Mass = 2.700000
Thermal Mass = 2.700000
Diameter/Width = 0.300000

Length = 0.300000

Height = 0.100000

name = Fuel Tank Support Structure

quantity = 16

parent = 1

materialID = 8

type = Flat Plate

Aero Mass = 2.300000

Thermal Mass = 2.300000

Diameter/Width = 0.400000

Length = 0.500000

name = Helium Tank Support Structure

quantity = 3

parent = 1

materialID = 8

type = Box

Aero Mass = 3.100000

Thermal Mass = 3.100000

Diameter/Width = 0.300000

Length = 0.300000

Height = 0.100000

name = LOX Support Structure

quantity = 20

parent = 1

materialID = 8

type = Box

Aero Mass = 1.780000

Thermal Mass = 1.780000

Diameter/Width = 0.105000

Length = 0.200000

Height = 0.050000

name = Engine Structure
quantity = 6
parent = 1
materialID = 56
type = Flat Plate
Aero Mass = 2.800000
Thermal Mass = 2.800000
Diameter/Width = 0.200000
Length = 0.500000

name = Engine Manifold
quantity = 1
parent = 1
materialID = 37
type = Cylinder
Aero Mass = 4.800000
Thermal Mass = 4.800000
Diameter/Width = 0.260000
Length = 0.800000

name = Fuel Core HERO 110
quantity = 1
parent = 1
materialID = -2
type = Flat Plate
Aero Mass = 2.382000
Thermal Mass = 2.382000
Diameter/Width = 1.380000
Length = 1.850000

name = Fuel Core HERO 71

quantity = 1

parent = 1

materialID = -2

type = Cylinder

Aero Mass = 13.630000

Thermal Mass = 13.630000

Diameter/Width = 1.850000

Length = 1.600000

name = Outer Aft Fuel Boss

quantity = 1

parent = 1

materialID = 8

type = Flat Plate

Aero Mass = 1.721000

Thermal Mass = 1.721000

Diameter/Width = 0.120000

Length = 0.500000

name = Inner Fore Fuel Boss

quantity = 1

parent = 1

materialID = 8

type = Flat Plate

Aero Mass = 1.130000

Thermal Mass = 1.130000

Diameter/Width = 0.140000

Length = 0.400000

name = Outer Fore Fuel Boxx

quantity = 1

parent = 1

materialID = 8

type = Cylinder
Aero Mass = 1.662000
Thermal Mass = 1.662000
Diameter/Width = 0.140000
Length = 0.400000

name = Laminate Fuel Tank Alpha
quantity = 1
parent = 1
materialID = -1
type = Cylinder
Aero Mass = 41.220001
Thermal Mass = 41.220001
Diameter/Width = 1.850000
Length = 1.833000

name = LOX Barrel Core HERO
quantity = 2
parent = 1
materialID = -2
type = Box
Aero Mass = 2.840000
Thermal Mass = 2.840000
Diameter/Width = 1.240000
Length = 1.240000
Height = 1.240000

name = LOX Barrel Spoiled Core HERO
quantity = 2
parent = 1
materialID = -2
type = Cylinder
Aero Mass = 3.751800

Thermal Mass = 3.751800
Diameter/Width = 1.850000
Length = 0.909000

name = LOX Dome to Barrel Wedge
quantity = 12
parent = 1
materialID = -3
type = Box
Aero Mass = 0.107000
Thermal Mass = 0.107000
Diameter/Width = 0.500000
Length = 0.925000
Height = 0.129000

name = LOX Dome to Barrel Wedge Ply tie
quantity = 4
parent = 1
materialID = -1
type = Flat Plate
Aero Mass = 1.101272
Thermal Mass = 1.101272
Diameter/Width = 0.200000
Length = 1.827000

name = RPLOX Circumferential Laminate Biscuit
quantity = 1
parent = 1
materialID = -1
type = Cylinder
Aero Mass = 1.919000
Thermal Mass = 1.919000
Diameter/Width = 0.140000

Length = 1.848000

name = Intertank Panel Core

quantity = 1

parent = 1

materialID = 7

type = Box

Aero Mass = 0.036600

Thermal Mass = 0.036600

Diameter/Width = 0.300000

Length = 0.430000

Height = 0.200000

name = Intertank Vertical Panel

quantity = 1

parent = 1

materialID = 5

type = Box

Aero Mass = 0.500000

Thermal Mass = 0.500000

Diameter/Width = 0.200000

Length = 0.500000

Height = 0.100000

name = Intertank Panel Master

quantity = 1

parent = 1

materialID = -1

type = Flat Plate

Aero Mass = 19.600000

Thermal Mass = 19.600000

Diameter/Width = 0.680000

Length = 2.340000

name = Turbopump Exhaust

quantity = 3

parent = 1

materialID = 36

type = Cylinder

Aero Mass = 3.920000

Thermal Mass = 3.920000

Diameter/Width = 0.300000

Length = 0.100000

name = copv bracket

quantity = 6

parent = 1

materialID = -1

type = Box

Aero Mass = 2.100000

Thermal Mass = 2.100000

Diameter/Width = 0.200000

Length = 0.600000

Height = 0.070000

name = RCS assemblies

quantity = 4

parent = 1

materialID = 9

type = Box

Aero Mass = 0.460000

Thermal Mass = 0.460000

Diameter/Width = 0.070000

Length = 0.080000

Height = 0.040000

name = FRE Cooling Manifold

quantity = 1

parent = 1

materialID = 8

type = Cylinder

Aero Mass = 2.670000

Thermal Mass = 2.670000

Diameter/Width = 0.304000

Length = 0.100000

name = FRE Heat Sink

quantity = 2

parent = 1

materialID = 19

type = Cylinder

Aero Mass = 8.400000

Thermal Mass = 8.400000

Diameter/Width = 0.300000

Length = 0.780000

**********OUTPUT****

Item Number = 1

name = Alpha2ndStage

Demise Altitude = 77.994797

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Nitrogen Tank Overwrap

Demise Altitude = 77.974365

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Nitrogen Tank

Demise Altitude = 77.229469

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Fuel Tank

Demise Altitude = 77.964142

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Helium Tank Overwrap

Demise Altitude = 77.974365

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Helium Tank

Demise Altitude = 69.008133

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = LOX Tank

Demise Altitude = 77.984589

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = LOx PMD baffle004005

Demise Altitude = 73.761269

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = LOx PMD Baffle0006

Demise Altitude = 74.342308

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = LOx PMD Base

Demise Altitude = 74.465233

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Intertank Bellows

Demise Altitude = 56.848366

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Component Panel

Demise Altitude = 77.994797

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = panel core

Demise Altitude = 73.161118

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Engine

Demise Altitude = 40.821194

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Propulsion Lines

Demise Altitude = 77.994797

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Avionics

Demise Altitude = 55.748714

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Sump

Demise Altitude = 61.382694

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = turbopump

Demise Altitude = 0.000000

Debris Casualty Area = 0.882494

Impact Kinetic Energy = 3217.970459

****

name = Nitrogen Tank Support Structure

Demise Altitude = 62.070076

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Fuel Tank Support Structure

Demise Altitude = 63.178066

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Helium Tank Support Structure

Demise Altitude = 59.717659

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = LOX Support Structure

Demise Altitude = 60.287811

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Engine Structure

Demise Altitude = 0.000000

Debris Casualty Area = 5.036840

Impact Kinetic Energy = 1282.884277

****

name = Engine Manifold

Demise Altitude = 0.000000

Debris Casualty Area = 1.115284

Impact Kinetic Energy = 1153.463745

****

name = Fuel Core HERO 110

Demise Altitude = 77.994797

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Fuel Core HERO 71

Demise Altitude = 77.994797

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Outer Aft Fuel Boss

Demise Altitude = 61.866035

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Inner Fore Fuel Boss

Demise Altitude = 67.209641

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Outer Fore Fuel Boxx

Demise Altitude = 69.899475

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Laminate Fuel Tank Alpha

Demise Altitude = 77.994797

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = LOX Barrel Core HERO

Demise Altitude = 77.994797

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = LOX Barrel Spoiled Core HERO

Demise Altitude = 77.994797

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = LOX Dome to Barrel Wedge

Demise Altitude = 77.994797

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = LOX Dome to Barrel Wedge Ply tie

Demise Altitude = 77.994797

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = RPLOX Circumferential Laminate Biscuit

