RANGE

(Ranging and Nanosatellite Guidance Experiment)

Orbital Debris Assessment Report (ODAR)

Revision A
12 February 2016

Prepared for NASA HQ in compliance with NASA-STD-8719.14 by Georgia Institute of Technology. This document contains ITAR and export control restrictions. The ITAR restrictions regard the launch vehicle, date, and location. NASA Debris Analysis Software (DAS) version 2.02 was used in preparing this report.

Submitted by:

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Concurrence by:

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NASA Chief, Safety and Mission Assurance

Approval and Risk accept by:

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Mission Directorate Associate Administrator

Record of Revisions

Revision	Date	Affected Pages	Description of Change	Authors
A	12 February 2016	All	Initial Revisions	Michael Herman Daniel Groesbeck

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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.

Orbital Debris Self-Assessment Report Evaluation: RANGE Mission

Requirement #	Launch Vehicle				Spacecraft			Comments
	Compliant	Not Compliant	Incomplete	Standard Non-Compliant	Compliant	Not Compliant	Incomplete	
4.3-1.a			X		X			No Debris Released in LEO.
4.3-1.b			X		X			No Debris Released in LEO.
4.3-2			X		X			No Debris Released in LEO.
4.4-1			X		X			
4.4-2			X		X			
4.4-3			X		X			No Planned Breakups.
4.4-4			X		X			No Planned Breakups.
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			No Tethers Used.

Assessment Report Format

ODAR Technical Sections Format Requirements:
This ODAR follows the format in NASA-STD-8719.14, Appendix A.1 and includes the content indicated at a minimum in each section 2 through 8 below for the RANGE satellite. Sections 9 through 14 apply to the launch vehicle ODAR and are omitted.

ODAR Section 1: Program Management and Mission Overview

Mission Description

The RANGE mission will demonstrate improved absolute positioning of two 1.5U nanosatellites through a low-cost inter-satellite ranging instrument. The positioning will be validated through ground laser measurements. The satellites will be propulsion-less and rely on differential drag for control. The satellite will launch from Vandenburg AFB and deploy from the Minotaur-C launch vehicle. It will be inserted into an orbit at 500 km perigee and apogee altitude on an inclination from the equator at 97.4065 degrees. Atmospheric drag will slow the satellite and reduce the altitude of the orbit, until de-orbiting occurs approximately 7.84 years after launch and will conclude the mission. [1]

Launch vehicle and launch site: Minotaur-C from Vandenberg AFB

Proposed launch date: October 2016

Mission duration: 1 year

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

The RANGE orbital elements are defined as follows:

Apogee: 500 km
Perigee: 500 km
Inclination: 97.4065 deg

RANGE has no propulsion and therefore does not actively change orbits. There is no parking or transfer orbit.

At this time, we know of no potential interaction or physical interference between RANGE and any other operational spacecraft. Further analysis is planned on proving beyond reasonable doubt that ISS interference is avoidable through a probabilistic differential drag collision avoidance maneuver study.

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[1] This page contains ITAR and export control restrictions regarding the launch vehicle, date, and location.

