Exhibit A – SSE GNOMES-2 Orbital Debris Assessment Report (ODAR)

GNOMES-ODAR 1.0

This report is presented as compliance with NASA-STD-8719.14 Revision B

DAS Software Version: v.3.0.1

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Revision Record

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

Requirement #	*Launch Vehicle*[1]				*Spacecraft*			*Comments*
	Compliant	Not Compliant	Incomplete	Standard Non-Compliant	Compliant	Not Compliant	Incomplete	
4.3-1.a	☐	☐	✓	☐	✓	☐	☐	No debris released in LEO
4.3-1.b	☐	☐	✓	☐	✓	☐	☐	No debris released in LEO
4.3-2	☐	☐	✓	☐	✓	☐	☐	No debris released near GEO
4.4-1	☐	☐	✓	☐	✓	☐	☐	
4.4-2	☐	☐	✓	☐	✓	☐	☐	
4.4-3	☐	☐	✓	☐	✓	☐	☐	No planned breakups
4.4-4	☐	☐	✓	☐	✓	☐	☐	No planned breakups
4.5-1	☐	☐	✓	☐	✓	☐	☐	
4.5-2	☐	☐	✓	☐	✓	☐	☐	
4.6-1.a	☐	☐	✓	☐	✓	☐	☐	
4.6-1.b	☐	☐	✓	☐	✓	☐	☐	Planned atmos. reentry
4.6-1.c	☐	☐	✓	☐	✓	☐	☐	No planned retrieval
4.6-2	☐	☐	✓	☐	✓	☐	☐	LEO orbit only
4.6-3	☐	☐	✓	☐	✓	☐	☐	LEO orbit only
4.6-4	☐	☐	✓	☐	✓	☐	☐	
4.7-1	☐	☐	✓	☐	✓	☐	☐	
4.8-1	☐	☐	✓	☐	✓	☐	☐	No tethers used

Space Sciences & Engineering, LLC is a U.S.-based company. This ODAR follows the format recommended in NASA-STD-8719.14 Revision B and includes the content indicated at a minimum in each Section 2 through 8. Sections 9 through 14 apply to the launch vehicle ODAR and are not covered here.

[1] The primary payload(s) for this launch belongs to other organizations. All other portions of the launch composite are not the responsibility of PlanetiQ and the GNOMES Program is not the lead launch organization.

Table of Contents

1 ODAR Section 1: Program Management and Mission Overview

Project manager: PlanetiQ

Foreign government or space agency participation: No foreign government or space agency participation is anticipated.

Schedule of upcoming mission milestones:

Shipment to SpaceX:	November 2020
Launch:	December 2020

Mission overview: GNOMES is a constellation of remote sensing satellites that capture GNSS signals to remotely sense the atmosphere. GNOMES are launched to altitudes between 500 and 750 km and are released from the launch vehicle by an 8-inch Lightband from Planetary Systems Corp (PSC). The GNOMES can be launched from a variety of launch vehicles, including the Antrix PSLV, Arianespace Vega, and SpaceX Falcon 9.

After system validation (no longer than 18 months), the GNOMES move to a circular orbit at 650 km. Each satellite downlinks the atmospheric observations via X-band transmitter. The common micro-satellite bus is a three axis controlled spacecraft that uses reaction wheels, magnetic torque rods, star trackers, magnetometers, sun sensors, and gyroscopes from Blue Canyon Technology (BCT) to enable precision 3-axis pointing. Each satellite also has an electric propulsion system with approximately 400 m/s of ΔV for orbit maintenance, phasing, and de-orbit acceleration.

Analysis is shown in this ODAR for the launch of GNOMES-2 satellite in Q4 2020. The GNOMES-2 spacecraft is technically equivalent to GNOMES-1, whose license was granted in February 2020[2]. GNOMES-2 will be launched as secondary payload to a targeted 525 x 525 km orbit, but after satellite commissioning, will be raised to the operational altitude of 650 km SSO.

ODAR summary: No debris released in normal operations; no credible scenario for breakups; the collision probability with other objects is compliant with NASA standards; and the estimated nominal lifetime is less than 25 years at the nominal operational altitude, as calculated by DAS v. 3.0.1.

Launch vehicle and launch site: *Falcon 9,* Vandenberg Air Force Base, California, U.S.A.

Proposed launch date: December 2020

Mission duration: Nominal lifetime of 7 years. Maximum orbit lifetime is less than 25 years by reentry from natural decay at 650 km, or less by lowering of perigee with on-board propulsion system.

Launch and deployment profile, including all parking, transfer, and operational orbits with apogee, perigee, and inclination: The GNOMES-2 satellite will deploy from the launch

[2] Reference FCC File #0011-EX-CN-2019

vehicle into a low-Earth orbit with 525 km altitude. The nominal operational altitude is 650 km to adhere with the Commission's proposed rule of timely orbit decay and disposal.