Demise Altitude = 77.994797

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Intertank Panel Core

Demise Altitude = 77.882988

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Intertank Vertical Panel

Demise Altitude = 75.699257

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Intertank Panel Master

Demise Altitude = 77.984589

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Turbopump Exhaust

Demise Altitude = 58.525444

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = copv bracket

Demise Altitude = 77.994797

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = RCS assemblies

Demise Altitude = 65.875565

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = FRE Cooling Manifold

Demise Altitude = 66.953079

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = FRE Heat Sink

Demise Altitude = 66.278687

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

**********INPUT****

Item Number = 2

name = Alpha1stStage

quantity = 1

parent = 0

materialID = -1

type = Cylinder

Aero Mass = 2894.800049

Thermal Mass = 2894.800049

Diameter/Width = 2.000000

name = LOX tank and support

quantity = 1

parent = 1

materialID = -1

type = Cylinder

Aero Mass = 2100.000000

Thermal Mass = 2100.000000

Diameter/Width = 2.000000

Length = 12.000000

name = Fuel tank and support

quantity = 1

parent = 1

materialID = -1

type = Cylinder

Aero Mass = 720.000000

Thermal Mass = 720.000000

Diameter/Width = 2.000000

Length = 6.000000

name = AvionicsS1

quantity = 11

parent = 1

materialID = 8

type = Box

Aero Mass = 6.100000

Thermal Mass = 6.100000

Diameter/Width = 0.200000

Length = 0.800000

Height = 0.018000

**********OUTPUT****

Item Number = 2

name = Alpha1stStage

Demise Altitude = 77.999794

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = LOX tank and support

Demise Altitude = 77.924110

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Fuel tank and support

Demise Altitude = 77.954422

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = AvionicsS1

Demise Altitude = 61.219875

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

**********INPUT****

Item Number = 3

name = PayloadFairing1

quantity = 1

parent = 0

materialID = -1

type = Flat Plate

Aero Mass = 108.599998

Thermal Mass = 108.599998

Diameter/Width = 2.200000

Length = 2.500000

name = P

quantity = 1

parent = 1

materialID = -1

type = Flat Plate

Aero Mass = 108.599998

Thermal Mass = 108.599998

Diameter/Width = 2.200000

Length = 2.500000

**********OUTPUT****

Item Number = 3

name = PayloadFairing1

Demise Altitude = 77.990257

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = P

Demise Altitude = 77.959877

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

**********INPUT****

Item Number = 4

name = PayloadFairing2

quantity = 1

parent = 0

materialID = -1

type = Flat Plate

Aero Mass = 98.199997

Thermal Mass = 98.199997

Diameter/Width = 2.200000

Length = 2.500000

name = P

quantity = 1

parent = 1

materialID = -1

type = Flat Plate

Aero Mass = 98.199997

Thermal Mass = 98.199997

Diameter/Width = 2.200000

Length = 2.500000

**********OUTPUT****

Item Number = 4

name = PayloadFairing2

Demise Altitude = 77.996223

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = P

Demise Altitude = 77.965012

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

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

User defined materials used in Requirement 4.7-1 analysis

User-Defined Material

	Material	Density	Specific Heat	Heat of Fusion	Melt Temper...
Ro...	Name	(kg/m^3)	(J/kg-K)	(J/kg)	(K)
1	CFRP	1430	4.122	232.6	700
2	Rohacell Hero 71	75	.372059	232.6	483
3	Divinycell F90	90	.364765	232.6	453.15

FIGURE 14: MATERIALS USED IN REQUIREMENT 4.7-1 ANALYSIS

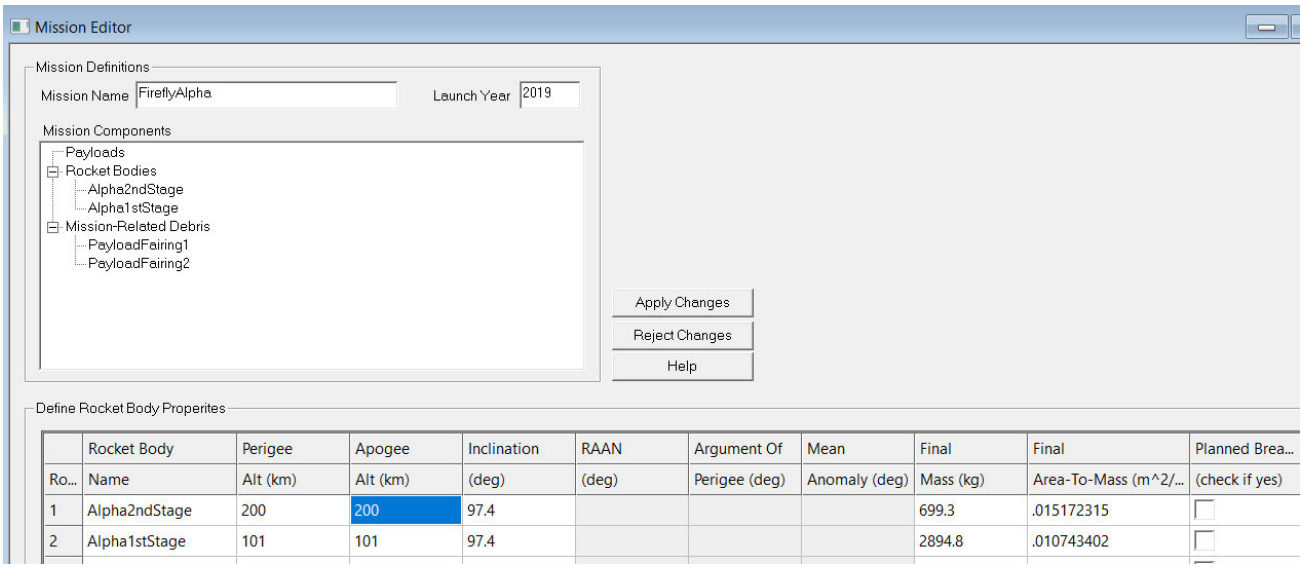
Appendix C Post-Deployment Engine Starts

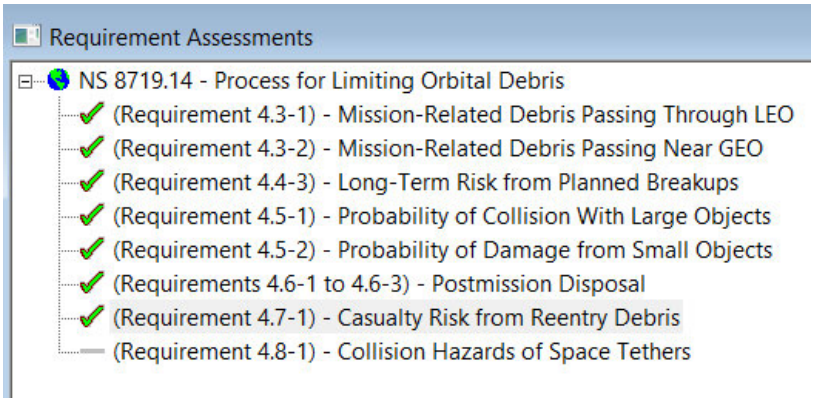
The Firefly Alpha team wishes to test the relight capability of the second stage after payload deployment. If performed on orbit, this action would change the final orbit of the second stage. To facilitate this optional testing, an envelope of final orbits was analyzed in DAS to help define the orbital limits for passive deorbit regulation compliance. Abbreviated results will be presented in this appendix for the family of orbits analyzed. Full results will be presented for the most likely post relight orbit of 300km x 500km. Full results are available for all orbits considered and can be provided on request.