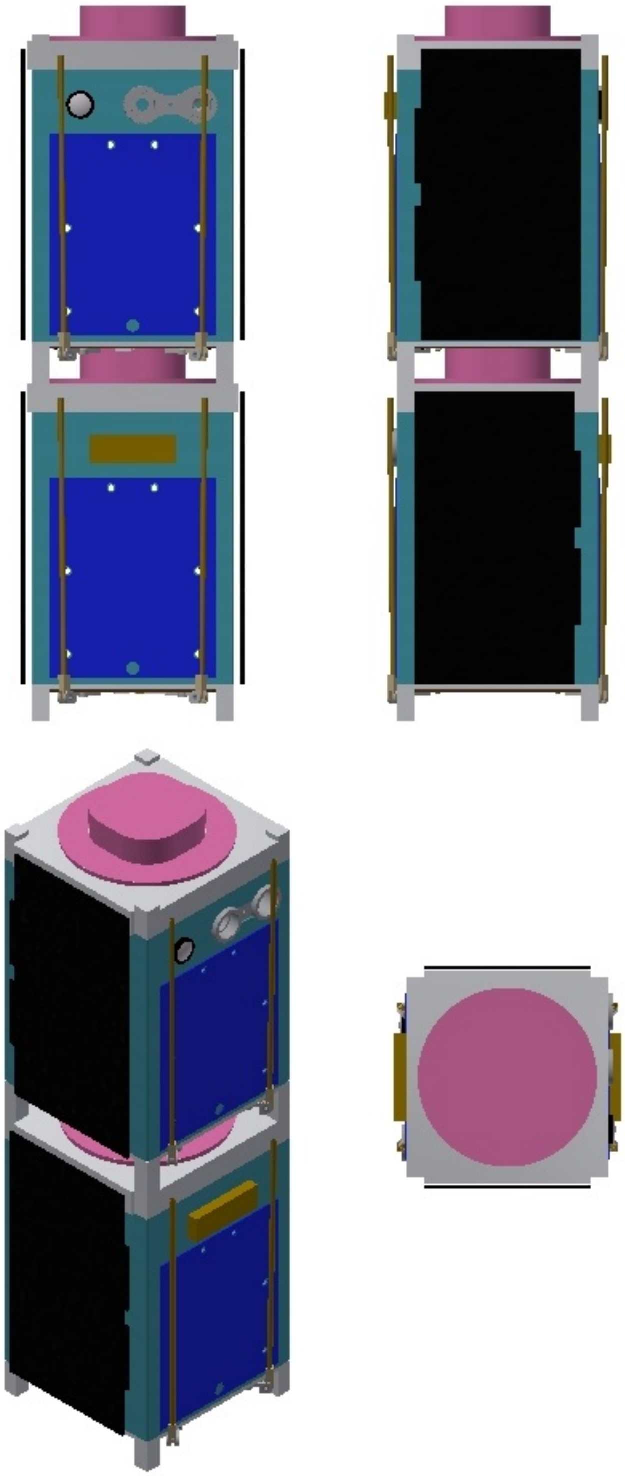

Figure 1: RANGE 4-view for undeployed stowed stack configuration

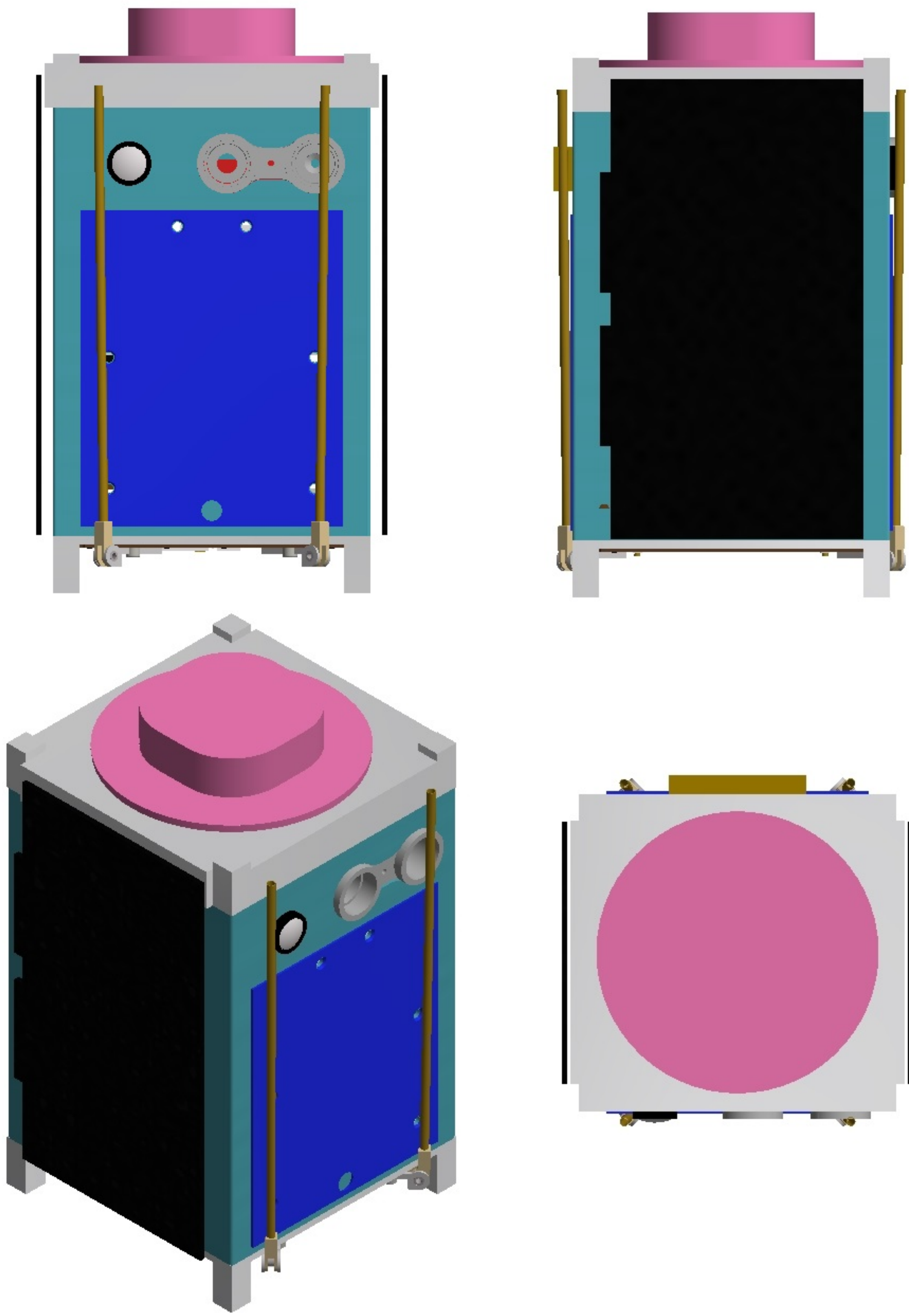

Figure 2: RANGE 4-view separated undeployed configuration

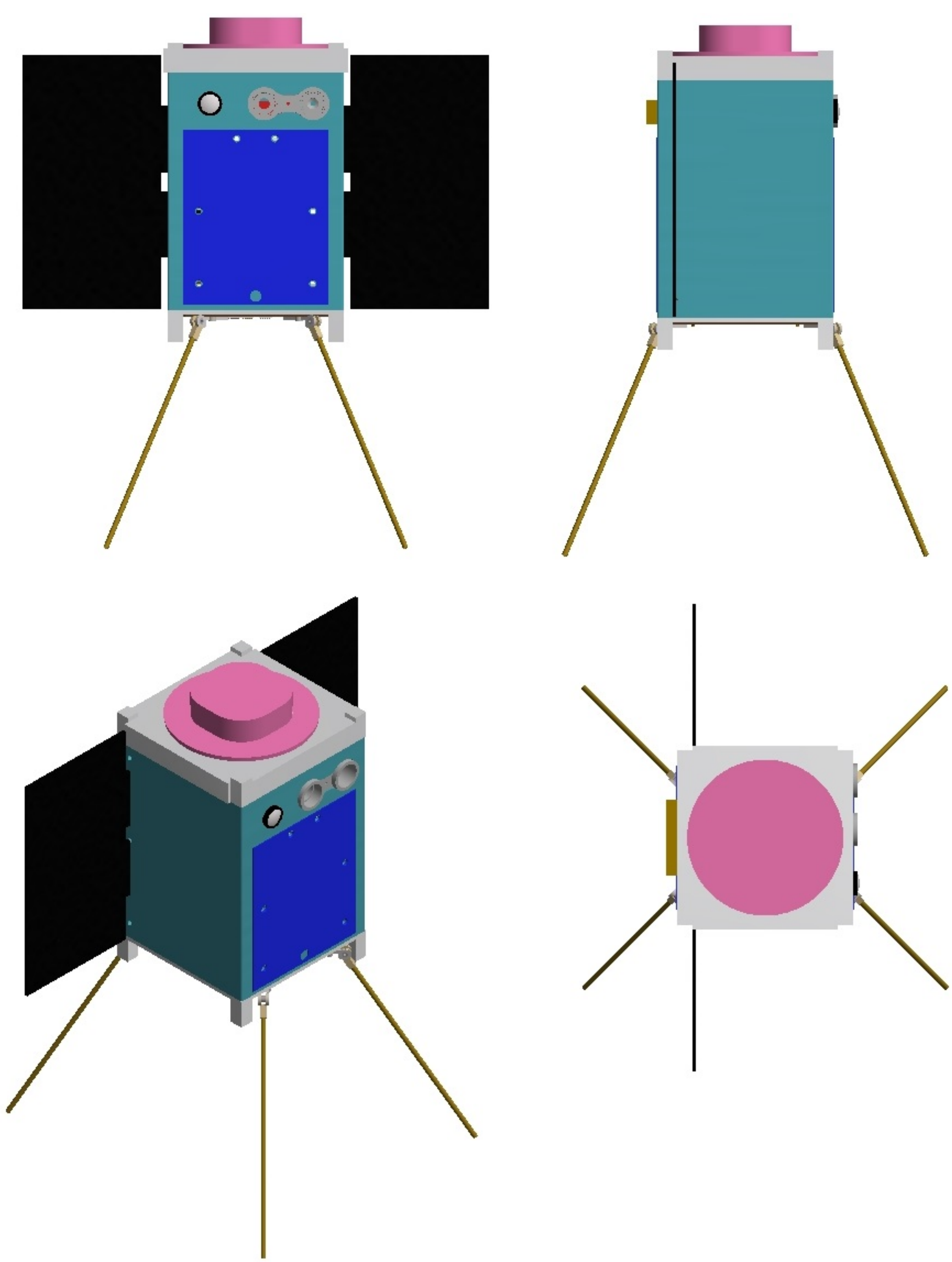

Figure 3: RANGE 4-view separated deployed configuration

Interaction or potential physical interference with other operational spacecraft:

- At this time, we know of no potential interaction or physical interference between RANGE and any other operational spacecraft.

Project Management:

- Principal Investigator: Dr. Brian Gunter
- Project Manager: Byron Davis

Key engineering personnel:

- ADCS Lead: Rohan Deshmukh
- COMM Lead: Michael Lucchi
- GNC Lead: Michael Herman
- Laser Ranging Lead: Zachary Levine
- OBC Lead: John Ridderhof
- Structures Lead: William O'Donoghue and Ariana Keeling
- Thermal Control System Lead:
- EPS Lead: Austin Claybrook

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 mission design and development milestones from NASA mission selection through proposed launch date, including spacecraft PDR and CDR (or equivalent) dates*:

Date	Milestone
May 2016	Design and Fabrication
July 2016	Integration
August 2016	Testing
September 2016	Shipment
October 2016	Launch
October 2016	Deployment and Operations

Section 2: Spacecraft Description

Physical description of the spacecraft:

The RANGE satellites are two separated 1.5U nanosatellites with dimensions of 15 cm X 10 cm X 10 cm and a total mass of about 2.125 kg each with un-deployed solar arrays. The un-separated configuration has dimensions of 30 cm X 10 cm X 10 cm with un-deployed solar arrays and a total mass of 4.25 kg. The satellites have 1U symmetric single sided deployable solar arrays that increase the separated deployed configuration to 15 cm X 30 cm X 10 cm.