Nominal operational case: Apogee: 650 km; Perigee: 650 km
Parking/transfer orbit range: Apogee: 525 km; Perigee: 525 km
Inclination: Sun-synchronous inclination: 97.5 degrees at launch, 98.0 degrees operational

All GNOMES have an on-board propulsion system for station-keeping, altitude adjustment, phasing, and acceleration of de-orbit operations. GNOMES-2 will operate at its launch vehicle injection altitude, and after system validation (a period of less than 18 months), PlanetiQ plans to change the altitude and inclination of GNOMES-2 to operate at a maximum of 650 km SSO.

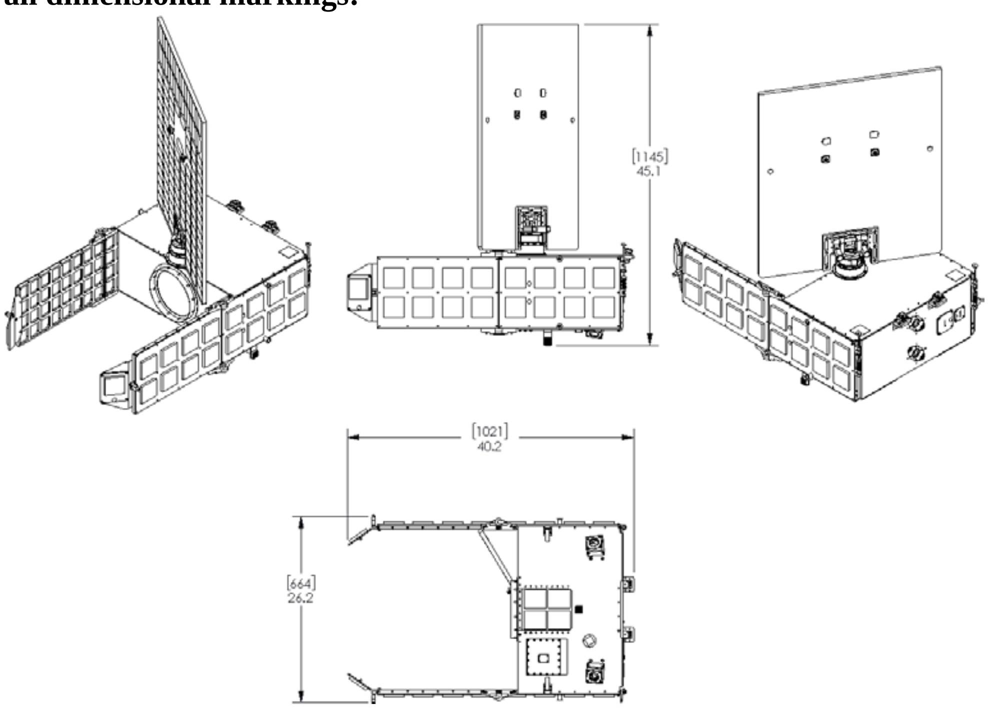
Reason for selection of operational orbit(s): The operational orbit was chosen to optimize measurement of the different atmospheric layers, while allowing frequent opportunities for ground station communication.

Identification of any interaction or potential physical interference with other operational spacecraft: None.

2 ODAR Section 2: Spacecraft Description

Physical description of the spacecraft: GNOMES-2 is a microsatellite, with a launch mass of approximately 40 kg and reentry mass of 36 kg. The stowed configuration of the satellite fits within a 600 x 700 x 800 mm^3 volume envelope. After separation from the launch vehicle by PSC's 8-inch Lightband, the GNOMES-2 solar panel and science antennas deploy.

Detailed illustration of the entire spacecraft in the mission operation configuration with clear overall dimensional markings:



Total spacecraft mass at launch, including all propellants and fluids: 40 kg

Dry mass of spacecraft at launch, excluding solid rocket motor propellants: 39.58 kg

Description of all propulsion systems (cold gas, mono-propellant, bi-propellant, electric, nuclear): The propulsion system consists of two Enpulsion IFM Nano thruster modules. The IFM Nano is a Field-Emission Electric Propulsion (FEEP) thruster using indium as its fuel source. The indium is unpressurized and is in its solid state when the system is unpowered (the melting point of indium is 156ºC). The system has flight heritage in 2018, as well as on GNOMES-1, and produces a total thrust of 0.6 milli-Newtons.

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: None.

Description of all fluid systems, including size, type, and qualifications of fluid containers such as propellant and pressurization tanks, including pressurized batteries: None. The Indium fuel is in a solid state until on orbit and unpressurized. The batteries are standard COTS, unpressurized lithium-ion battery cells.