Table 6: Second Stage Relight Final Orbit Evaluations

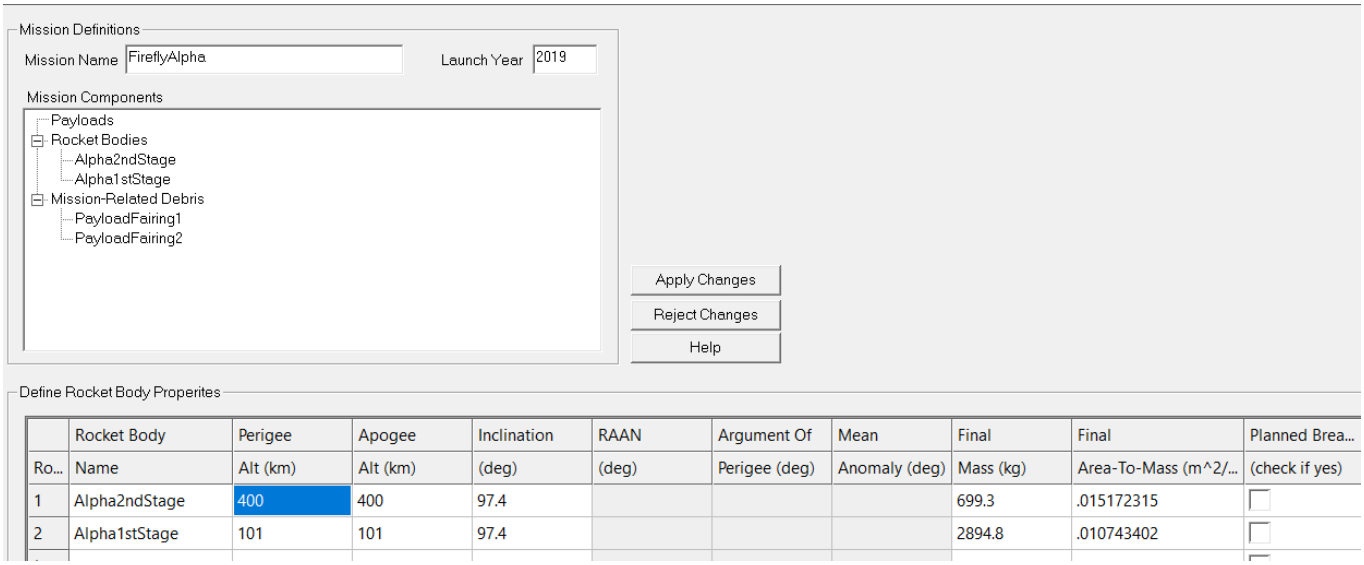
Final Orbit	PASS/FAIL (Orbit considered a FAIL if a single requirement fails)
200km circular	PASS
300km circular	PASS
400km circular	PASS
500km circular	PASS
600km circular	PASS
650km circular	PASS
675km circular	FAIL
700km circular	FAIL
300km x 400km	PASS
300km x 500km	PASS
300km x 650km	PASS