Each RANGE satellite will contain the following systems:

- GomSpace ANT430 antenna
- GomSpace NanoPower p31us EPS board with Lithium Ion battery pack
- GomSpace NanoCom AX100 UHF/VHF transceiver

- GomSpace NanoHub
- GomSpace NanoMind 3200 onboard computer
- Solar MEMS Nano SSOC D60 fine sun sensor
- Four in-house built coarse sun sensors
- Novatel OEM628 GPS receiver
- ANTCOM GPS antenna
- CubeSense single axis reaction wheel
- In-house built three axis magnetorquer system
- In-house built laser ranging system
- Micrometer
- ThorLabs laser diode
- Princeton Lightwave Geiger-mode avalanche photodiode
- Microsemi GPS-2750 10 MHz CSAC-based Disciplined Oscillator with QUANTUM SA.45s Chip Scale Atomic Clock
- Pumpkin solar cells.

Total satellite mass at launch, including all propellants and fluids:
- 4.25 kg

Dry mass of satellite at launch, excluding solid rocket motor propellants:
- 4.25 kg

Description of all propulsion systems (cold gas, mono-propellant, bi-propellant, electric, nuclear):
- There will be no propulsion systems on RANGE.

Identification, including mass and pressure, of all fluids (liquids and gases) planned to be on board and a description of the fluid loading plan or strategies, excluding fluids in sealed heat pipes:
- Not applicable as there will be no fluids or gasses on board.

Fluids in Pressurized Batteries:
- None. RANGE uses unpressurized standard COTS Lithium-Ion battery cells.

Description of attitude control system and indication of the normal attitude of the spacecraft with respect to the velocity vector:
- RANGE uses magnetorquer and reaction wheel control systems. The magnetorquers will provide three degree of freedom control with redundancy. The reaction wheel will only provide single y-axis control for differential drag ratio modifications.