Description of all active and/or passive attitude control systems with an indication of the normal attitude of the spacecraft with respect to the velocity vector: The principal source of internal kinetic energy is the combination of the three reaction wheels. There are no credible failure scenarios in which this rotational kinetic energy could become sufficient to fragment the spacecraft.

The velocity vector will be normal to the plane of the two science antennas during science operations and communication with the ground stations. While in propulsion mode, the velocity vector will be normal to the (nominally) zenith deck that contains the upper stage of the Lightband.

Description of any range safety or other pyrotechnic devices: Two split spool Hold Down and Release Mechanisms (HDRMs) are used for the deployment mechanism for the solar panel. The HDRMs are non-pyrotechnic, and all debris will be retained.

Description of the electrical generation and storage system: The spacecraft contains a 24-cell lithium-ion battery with three strings of eight cells each, for a voltage range of 26-33V and capacity of 10.2 A-hr. Each string is packaged individually with 8 cells held in an aluminum bracket. The LG 18650-MJ1 cells are not pressure vessels.

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

Identification of any radioactive materials onboard or made a positive statement that there are no radioactive materials onboard: No radioactive materials are onboard GNOMES-2.

3 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: PlanetiQ has assessed the potential for any amount of debris to be released into the space environment under normal satellite operations, and has taken all possible spacecraft hardware design and operational planning measures to minimize the possibility of any such orbital debris. There are no planned intentional releases of objects from GNOMES-2 during any mission phase, including deployment, operations, and disposal. The GNOMES-2 design does not incorporate any shrouds or covers to be removed upon deployment, and no shrapnel will be generated as a result of the deployment of the science antennas or solar array. GNOMES-2 will utilize a Lightband separation system (MLB from PSC) that uses non-explosive actuators and retain all of the separation hardware.

Rationale/necessity for release of each object: N/A

Time of release of each object, relative to launch time: N/A

Release velocity of each object with respect to spacecraft: N/A

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

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

Assessment of spacecraft compliance with Requirements 4.3-1 and 4.3-2:

Requirement 4.3-1. Debris passing through LEO: For missions leaving debris in orbits passing though LEO, released debris with diameters of 1 mm or larger shall satisfy both Requirement 4.3-1a and Requirement 4.3-1b: a. All debris released during the deployment, operation, and disposal phases shall be limited to a maximum orbital lifetime of 25 years from date of release. b. The total object-time product shall be no larger than 100 object-years per mission. The object-time product is the sum of all debris of the total time spent below 2000 km altitude during the orbital lifetime of each object.
Compliance Statement: COMPLIANT There are no intentional releases.

Requirement 4.3-2. Debris passing near GEO: For missions leaving debris in orbits with the potential of traversing GEO (GEO altitude +/- 200 km and +/- 15 degrees latitude), released debris with diameters of 5 cm or greater shall be left in orbits which will ensure that within 25 years after release the apogee will no longer exceed GEO – 200 km.
Compliance Statement: COMPLIANT No released debris.

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

Identification of all potential causes of spacecraft breakup during deployment and mission operations: There is no credible scenario that would result in spacecraft breakup during normal deployment and operations.

Summary of failure modes and effects analyses of all credible failure modes which may lead to an accidental explosion: The probability of accidental explosion on orbit, either during normal operations or during end-of-life disposal, is minimal for GNOMES-2. All components involved in the retention and control of energy sources are space-qualified, and energy sources will be managed autonomously, minimized, or depleted upon Earth re-entry.

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

Detailed plan for any designed spacecraft breakup, including explosions and intentional collisions: There are no planned breakups.

List of components which are passivated at EOM. List includes method of passivation and amount which cannot be passivated: When the mission is completed, the battery system will be passivated by completely discharging the battery. This will be accomplished by disabling the on-board fault protection that would recover the spacecraft to a safe state, and then loading a table into permanent memory to off-point the solar panels so that all loads are supported by the battery. The battery will discharge with no action taken by the spacecraft to recover.

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

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

Requirement 4.4-1. <u>Limiting the risk to other space systems from accidental explosions during deployment and mission operations while in orbit about Earth or the Moon:</u> 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).
Compliance Statement: COMPLIANT 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 the selected COTS batteries is such that while the spacecraft could be expected to vent gases, most debris from the battery rupture should be contained within the spacecraft due to the lack of penetration energy.

Probability: Extremely low. It is believed to be less than 0.1% probability 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 likelihood and impact 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: Spacecraft thermal design must be incorrect AND external over-current detection and disconnect function must fail to enable this failure mode.

Failure mode 3: Excessive discharge rate or short-circuit due to external device failure or terminal contact with conductors not at battery voltage levels (due to abrasion or inadequate proximity separation).

Mitigation 3: 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 failure must all occur to enable this failure mode.

Failure mode 4: Inoperable vents.

Mitigation 4: Battery vents are not inhibited by the battery holder design or the spacecraft.

Combined faults required for realized failure: The final assembler fails to install proper venting.