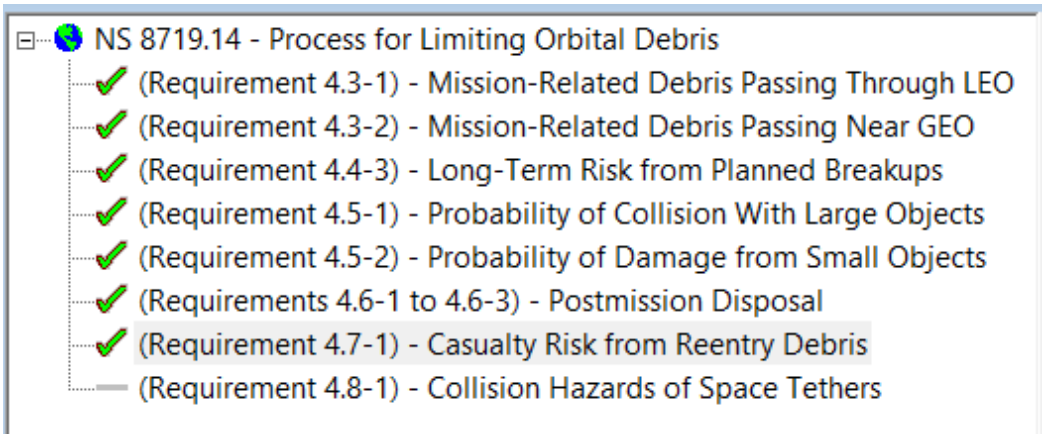
C.1 200KM CIRCULAR FINAL ORBIT



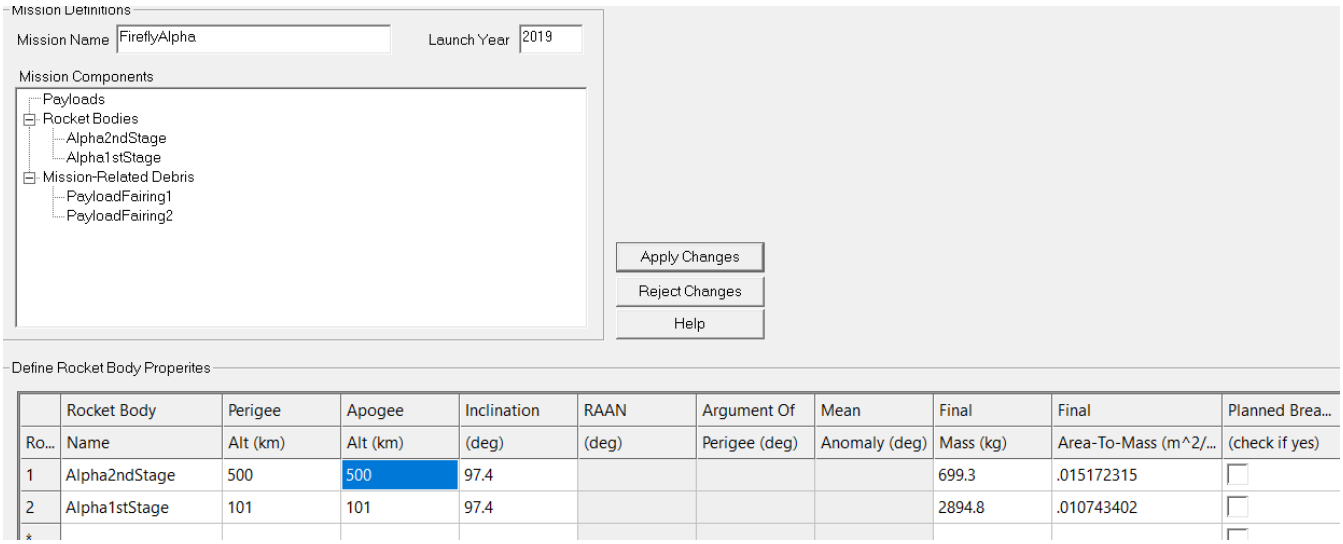


C.2 400KM CIRCULAR FINAL ORBIT

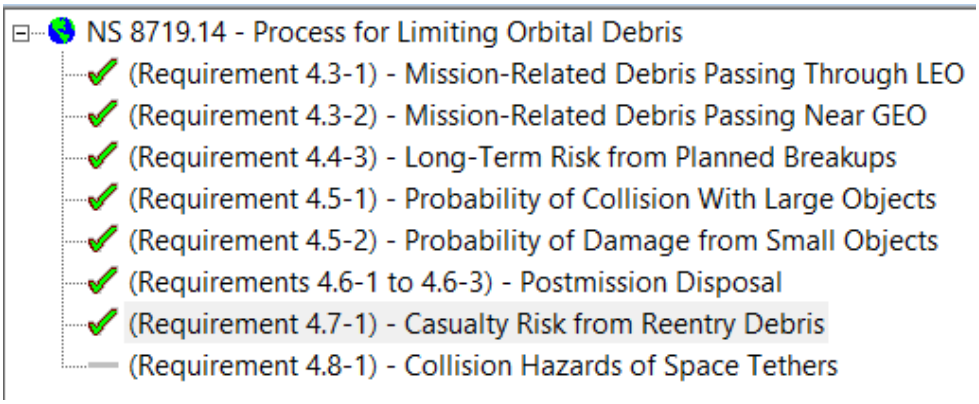




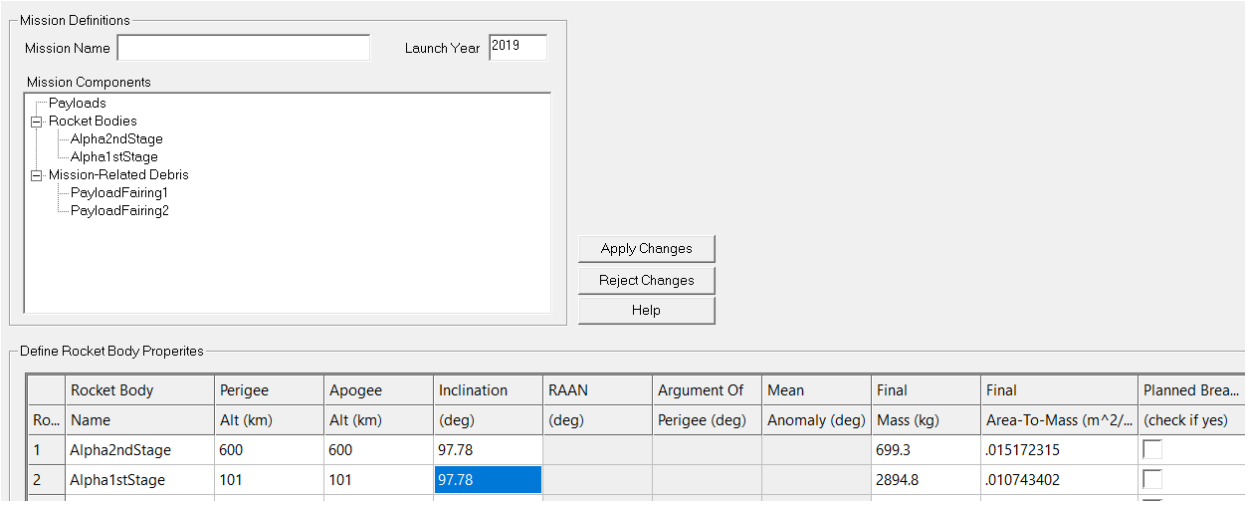
C.3 500KM CIRCULAR FINAL ORBIT



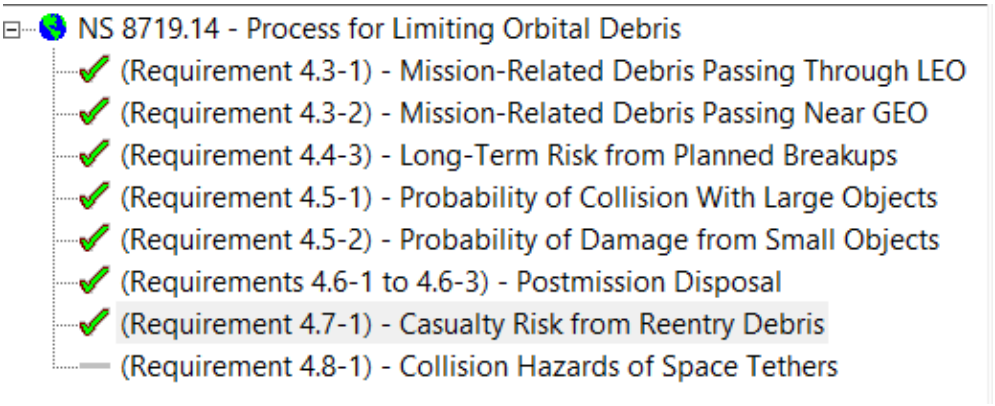
	Rocket Body	Perigee	Apogee	Inclination	RAAN	Argument Of	Mean	Final	Final	Planned Brea...
Ro...	Name	Alt (km)	Alt (km)	(deg)	(deg)	Perigee (deg)	Anomaly (deg)	Mass (kg)	Area-To-Mass (m^2/...	(check if yes)
1	Alpha2ndStage	500	500	97.4				699.3	.015172315	
2	Alpha1stStage	101	101	97.4				2894.8	.010743402	



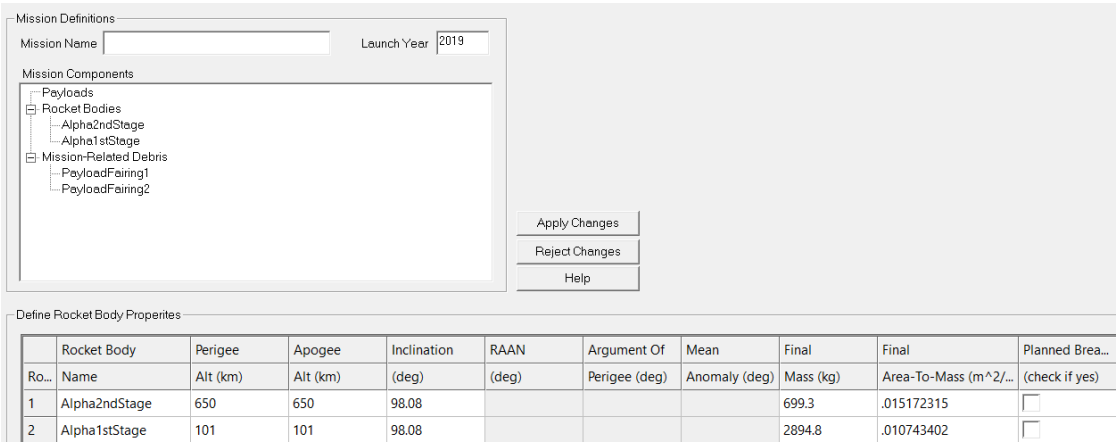
C.4 600KM CIRCULAR FINAL ORBIT



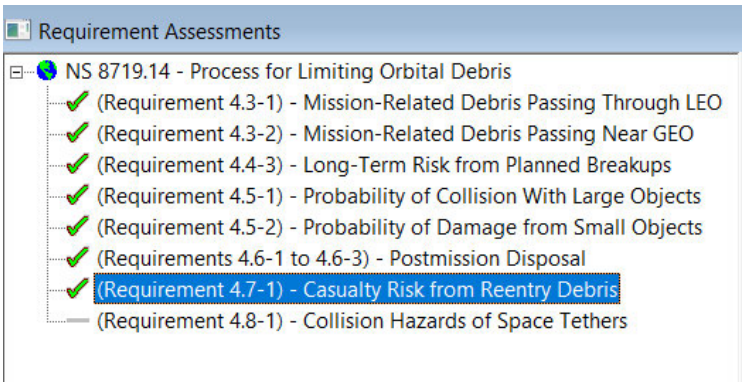
	Rocket Body	Perigee	Apogee	Inclination	RAAN	Argument Of	Mean	Final	Final	Planned Brea...
Ro...	Name	Alt (km)	Alt (km)	(deg)	(deg)	Perigee (deg)	Anomaly (deg)	Mass (kg)	Area-To-Mass (m^2/...	(check if yes)
1	Alpha2ndStage	600	600	97.78				699.3	.015172315	
2	Alpha1stStage	101	101	97.78				2894.8	.010743402	



C.5 650KM CIRCULAR FINAL ORBIT



	Rocket Body	Perigee	Apogee	Inclination	RAAN	Argument Of	Mean	Final	Final	Planned Brea...
Ro...	Name	Alt (km)	Alt (km)	(deg)	(deg)	Perigee (deg)	Anomaly (deg)	Mass (kg)	Area-To-Mass (m^2/...	(check if yes)
1	Alpha2ndStage	650	650	98.08				699.3	.015172315	☐
2	Alpha1stStage	101	101	98.08				2894.8	.010743402	☐



C.6 675KM CIRCULAR FINAL ORBIT

Mission Definitions

Mission Name

Launch Year 2019

Mission Components

- Payloads
- Rocket Bodies
  - Alpha2ndStage
  - Alpha1stStage
- Mission-Related Debris
  - PayloadFairing1
  - PayloadFairing2