Description of any range safety or other pyrotechnic devices:
- RANGE will use a burn wire for deployment of the single-sided single-deploy 1U solar arrays. The wire will burn at a resistor temperature of 200 C and a voltage between 12.5 and 16.8 V.

Description of the electrical generation and storage system:
- The power will be generated using solar panels and Lithium-Ion batteries. The batteries used will be the GomSpace NanoPower P31us with 6-8.4 V onboard lithium ion battery pack. The solar

panels will be Pumpkin single-sided single-deploy solar array configuration with two cells on the front body mounted face, two cells on the back body mounted face, and six cells on the deployable solar arrays. The body mounted side, top, and bottom faces will be clear of solar cells.

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

Identification of any radioactive materials on board:
- None.

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

Identification of any object (>1 mm) expected to be released from the spacecraft any time after launch, including object dimensions, mass, and material:
- There are no intentional releases.

Rationale/necessity for release of each object:
- Not applicable.

Time of release of each object, relative to launch time:
- Not applicable.

Release velocity of each object with respect to spacecraft:
- Not applicable.

Expected orbital parameters (apogee, perigee, and inclination) of each object after release:
- Not applicable.

Calculated orbital lifetime of each object, including time spent in Low Earth Orbit (LEO):
- Not applicable.

Assessment of spacecraft compliance with Requirements 4.3-1 and 4.3-2 (per DAS v2.0):
- **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 operation. 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. A controlled separation of the 3U nanosatellite package into two separate 1.5U nanosatellites will be executed following detumble.

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

- The battery safety systems discussed in the FMEA (see requirement 4.4-1 below) describe the combined faults that must occur for any of nine independent, mutually exclusive failure modes that could lead to a battery venting. If the LiIon 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 planned intentional breakups 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:

- RANGE contains no components which are passivated at EOM. The satellite will breakup in atmospheric reentry. There is no plan to passivate the batteries, however in the case 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:

- It was deemed unnecessary to passivate the lithium ion batteries for EOM, as the satellite will break up on re-entry at the end of the mission.

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 and FMEA details:

Battery explosion:

Effect:

- All failure modes below might result in battery explosion with the possibility of orbital debris generation. However, in the unlikely event that a battery cell does explosively rupture, the small size, mass, and potential energy, of these small batteries is such that while the spacecraft could be expected to vent gases, most debris from the battery rupture should be contained within the vessel due to the lack of penetration energy.

Probability:

- Extremely Low. It is believed to be less than 0.01% given that multiple independent (not common mode) faults must occur for each failure mode to cause the ultimate effect (explosion).

Failure mode 1: Internal short circuit.

Mitigation 1: Qualification and acceptance shock, vibration, thermal cycling, and vacuum tests followed by maximum system rate-limited charge and discharge to prove that no internal short circuit sensitivity exists.

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

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

Mitigation 2: Cells were tested in lab for high load discharge rates in a variety of flight like configurations to determine if the feasibility of an out of control thermal rise in the cell. Cells were also tested in a hot environment to test the upper limit of the cells capability. No failures were seen.

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

Failure Mode 3: Overcharging and excessive charge rate.

Mitigation 3: The satellite bus battery charging circuit design eliminates the possibility of the batteries being overcharged if circuits function nominally. This circuit has been proto- qualification tested for survival in shock, vibration, and thermal-vacuum environments. The charge circuit disconnects the incoming current when battery voltage indicates normal full charge at 8.4 V. If this circuit fails to operate, continuing charge can cause gas generation. The batteries include overpressure release vents that allow gas to escape, virtually eliminating any explosion hazard.

Combined faults required for realized failure:

1. **For overcharging:** The charge control circuit must fail to function AND the PTC device must fail (or temperatures generated must be insufficient to cause the PTC device to modulate) AND the overpressure relief device must be inadequate to vent generated gasses at acceptable rates to avoid explosion.

2. **For excessive charge rate:** The maximum charging rate from a single solar panel when in AM 1.5G conditions (in space, perpendicular to the sun) is 124 mA. The maximum charge rate our battery can accept is 3 A. The battery is a proto-qualified Molicell from the JSC ISS program, and has two 18650 cells. The battery itself has one string of 2 cells connected in series. Due to

solar panel current limits and their direction-facing arrangement on the satellite, there is no physical means of exceeding charging rate limits, even if the single string from the battery was accepting charge. The overpressure relief vent keeps the battery cells from rupturing, and is thus limited to worst-case effects of overcharging.

Failure Mode 4: Excessive discharge rate or short circuit due to external device failure or terminal contact with conductors not at battery voltage levels (due to abrasion or inadequate proximity separation).

Mitigation 4: This failure mode is negated by a) qualification tested short circuit protection on each external circuit, b) design of battery packs and insulators such that no contact with nearby board traces is possible without being caused by some other mechanical failure, c) obviation of such other mechanical failures by proto-qualification and acceptance environmental tests (shock, vibration, thermal cycling, and thermal-vacuum tests).

Combined faults required for realized failure: An external load must fail/short-circuit **AND** external over-current detection and disconnect function must all occur to enable this failure mode.

Failure Mode 5: Inoperable vents. *Mitigation 5:* Battery vents are not inhibited by the battery holder design or the spacecraft. *Combined effects required for realized failure:* The manufacturer fails to install proper venting.

Failure Mode 6: Crushing.

Mitigation 6: This mode is negated by spacecraft design. There are no moving parts in the proximity of the batteries.

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

Failure Mode 7: Low level current leakage or short-circuit through battery pack case or due to moisture-based degradation of insulators.

Mitigation 7: These modes are negated by a) battery holder/case design made of non-conductive plastic, and b) operation in vacuum such that no moisture can affect insulators.

Combined faults required for realized failure: Abrasion or piercing failure of circuit board coating or wire insulators **AND** dislocation of battery packs **AND** failure of battery terminal insulators **AND** failure to detect such failures in environmental tests must occur to result in this failure mode.