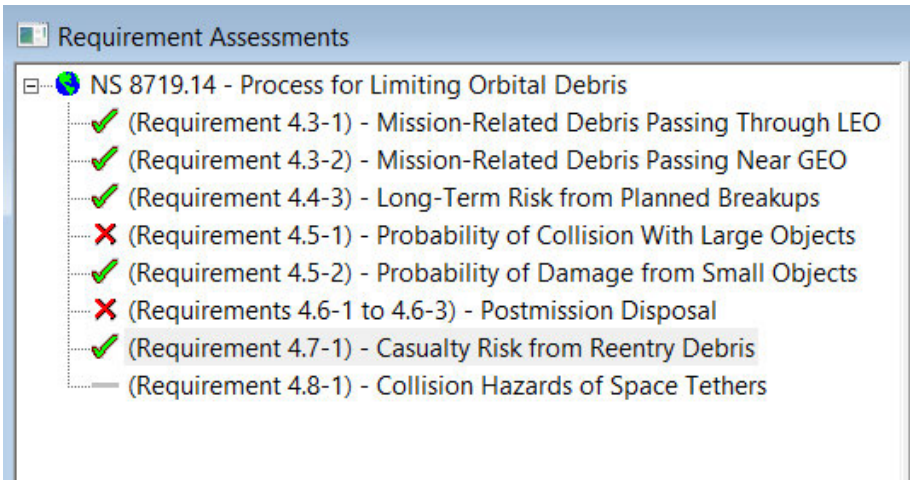
Apply Changes

Reject Changes

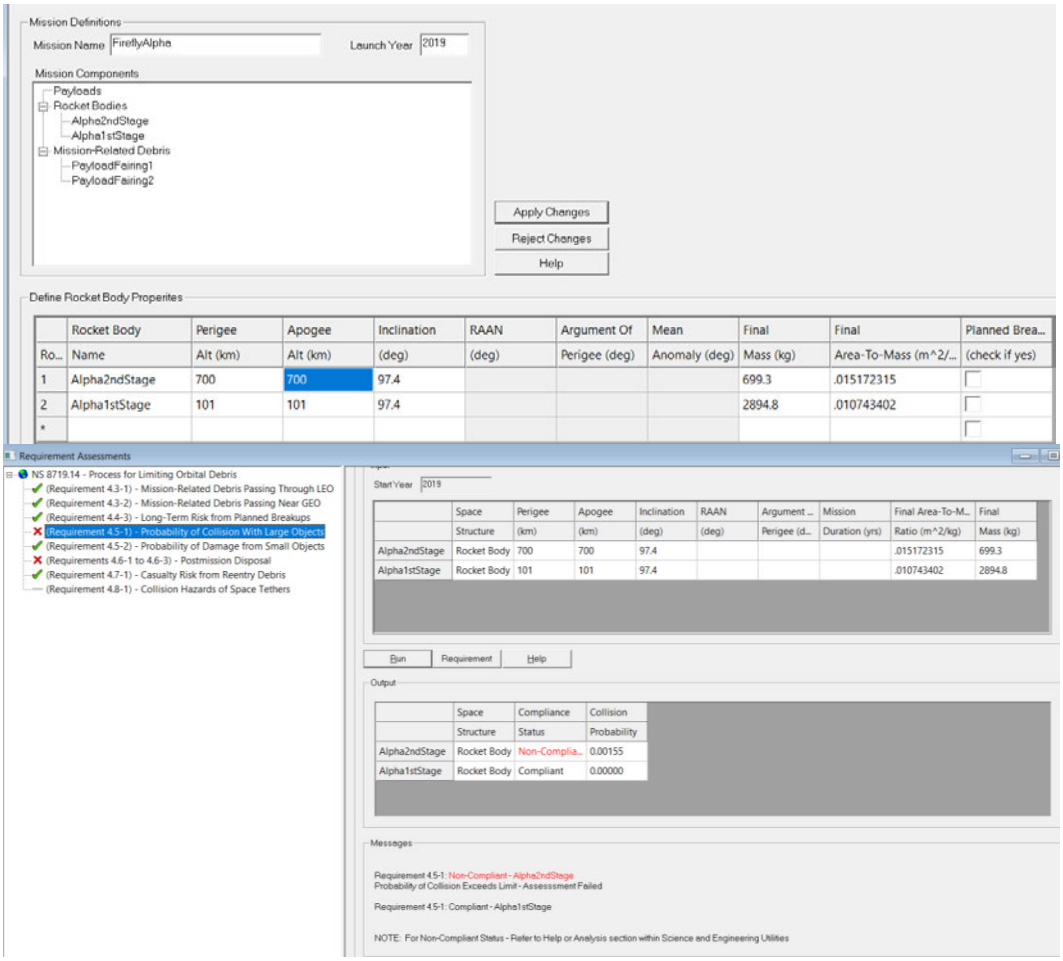
Help

Define Rocket Body Properites

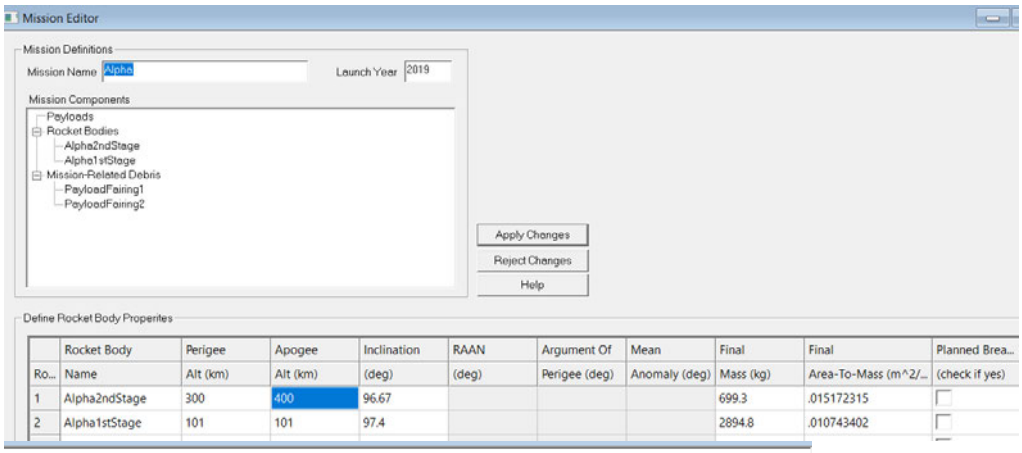
	Rocket Body	Perigee	Apogee	Inclination	RAAN	Argument Of	Mean	Final	Final	Planned Brea...
Ro...	Name	Alt (km)	Alt (km)	(deg)	(deg)	Perigee (deg)	Anomaly (deg)	Mass (kg)	Area-To-Mass (m^2/...	(check if yes)
1	Alpha2ndStage	675	675	98.08				699.3	.015172315	☐
2	Alpha1stStage	101	101	98.08				2894.8	.010743402	☐