Failure Mode 8: Excess temperatures due to orbital environment and high discharge combined.

Mitigation 8: The spacecraft thermal design will negate this possibility. Thermal rise has been analyzed in combination with space environment temperatures showing that batteries do not exceed normal allowable operating temperatures which are well below temperatures of concern for explosions. *Combined faults required for realized failure:* Thermal analysis **AND** thermal design **AND** mission simulations in thermal-vacuum chamber testing **AND** the PTC device must fail **AND** over- current monitoring and control must all fail for this failure mode to occur.

Failure Mode 9: Polarity reversal due to over-discharge caused by continuous load during periods of negative power generation vs. consumption.

Mitigation 9: In nominal operations, the spacecraft EPS design negates this mode because the processor will stop when voltage drops too low, below 7 V. This disables ALL connected loads, creating a guaranteed power-positive charging scenario. The spacecraft will not restart or connect any loads until battery voltage is above the acceptable threshold. At this point, only the safemode processor and radio receiver are enabled and charging the battery. Once the battery reaches 90% of the peak voltage (around 7.5 V), it will switch to nominal mode and will be able to receive ground commands for continuing mission functions.

Combined faults required for realized failure: The microcontroller must stop executing code **AND** significant loads must be commanded/stuck "on" **AND** power margin analysis must be wrong **AND** the charge control circuit must fail for this failure mode to occur.

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

Design of all spacecraft and launch vehicle orbital stages shall include the ability to deplete all onboard sources of stored energy and disconnect all energy generation sources when they are no longer required for mission operations or 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:

- SkyCube's battery charge circuits include overcharge protection and to limit the risk of battery failure. However, in the unlikely event that a battery cell does explosively rupture, the small size, mass, and potential energy, of these small batteries is such that while the spacecraft could be expected to vent gases, most debris from the battery rupture should be contained within the vessel due to the lack of penetration energy.

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

Assessment of spacecraft compliance with Requirements 4.5-1 and 4.5-2 (per DAS v2.02, 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: 0.000000; 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: 0.000000; COMPLIANT

  Figures 4 and 5 show the DAS derived ISS avoidance maneuver time analyses. Figure 4 illustrates how switching between high and low drag modes will yield a avoidance maneuver time based on the given radial keepout distance. Figure 4 uses a radial keepout distance of ±1km. Figure 5 shows how the avoidance maneuver time varies with the radial keepout distance. The most realistic case is a radial keepout distance of ±10km. This keepout distance yields an avoidance maneuver time of approximately 40 days and is defined as the nominal avoidance scenario.

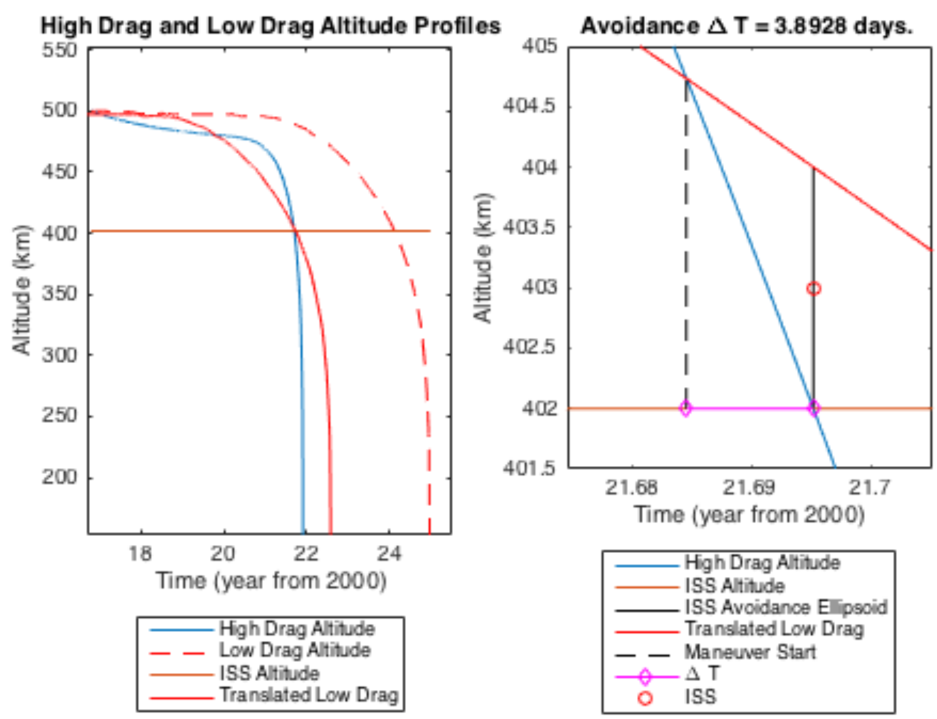

Figure 4: RANGE ISS Avoidance Maneuver Time Analysis from DAS Output

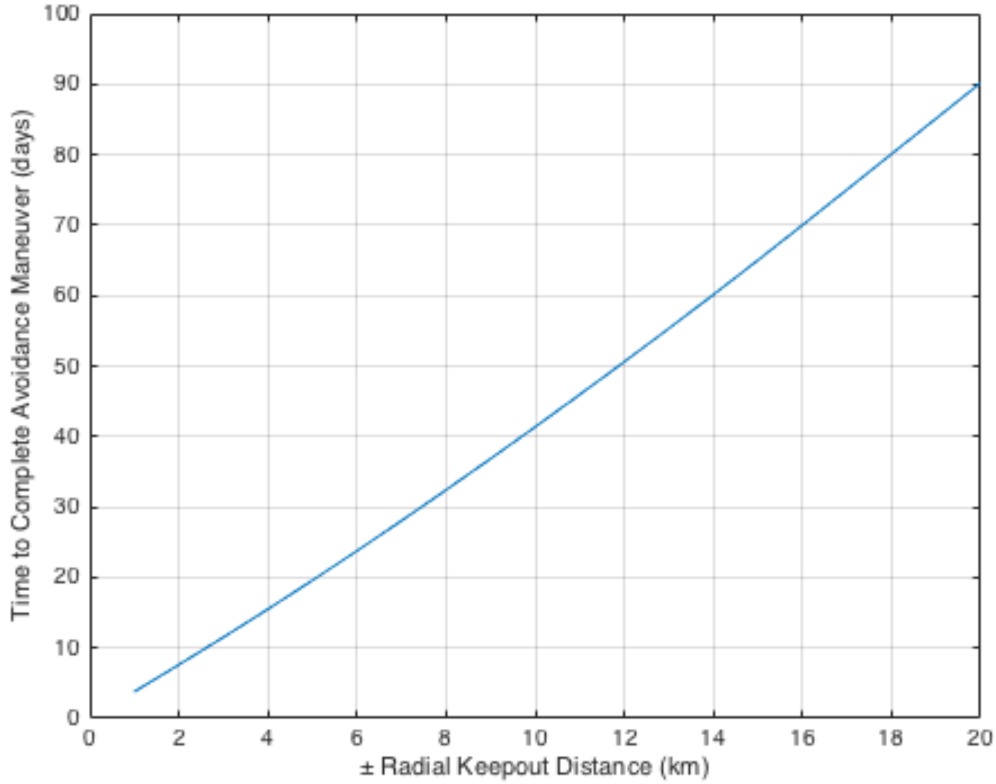

Figure 5: RANGE ISS Avoidance Maneuver Time versus Radial Keepout Distance from DAS Output

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

6.1 Description of spacecraft disposal option selected:

- The satellite will de-orbit naturally by atmospheric re-entry. There is no propulsion system.

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

- None.

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

- **Spacecraft Mass:** 2.125 kg
- **Cross-sectional Area:** 0.015 m^2 (Calculated by DAS 2.02 for the configuration in Figure 3).

- **Area to mass ratio:** 0.015/2.125 = 0.007059 m^2/kg

6.4 Assessment of spacecraft compliance with Requirements 4.6-1 through 4.6-5 (per DAS v 2.0 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: (Requirement 56557)

  a. Atmospheric reentry option:
  - Leave the space structure in an orbit in which natural forces will lead to atmospheric reentry within 25 years after the completion of mission but no more than 30 years after launch; or
  - Maneuver the space structure into a controlled de-orbit trajectory as soon as practical after completion of mission.

  b. Storage orbit option:
  - Maneuver the space structure into an orbit with perigee altitude greater than 2000 km and apogee less than GEO - 500 km.

  c. Direct retrieval:
  - Retrieve the space structure and remove it from orbit within 10 years after completion of mission.

Analysis: The RANGE satellite reentry is COMPLIANT using Method “a”. RANGE will re-enter approximately 7.84 years after launch with orbit history as shown in Figure 6 (analysis assumes a nadir pointing configuration).