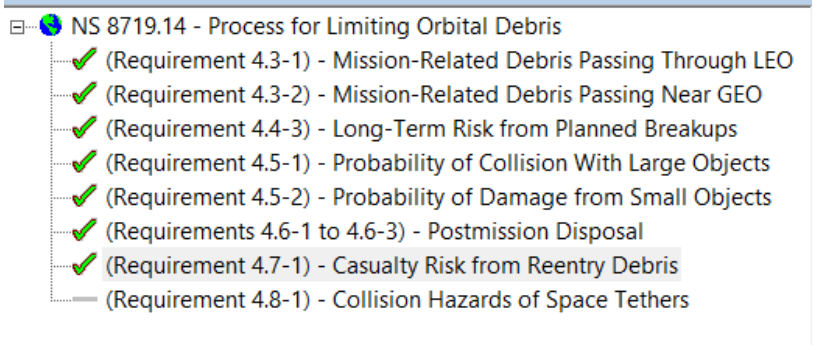


C.7 700KM CIRCULAR FINAL ORBIT

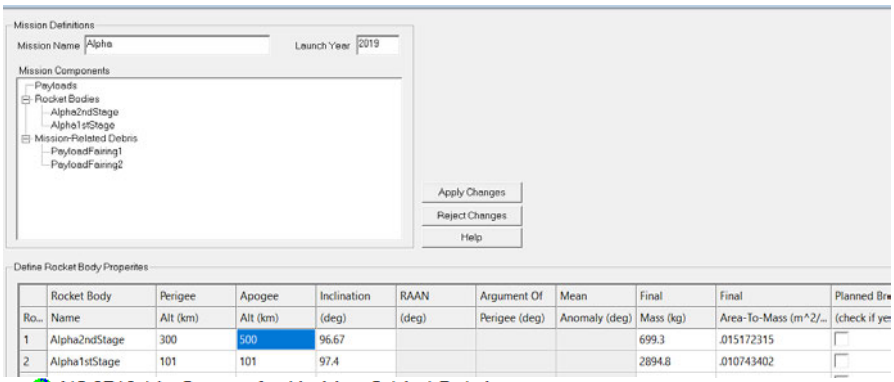


C.8 300X400KM ELLIPTICAL FINAL ORBIT



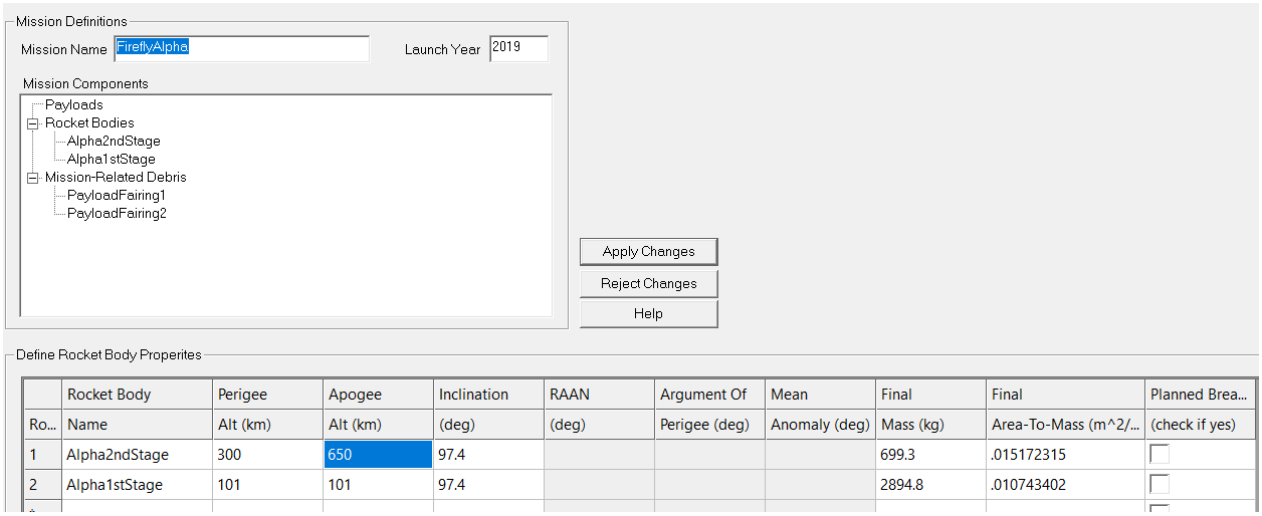


C.9 300X500KM ELLIPTICAL FINAL ORBIT

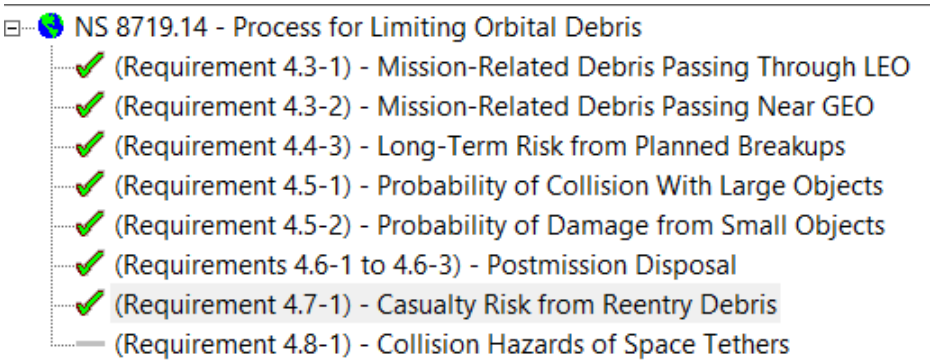


- NS 8719.14 - Process for Limiting Orbital Debris
  - (Requirement 4.3-1) - Mission-Related Debris Passing Through LEO
  - (Requirement 4.3-2) - Mission-Related Debris Passing Near GEO
  - (Requirement 4.4-3) - Long-Term Risk from Planned Breakups
  - (Requirement 4.5-1) - Probability of Collision With Large Objects
  - (Requirement 4.5-2) - Probability of Damage from Small Objects
  - (Requirements 4.6-1 to 4.6-3) - Postmission Disposal
  - (Requirement 4.7-1) - Casualty Risk from Reentry Debris
  - (Requirement 4.8-1) - Collision Hazards of Space Tethers

C.10300X650KM ELLIPTICAL FINAL ORBIT



	Rocket Body	Perigee	Apogee	Inclination	RAAN	Argument Of	Mean	Final	Final	Planned Brea...
Ro...	Name	Alt (km)	Alt (km)	(deg)	(deg)	Perigee (deg)	Anomaly (deg)	Mass (kg)	Area-To-Mass (m^2/...	(check if yes)
1	Alpha2ndStage	300	650	97.4				699.3	.015172315	
2	Alpha1stStage	101	101	97.4				2894.8	.010743402	



C.11300X500KM ELLIPTICAL FINAL ORBIT FULL RESULTS

Processing Requirement 4.3-1: Return Status : Passed

==========

Project Data

==========

Objects Passing Through LEO = True

Number of Objects = 2

INPUT

Quantity = 1

Final Area-To-Mass Ratio = 0.156896 (m^2/kg)

Perigee Altitude = 143.000000 (km)

Apogee Altitude = 143.000000 (km)

Inclination = 96.6700000 (deg)

RAAN = -1.000000 (deg)

Argument of Perigee = -1.000000 (deg)

Mean Anomaly = -1.000000 (deg)

Released Year = 2019.000000 (yr)

OUTPUT

Perigee Altitude = -6378.136000 (km)

Apogee Altitude = -6378.136000 (km)

Inclination = 0.000000 (deg)

Lifetime = 0.005137 (yr)

Object Reentered within 25 years of Release = True

Object-Time = 0.000000 (obj-yrs)

Total Object-Time = 0.000000 (obj-yrs)

Status = Pass

Returned Error Message - Normal Processing

==========

INPUT

Quantity = 1

Final Area-To-Mass Ratio = 0.173569 (m^2/kg)

Perigee Altitude = 143.000000 (km)

Apogee Altitude = 143.000000 (km)

Inclination = 96.6700000 (deg)

RAAN = -1.000000 (deg)

Argument of Perigee = -1.000000 (deg)

Mean Anomaly = -1.000000 (deg)

Released Year = 2019.000000 (yr)

OUTPUT

Perigee Altitude = -6378.136000 (km)

Apogee Altitude = -6378.136000 (km)

Inclination = 0.000000 (deg)

Lifetime = 0.005137 (yr)

Object Reentered within 25 years of Release = True

Object-Time = 0.000000 (obj-yrs)

Total Object-Time = 0.000000 (obj-yrs)

Status = Pass

Returned Error Message - Normal Processing

==========

========== End of Requirement 4.3-1 ==========

10 30 2019; 05:15:37AM Processing Requirement 4.3-2: Return Status : Passed

==========

No Project Data Available

==========

========== End of Requirement 4.3-2 ==========

10 30 2019; 05:15:39AM Requirement 4.4-3: Compliant

========== End of Requirement 4.4-3 ==========

10 30 2019; 05:18:53AM Processing Requirement 4.5-1: Return Status : Passed

==========

Run Data

==========

INPUT

Space Structure Name = Alpha2ndStage

Space Structure Type = Rocket Body

Perigee Altitude = 300.000000 (km)

Apogee Altitude = 500.000000 (km)

Inclination = 96.670000 (deg)

RAAN = 0.000000 (deg)

Argument of Perigee = 0.000000 (deg)

Mean Anomaly = 0.000000 (deg)

Final Area-To-Mass Ratio = 0.015172 (m^2/kg)

Start Year = 2019.000000 (yr)

Initial Mass = 699.300000 (kg)

Final Mass = 699.300000 (kg)

Duration = 0.000000 (yr)

Station-Kept = False

Abandoned = True

PMD Perigee Altitude = -1.000000 (km)

PMD Apogee Altitude = -1.000000 (km)

PMD Inclination = 0.000000 (deg)

PMD RAAN = 0.000000 (deg)

PMD Argument of Perigee = 0.000000 (deg)

PMD Mean Anomaly = 0.000000 (deg)

OUTPUT

Collision Probability = 0.000008

Returned Error Message: Normal Processing

Date Range Error Message: Normal Date Range

Status = Pass

==========

INPUT

Space Structure Name = Alpha1stStage

Space Structure Type = Rocket Body

Perigee Altitude = 101.000000 (km)

Apogee Altitude = 101.000000 (km)

Inclination = 96.6700000 (deg)

RAAN = 0.000000 (deg)

Argument of Perigee = 0.000000 (deg)

Mean Anomaly = 0.000000 (deg)

Final Area-To-Mass Ratio = 0.010743 (m^2/kg)

Start Year = 2019.000000 (yr)

Initial Mass = 2894.800000 (kg)

Final Mass = 2894.800000 (kg)

Duration = 0.000000 (yr)

Station-Kept = False

Abandoned = True

PMD Perigee Altitude = -1.000000 (km)

PMD Apogee Altitude = -1.000000 (km)

PMD Inclination = 0.000000 (deg)

PMD RAAN = 0.000000 (deg)

PMD Argument of Perigee = 0.000000 (deg)

PMD Mean Anomaly = 0.000000 (deg)

OUTPUT

Collision Probability = 0.000000

Returned Error Message: Normal Processing

Date Range Error Message: Normal Date Range

Status = Pass

==========

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

10 30 2019; 05:22:36AM Requirement 4.5-2: Compliant

10 30 2019; 05:22:37AM Processing Requirement 4.6 Return Status : Passed

==========

Project Data

==========

INPUT

Space Structure Name = Alpha2ndStage

Space Structure Type = Rocket Body

Perigee Altitude = 300.000000 (km)

Apogee Altitude = 500.000000 (km)

Inclination = 96.670000 (deg)

RAAN = 0.000000 (deg)

Argument of Perigee = 0.000000 (deg)

Mean Anomaly = 0.000000 (deg)

Area-To-Mass Ratio = 0.015172 (m^2/kg)

Start Year = 2019.000000 (yr)

Initial Mass = 699.300000 (kg)

Final Mass = 699.300000 (kg)

Duration = 1.000000 (yr)

Station Kept = False

Abandoned = True

PMD Perigee Altitude = 247.049445 (km)

PMD Apogee Altitude = 304.960611 (km)

PMD Inclination = 96.675261 (deg)

PMD RAAN = 348.550343 (deg)

PMD Argument of Perigee = 48.212321 (deg)

PMD Mean Anomaly = 0.000000 (deg)

OUTPUT

Suggested Perigee Altitude = 247.049445 (km)

Suggested Apogee Altitude = 304.960611 (km)

Returned Error Message = Passes LEO reentry orbit criteria.