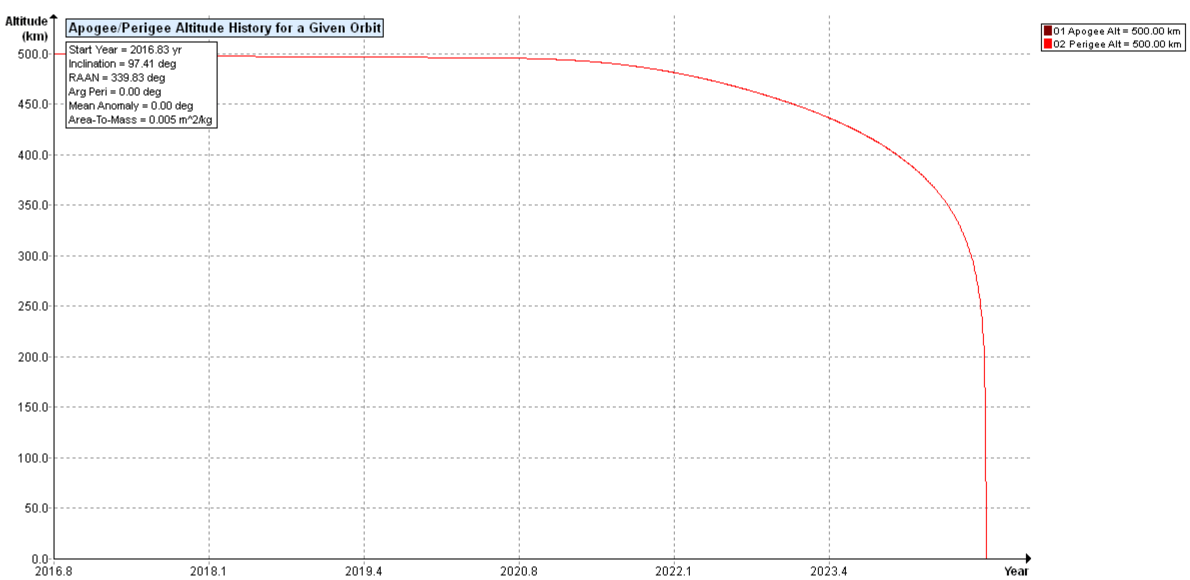

Figure 6: RANGE orbit history for low-drag configuration

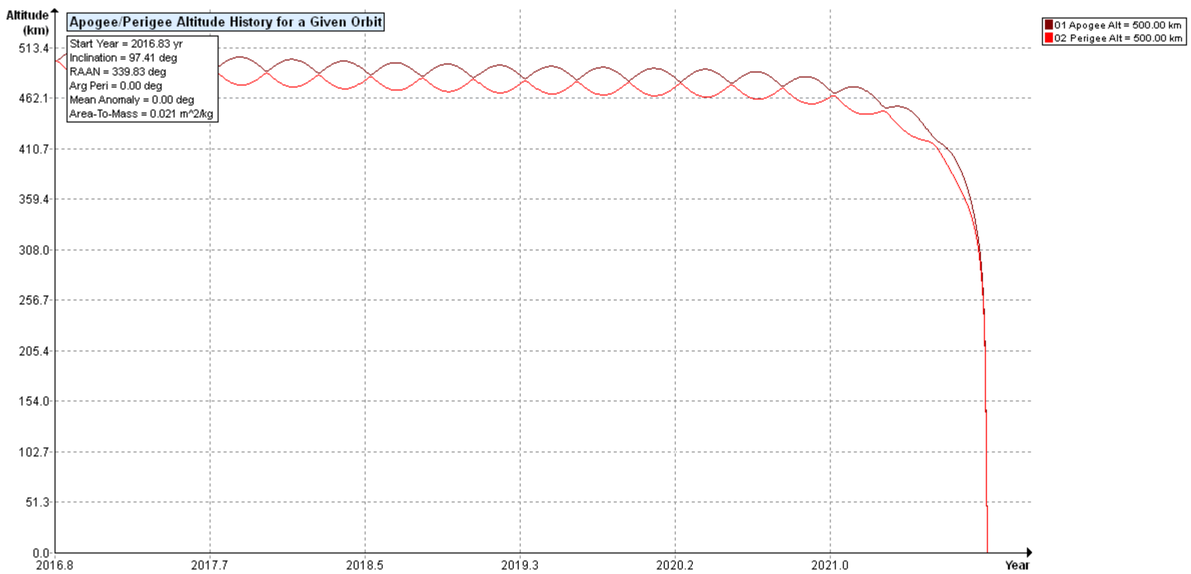

Figure 7: RANGE orbit history for high-drag configuration

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

Analysis: Not applicable. RANGE orbit is LEO.

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

Analysis: Not applicable. RANGE orbit is LEO.

Requirement 4.6-4. Reliability of Postmission Disposal Operations

Analysis: RANGE de-orbiting does not rely on de-orbiting devices. Deployment from launch vehicle will result in de-orbiting in approximately 7.84 years with no disposal or de-orbiting actions required.

ODAR Section 7: Assessment of Spacecraft Reentry Hazards

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:

a. 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 reports that RANGE is compliant with the requirement. It predicts that no components reach the ground. As seen in the analysis outputs below, the impact kinetic energies are 0.000000 Joules and impact casualty areas are all 0.000000 square meters.

02 09 2016; 17:18:03PM DAS Application Started
02 09 2016; 17:18:03PM Opened Project C:\Program Files (x86)\NASA\DAS 2.0\project\Range\
02 09 2016; 17:18:11PM Processing Requirement 4.3-1: Return Status : Not Run

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

=============== End of Requirement 4.3-1 ===============
02 09 2016; 17:18:14PM Processing Requirement 4.3-2: Return Status : Passed

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

=============== End of Requirement 4.3-2 ===============
02 09 2016; 17:18:16PM Requirement 4.4-3: Compliant

=============== End of Requirement 4.4-3 ===============
02 09 2016; 17:18:22PM Processing Requirement 4.5-1: Return Status : Passed

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

INPUT

Space Structure Name = Range 1
Space Structure Type = Payload
Perigee Altitude = 500.000000 (km)
Apogee Altitude = 500.000000 (km)
Inclination = 97.406500 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Final Area-To-Mass Ratio = 0.007059 (m^2/kg)
Start Year = 2016.830000 (yr)
Initial Mass = 2.250000 (kg)
Final Mass = 2.250000 (kg)
Duration = 6.642000 (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 ===============
02 09 2016; 17:18:28PM Requirement 4.5-2: Compliant
02 09 2016; 17:18:29PM Processing Requirement 4.6 Return Status : Passed

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

INPUT

Space Structure Name = Range 1
Space Structure Type = Payload

Perigee Altitude = 500.000000 (km)
Apogee Altitude = 500.000000 (km)
Inclination = 97.406500 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Area-To-Mass Ratio = 0.007059 (m^2/kg)
Start Year = 2016.830000 (yr)
Initial Mass = 2.250000 (kg)
Final Mass = 2.250000 (kg)
Duration = 6.642000 (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 = 500.000000 (km)
Suggested Apogee Altitude = 500.000000 (km)
Returned Error Message = Reentry during mission (no PMD req.).

Released Year = 2023 (yr)
Requirement = 61
Compliance Status = Pass

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

=============== End of Requirement 4.6 ===============
02 09 2016; 17:25:39PM *********Processing Requirement 4.7-1
Return Status : Passed

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

name = Range 1
quantity = 1
parent = 0
materialID = 5
type = Box
Aero Mass = 2.250000
Thermal Mass = 2.250000
Diameter/Width = 0.100000
Length = 0.170000
Height = 0.100000

name = CSAC
quantity = 1
parent = 1
materialID = 23
type = Box
Aero Mass = 0.035000
Thermal Mass = 0.035000
Diameter/Width = 0.065000
Length = 0.090150
Height = 0.015000

name = CubeSense Camera
quantity = 1
parent = 1
materialID = 23
type = Box
Aero Mass = 0.080000