Released Year = 2020 (yr)

Requirement = 61

Compliance Status = Pass

==========

INPUT

Space Structure Name = Alpha1stStage

Space Structure Type = Rocket Body

Perigee Altitude = 101.000000 (km)

Apogee Altitude = 101.000000 (km)

Inclination = 96.6700000 (deg)

RAAN = 0.000000 (deg)

Argument of Perigee = 0.000000 (deg)

Mean Anomaly = 0.000000 (deg)

Area-To-Mass Ratio = 0.010743 (m^2/kg)

Start Year = 2019.000000 (yr)

Initial Mass = 2894.800000 (kg)

Final Mass = 2894.800000 (kg)

Duration = 1.000000 (yr)

Station Kept = False

Abandoned = True

PMD Perigee Altitude = -1.000000 (km)

PMD Apogee Altitude = -1.000000 (km)

PMD Inclination = 0.000000 (deg)

PMD RAAN = 0.000000 (deg)

PMD Argument of Perigee = 0.000000 (deg)

PMD Mean Anomaly = 0.000000 (deg)

OUTPUT

Suggested Perigee Altitude = 101.000000 (km)

Suggested Apogee Altitude = 101.000000 (km)

Returned Error Message = Reentry during mission (no PMD req.).

Released Year = 2019 (yr)

Requirement = 61

Compliance Status = Pass

==========

========== End of Requirement 4.6 ==========

10 30 2019; 05:22:49AM *********Processing Requirement 4.7-1

Return Status : Passed

**********INPUT****

Item Number = 1

name = Alpha2ndStage

quantity = 1

parent = 0

materialID = -1

type = Flat Plate

Aero Mass = 699.299988

Thermal Mass = 699.299988

Diameter/Width = 6.200000

Length = 6.200000

name = Nitrogen Tank Overwrap

quantity = 1

parent = 1

materialID = -1

type = Cylinder

Aero Mass = 10.028000
Thermal Mass = 9.699000
Diameter/Width = 0.397000
Length = 0.537000

name = Nitrogen Tank
quantity = 1
parent = 2
materialID = 8
type = Cylinder
Aero Mass = 0.329000
Thermal Mass = 0.329000
Diameter/Width = 0.376000
Length = 0.478000

name = Fuel Tank
quantity = 1
parent = 1
materialID = -1
type = Sphere
Aero Mass = 35.169998
Thermal Mass = 35.169998
Diameter/Width = 0.913000

name = Helium Tank Overwrap
quantity = 1
parent = 1
materialID = -1
type = Cylinder
Aero Mass = 28.306999
Thermal Mass = 18.990000
Diameter/Width = 0.435900
Length = 0.910800

name = Helium Tank

quantity = 1

parent = 5

materialID = 8

type = Cylinder

Aero Mass = 9.317000

Thermal Mass = 9.317000

Diameter/Width = 0.413000

Length = 0.910800

name = LOX Tank

quantity = 1

parent = 1

materialID = -1

type = Cylinder

Aero Mass = 71.279999

Thermal Mass = 68.000000

Diameter/Width = 1.800000

Length = 2.916500

name = LOx PMD baffle004005

quantity = 2

parent = 7

materialID = 8

type = Flat Plate

Aero Mass = 0.352000

Thermal Mass = 0.352000

Diameter/Width = 0.119000

Length = 0.372000

name = LOx PMD Baffle0006

quantity = 16

parent = 7
materialID = 8
type = Flat Plate
Aero Mass = 0.136000
Thermal Mass = 0.136000
Diameter/Width = 0.100000
Length = 0.151700

name = LOx PMD Base
quantity = 2
parent = 7
materialID = 8
type = Flat Plate
Aero Mass = 0.200000
Thermal Mass = 0.200000
Diameter/Width = 0.139000
Length = 0.200000

name = Intertank Bellows
quantity = 1
parent = 1
materialID = 59
type = Cylinder
Aero Mass = 1.548000
Thermal Mass = 1.548000
Diameter/Width = 0.060000
Length = 0.200000

name = Component Panel
quantity = 3
parent = 1
materialID = -1
type = Box

Aero Mass = 6.700000

Thermal Mass = 4.900000

Diameter/Width = 0.480000

Length = 0.480000

Height = 0.480000

name = panel core

quantity = 3

parent = 12

materialID = 5

type = Box

Aero Mass = 1.800000

Thermal Mass = 1.800000

Diameter/Width = 0.480000

Length = 0.480000

Height = 0.480000

name = Engine

quantity = 1

parent = 1

materialID = 19

type = Cylinder

Aero Mass = 33.262001

Thermal Mass = 33.262001

Diameter/Width = 0.197000

Length = 0.656000

name = Propulsion Lines

quantity = 12

parent = 1

materialID = 54

type = Flat Plate

Aero Mass = 10.580000

Thermal Mass = 10.580000

Diameter/Width = 10.575000

Length = 400.000000

name = Avionics

quantity = 14

parent = 1

materialID = 8

type = Box

Aero Mass = 4.280000

Thermal Mass = 4.280000

Diameter/Width = 0.200000

Length = 0.800000

Height = 0.018000

name = Sump

quantity = 1

parent = 1

materialID = 9

type = Cylinder

Aero Mass = 8.400000

Thermal Mass = 8.400000

Diameter/Width = 0.420000

Length = 0.200000

name = turbopump

quantity = 1

parent = 1

materialID = 59

type = Cylinder

Aero Mass = 6.300000

Thermal Mass = 6.300000

Diameter/Width = 0.320000

Length = 0.360000

name = Nitrogen Tank Support Structure

quantity = 5

parent = 1

materialID = 8

type = Box

Aero Mass = 2.700000

Thermal Mass = 2.700000

Diameter/Width = 0.300000

Length = 0.300000

Height = 0.100000

name = Fuel Tank Support Structure

quantity = 16

parent = 1

materialID = 8

type = Flat Plate

Aero Mass = 2.300000

Thermal Mass = 2.300000

Diameter/Width = 0.400000

Length = 0.500000

name = Helium Tank Support Structure

quantity = 3

parent = 1

materialID = 8

type = Box

Aero Mass = 3.100000

Thermal Mass = 3.100000

Diameter/Width = 0.300000

Length = 0.300000

Height = 0.100000

name = LOX Support Structure

quantity = 20

parent = 1

materialID = 8

type = Box

Aero Mass = 1.780000

Thermal Mass = 1.780000

Diameter/Width = 0.105000

Length = 0.200000

Height = 0.050000

name = Engine Structure

quantity = 6

parent = 1

materialID = 56

type = Flat Plate

Aero Mass = 2.800000

Thermal Mass = 2.800000

Diameter/Width = 0.200000

Length = 0.500000

name = Engine Manifold

quantity = 1

parent = 1

materialID = 37

type = Cylinder

Aero Mass = 4.800000

Thermal Mass = 4.800000

Diameter/Width = 0.260000

Length = 0.800000

name = Fuel Core HERO 110

quantity = 1

parent = 1

materialID = -2

type = Flat Plate

Aero Mass = 2.382000

Thermal Mass = 2.382000

Diameter/Width = 1.380000

Length = 1.850000

name = Fuel Core HERO 71

quantity = 1

parent = 1

materialID = -2

type = Cylinder

Aero Mass = 13.630000

Thermal Mass = 13.630000

Diameter/Width = 1.850000

Length = 1.600000

name = Outer Aft Fuel Boss

quantity = 1

parent = 1

materialID = 8

type = Flat Plate

Aero Mass = 1.721000

Thermal Mass = 1.721000

Diameter/Width = 0.120000

Length = 0.500000

name = Inner Fore Fuel Boss

quantity = 1

parent = 1

materialID = 8

type = Flat Plate
Aero Mass = 1.130000
Thermal Mass = 1.130000
Diameter/Width = 0.140000
Length = 0.400000

name = Outer Fore Fuel Boxx
quantity = 1
parent = 1
materialID = 8
type = Cylinder
Aero Mass = 1.662000
Thermal Mass = 1.662000
Diameter/Width = 0.140000
Length = 0.400000

name = Laminate Fuel Tank Alpha
quantity = 1
parent = 1
materialID = -1
type = Cylinder
Aero Mass = 41.220001
Thermal Mass = 41.220001
Diameter/Width = 1.850000
Length = 1.833000

name = LOX Barrel Core HERO
quantity = 2
parent = 1
materialID = -2
type = Box
Aero Mass = 2.840000
Thermal Mass = 2.840000