Thermal Mass = 0.080000
Diameter/Width = 0.090000
Length = 0.096000
Height = 0.010000

name = Mid Panel for NanoPower
quantity = 1
parent = 1
materialID = 5
type = Flat Plate
Aero Mass = 0.100000
Thermal Mass = 0.100000
Diameter/Width = 0.100000
Length = 0.100000

name = Lidar Housing
quantity = 1
parent = 1
materialID = 23
type = Box
Aero Mass = 0.022000
Thermal Mass = 0.022000
Diameter/Width = 0.037000
Length = 0.048000
Height = 0.020000

name = L-Plate
quantity = 2
parent = 1
materialID = 5
type = Box
Aero Mass = 0.093213
Thermal Mass = 0.093213
Diameter/Width = 0.100000
Length = 0.125000
Height = 0.100000

name = Side PCB
quantity = 4
parent = 1
materialID = 5
type = Box
Aero Mass = 0.004500
Thermal Mass = 0.004500
Diameter/Width = 0.080000
Length = 0.095000

Height = 0.002000

name = GPS Antenna
quantity = 1
parent = 1
materialID = 23
type = Cylinder
Aero Mass = 0.001500
Thermal Mass = 0.001500
Diameter/Width = 0.024000
Length = 0.089000

name = Reaction Wheel Mount
quantity = 1
parent = 1
materialID = 5
type = Box
Aero Mass = 0.001323
Thermal Mass = 0.001323
Diameter/Width = 0.028000
Length = 0.031000
Height = 0.001000

name = Reaction Wheel
quantity = 1
parent = 1
materialID = 5
type = Box
Aero Mass = 0.058590
Thermal Mass = 0.058590
Diameter/Width = 0.031000
Length = 0.031000
Height = 0.028000

name = Sun Sensor
quantity = 1
parent = 1
materialID = 24
type = Box
Aero Mass = 0.006500
Thermal Mass = 0.006500
Diameter/Width = 0.014000
Length = 0.043000
Height = 0.006000

name = Solar Panel

quantity = 4
parent = 1
materialID = 24
type = Flat Plate
Aero Mass = 0.302682
Thermal Mass = 0.302682
Diameter/Width = 0.083000
Length = 0.098000

name = Bottom Panel
quantity = 1
parent = 1
materialID = 5
type = Box
Aero Mass = 0.094997
Thermal Mass = 0.094997
Diameter/Width = 0.100000
Length = 0.100000
Height = 0.015000

name = Mid Panel
quantity = 1
parent = 1
materialID = 5
type = Flat Plate
Aero Mass = 0.011389
Thermal Mass = 0.011389
Diameter/Width = 0.100000
Length = 0.100000

name = End Cap
quantity = 1
parent = 1
materialID = 5
type = Box
Aero Mass = 0.189559
Thermal Mass = 0.189559
Diameter/Width = 0.100000
Length = 0.100000
Height = 0.008000

name = NanoHub Internal
quantity = 1
parent = 1
materialID = 23
type = Box

Aero Mass = 0.045000
Thermal Mass = 0.045000
Diameter/Width = 0.089000
Length = 0.096000
Height = 0.018000

name = Novatell GPS Receiver
quantity = 1
parent = 1
materialID = 23
type = Box
Aero Mass = 0.037000
Thermal Mass = 0.037000
Diameter/Width = 0.060000
Length = 0.100000
Height = 0.009000

name = Nanocom-ant430
quantity = 1
parent = 1
materialID = 5
type = Box
Aero Mass = 0.024000
Thermal Mass = 0.024000
Diameter/Width = 0.113000
Length = 0.113000
Height = 0.098000

name = MotherBoard
quantity = 1
parent = 1
materialID = 23
type = Box
Aero Mass = 0.138404
Thermal Mass = 0.138404
Diameter/Width = 0.089000
Length = 0.092000
Height = 0.019000

name = BP4
quantity = 1
parent = 1
materialID = 46
type = Box
Aero Mass = 0.270000
Thermal Mass = 0.270000

Diameter/Width = 0.087000
Length = 0.093000
Height = 0.029000

name = Placeholder Side Panel
quantity = 2
parent = 1
materialID = 5
type = Flat Plate
Aero Mass = 0.042383
Thermal Mass = 0.042383
Diameter/Width = 0.079000
Length = 0.145000

name = NanoPower-P31us
quantity = 1
parent = 1
materialID = 5
type = Box
Aero Mass = 0.200000
Thermal Mass = 0.200000
Diameter/Width = 0.089000
Length = 0.093000
Height = 0.012000

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

name = Range 1
Demise Altitude = 77.993918
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = CSAC
Demise Altitude = 77.412707
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = CubeSense Camera
Demise Altitude = 76.841738
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****

name = Mid Panel for NanoPower
Demise Altitude = 75.631840
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Lidar Housing
Demise Altitude = 77.240004
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = L-Plate
Demise Altitude = 77.231433
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Side PCB
Demise Altitude = 77.876629
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = GPS Antenna
Demise Altitude = 77.944535
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Reaction Wheel Mount
Demise Altitude = 77.784285
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Reaction Wheel
Demise Altitude = 74.003472
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Sun Sensor
Demise Altitude = 77.726293
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Solar Panel
Demise Altitude = 75.790379
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Bottom Panel
Demise Altitude = 76.103363
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Mid Panel
Demise Altitude = 77.723676
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = End Cap
Demise Altitude = 73.958019
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = NanoHub Internal
Demise Altitude = 77.400199
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Novatell GPS Receiver
Demise Altitude = 77.354097
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Nanocom-ant430
Demise Altitude = 77.785988
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = MotherBoard
Demise Altitude = 76.141238

Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = BP4
Demise Altitude = 0.000000
Debris Casualty Area = 0.453527
Impact Kinetic Energy = 125.910988

****
name = Placeholder Side Panel
Demise Altitude = 77.190613
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = NanoPower-P31us
Demise Altitude = 73.489878
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

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=============== End of Requirement 4.7-1 ===============
02 09 2016; 17:26:08PM Project Data Saved To File

Requirements 4.7-1b and 4.7-1c below are non-applicable requirements because RANGE 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

Not applicable. There are no tethers in the RANGE mission.

END of ODAR for RANGE.