Diameter/Width = 1.240000

Length = 1.240000

Height = 1.240000

name = LOX Barrel Spoiled Core HERO

quantity = 2

parent = 1

materialID = -2

type = Cylinder

Aero Mass = 3.751800

Thermal Mass = 3.751800

Diameter/Width = 1.850000

Length = 0.909000

name = LOX Dome to Barrel Wedge

quantity = 12

parent = 1

materialID = -3

type = Box

Aero Mass = 0.107000

Thermal Mass = 0.107000

Diameter/Width = 0.500000

Length = 0.925000

Height = 0.129000

name = LOX Dome to Barrel Wedge Ply tie

quantity = 4

parent = 1

materialID = -1

type = Flat Plate

Aero Mass = 1.101272

Thermal Mass = 1.101272

Diameter/Width = 0.200000

Length = 1.827000

name = RPLOX Circumferential Laminate Biscuit
quantity = 1
parent = 1
materialID = -1
type = Cylinder
Aero Mass = 1.919000
Thermal Mass = 1.919000
Diameter/Width = 0.140000
Length = 1.848000

name = Intertank Panel Core
quantity = 1
parent = 1
materialID = 7
type = Box
Aero Mass = 0.036600
Thermal Mass = 0.036600
Diameter/Width = 0.300000
Length = 0.430000
Height = 0.200000

name = Intertank Vertical Panel
quantity = 1
parent = 1
materialID = 5
type = Box
Aero Mass = 0.500000
Thermal Mass = 0.500000
Diameter/Width = 0.200000
Length = 0.500000
Height = 0.100000

name = Intertank Panel Master

quantity = 1

parent = 1

materialID = -1

type = Flat Plate

Aero Mass = 19.600000

Thermal Mass = 19.600000

Diameter/Width = 0.680000

Length = 2.340000

name = Turbopump Exhaust

quantity = 3

parent = 1

materialID = 36

type = Cylinder

Aero Mass = 3.920000

Thermal Mass = 3.920000

Diameter/Width = 0.300000

Length = 0.100000

name = copv bracket

quantity = 6

parent = 1

materialID = -1

type = Box

Aero Mass = 2.100000

Thermal Mass = 2.100000

Diameter/Width = 0.200000

Length = 0.600000

Height = 0.070000

name = RCS assemblies

quantity = 4

parent = 1

materialID = 9

type = Box

Aero Mass = 0.460000

Thermal Mass = 0.460000

Diameter/Width = 0.070000

Length = 0.080000

Height = 0.040000

name = FRE Cooling Manifold

quantity = 1

parent = 1

materialID = 8

type = Cylinder

Aero Mass = 2.670000

Thermal Mass = 2.670000

Diameter/Width = 0.304000

Length = 0.100000

name = FRE Heat Sink

quantity = 2

parent = 1

materialID = 19

type = Cylinder

Aero Mass = 8.400000

Thermal Mass = 8.400000

Diameter/Width = 0.300000

Length = 0.780000

**********OUTPUT****

Item Number = 1

name = Alpha2ndStage

Demise Altitude = 77.991905

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Nitrogen Tank Overwrap

Demise Altitude = 77.971474

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Nitrogen Tank

Demise Altitude = 77.236000

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Fuel Tank

Demise Altitude = 77.961258

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Helium Tank Overwrap

Demise Altitude = 77.971474

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Helium Tank

Demise Altitude = 68.994026

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = LOX Tank

Demise Altitude = 77.981697

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = LOx PMD baffle004005

Demise Altitude = 73.747971

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = LOx PMD Baffle0006

Demise Altitude = 74.351906

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = LOx PMD Base

Demise Altitude = 74.452072

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Intertank Bellows

Demise Altitude = 56.816074

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Component Panel

Demise Altitude = 77.991905

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = panel core

Demise Altitude = 73.103767

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Engine

Demise Altitude = 40.669407

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Propulsion Lines

Demise Altitude = 77.991905

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Avionics

Demise Altitude = 55.560081

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Sump

Demise Altitude = 61.334454

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = turbopump

Demise Altitude = 0.000000

Debris Casualty Area = 0.882494

Impact Kinetic Energy = 3218.195068

****

name = Nitrogen Tank Support Structure

Demise Altitude = 61.974270

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Fuel Tank Support Structure

Demise Altitude = 62.947655

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Helium Tank Support Structure

Demise Altitude = 59.636314

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = LOX Support Structure

Demise Altitude = 60.238560

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Engine Structure

Demise Altitude = 0.000000

Debris Casualty Area = 5.036840

Impact Kinetic Energy = 1282.865479

****

name = Engine Manifold

Demise Altitude = 0.000000

Debris Casualty Area = 1.115284

Impact Kinetic Energy = 1153.387573

****

name = Fuel Core HERO 110

Demise Altitude = 77.991905

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Fuel Core HERO 71

Demise Altitude = 77.991905

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Outer Aft Fuel Boss

Demise Altitude = 61.818882

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Inner Fore Fuel Boss

Demise Altitude = 67.150993

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Outer Fore Fuel Boxx

Demise Altitude = 69.871414

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Laminate Fuel Tank Alpha

Demise Altitude = 77.991905

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = LOX Barrel Core HERO

Demise Altitude = 77.991905

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = LOX Barrel Spoiled Core HERO

Demise Altitude = 77.991905

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = LOX Dome to Barrel Wedge

Demise Altitude = 77.991905

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = LOX Dome to Barrel Wedge Ply tie

Demise Altitude = 77.991905

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = RPLOX Circumferential Laminate Biscuit

Demise Altitude = 77.991905

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Intertank Panel Core

Demise Altitude = 77.880119

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Intertank Vertical Panel

Demise Altitude = 75.676437

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Intertank Panel Master

Demise Altitude = 77.981697

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Turbopump Exhaust

Demise Altitude = 58.422543

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = copv bracket

Demise Altitude = 77.991905

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = RCS assemblies

Demise Altitude = 65.861137

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = FRE Cooling Manifold

Demise Altitude = 66.923584

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = FRE Heat Sink

Demise Altitude = 66.218376

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

**********INPUT****

Item Number = 2

name = Alpha1stStage

quantity = 1

parent = 0

materialID = -1

type = Cylinder

Aero Mass = 2894.800049

Thermal Mass = 2894.800049

Diameter/Width = 2.000000

name = LOX tank and support

quantity = 1

parent = 1

materialID = -1

type = Cylinder

Aero Mass = 2100.000000

Thermal Mass = 2100.000000

Diameter/Width = 2.000000

Length = 12.000000

name = Fuel tank and support

quantity = 1

parent = 1

materialID = -1

type = Cylinder

Aero Mass = 720.000000

Thermal Mass = 720.000000

Diameter/Width = 2.000000

Length = 6.000000

name = AvionicsS1

quantity = 11

parent = 1

materialID = 8

type = Box

Aero Mass = 6.100000

Thermal Mass = 6.100000

Diameter/Width = 0.200000

Length = 0.800000

Height = 0.018000

**********OUTPUT****

Item Number = 2

name = Alpha1stStage

Demise Altitude = 77.999794

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = LOX tank and support

Demise Altitude = 77.924110

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = Fuel tank and support

Demise Altitude = 77.954422

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = AvionicsS1

Demise Altitude = 61.219875

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

**********INPUT****

Item Number = 3

name = PayloadFairing1

quantity = 1

parent = 0

materialID = -1

type = Flat Plate

Aero Mass = 108.599998

Thermal Mass = 108.599998

Diameter/Width = 2.200000

Length = 2.500000

name = P

quantity = 1

parent = 1

materialID = -1

type = Flat Plate

Aero Mass = 108.599998

Thermal Mass = 108.599998

Diameter/Width = 2.200000

Length = 2.500000

**********OUTPUT****

Item Number = 3

name = PayloadFairing1

Demise Altitude = 77.990257

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = P

Demise Altitude = 77.959877

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

**********INPUT****

Item Number = 4

name = PayloadFairing2

quantity = 1

parent = 0

materialID = -1

type = Flat Plate

Aero Mass = 98.199997

Thermal Mass = 98.199997

Diameter/Width = 2.200000

Length = 2.500000

name = P

quantity = 1

parent = 1

materialID = -1

type = Flat Plate

Aero Mass = 98.199997

Thermal Mass = 98.199997

Diameter/Width = 2.200000

Length = 2.500000

**********OUTPUT****

Item Number = 4

name = PayloadFairing2

Demise Altitude = 77.996223

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

name = P

Demise Altitude = 77.965012

Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****

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