Failure mode 5: Crushing.

Mitigation 5: This mode is negated by spacecraft design. There are no moving parts in the proximity of the batteries.

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

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

Mitigation 6: 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 failure modes in environmental tests must occur to result in this failure mode.

Failure mode 7: Excess temperatures due to orbital environment and high discharge combined.

Mitigation 7: The spacecraft thermal design will negate this possibility. Thermal rise has been analyzed in combination with space environment temperatures showing that batteries do not exceed normal allowable operating temperatures under a variety of modeled cases, including worst case orbital scenarios. Analysis shows these temperatures to be well below temperatures of concern for explosions.

Combined faults required for realized failure: Thermal analysis AND thermal design AND mission simulations in thermal-vacuum chamber testing AND over-current monitoring and control must all fail for this failure mode to occur.

Requirement 4.4-2. <u>Design for passivation after completion of mission operations while in orbit about the Earth or the Moon:</u> Design of all spacecraft and launch vehicle orbital stages shall include the ability and a plan 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 cannot cause an explosion or deflagration large enough to release orbital debris or break up the spacecraft.
Compliance Statement: COMPLIANT As mentioned before, the satellite design allows for passivation by completely discharging the battery. In the unlikely event that a battery cell does explosively rupture, the small size, mass, and potential energy of these small batteries is such that while the spacecraft could be expected to vent gases, most debris from the battery rupture should be contained within the spacecraft due to the lack of penetration energy to the multiple enclosures surrounding the batteries.

Requirement 4.4-3. <u>Limiting the long-term risk to other space systems from planned breakups:</u> Planned explosions or intentional collisions shall:

a. Be conducted at an altitude such that for orbital debris fragments larger than 10 cm the object-time product does not exceed 100 object-years. For example, if the debris fragments greater than 10 cm decay in the maximum allowed 1 year, a maximum of 100 such fragments can be generated by the breakup. b. Not generate debris larger than 1 mm that shall remain in Earth orbit longer than one year.
Compliance Statement: COMPLIANT There are no planned breakups.

Requirement 4.4-4. Limiting the short-term risk to other space systems from planned breakups: Immediately before a planned explosion or intentional collision, the probability of debris, orbital or ballistic, larger than 1 mm colliding with any operating spacecraft within 24 hours of the breakup shall be verified to not exceed 10^{-6}.
Compliance Statement: COMPLIANT There are no planned breakups.

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

Calculation of spacecraft probability of collision with space objects larger than 10 cm in diameter during the orbital lifetime of the spacecraft. Calculation of spacecraft probability of collision with space objects, including orbital debris and meteoroids, of sufficient size to prevent postmission disposal: Because catastrophic collisions during orbital lifetime represent a direct source of debris in the space environment, PlanetiQ addresses the probability of a physical collision with large objects (>10 centimeters) in LEO, which includes other operational satellites, spent hardware, and space debris. To assess the likelihood of a collision with objects large enough to render GNOMES-2 as a source of debris over its lifetime, PlanetiQ used the DAS v.3.0.1 tool for analysis (see Section 9 for software output). Probabilities are shown at the launch attitude and inclination over 18 months (maximum time spent in the injection orbit) and for the operational orbit for up to 7 years: 525 km SSO and 650 km SSO.[3] For each orbit scenario, the collision probability is less than 0.001.

Assessment of spacecraft compliance with Requirement 4.5-1:

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.
Compliance Statement: COMPLIANT Large object impact and debris generation probabilities at:

[3] The analysis in this section assumes the worst-case scenario, *i.e.*, the sum of the collision probabilities associated with: (i) operations for 18 months at the injection orbit; and (ii) operations for 7 years at 650 km plus the maximum de-orbit period of 18 years.

Injection orbit[4] 525 km SSO for 18 months (worst-case): 0.000014 *Operational orbit* 650 km SSO for 7 years (worst-case) and de-orbit: 0.000018 Aggregate collision probability for the injection orbit scenario above: 650 km SSO: 0.000033

Small debris and meteoroids pose a threat of collision to the GNOMES constellation. Impacts with debris can result in damage to vital Pyxis-RO components that allow the spacecraft to perform mission operations, maintain satellite control, and perform post-mission disposal acceleration maneuvers. PlanetiQ used the DAS software[5] to assess the probability of GNOMES-2 collisions with particles larger than one centimeter (see Section 9 for output).

Assessment of spacecraft compliance with Requirement 4.5-2:

Requirement 4.5-2. <u>Limiting debris generated by collisions with small objects when operating in Earth or lunar orbit:</u> 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.
Compliance Statement: COMPLIANT Small object impact and debris generation probabilities at: *Injection orbit* 525 km SSO for 18 months: < 0.00025 *Operational orbit* 650 km SSO for 7 years: < 0.0004

For particles smaller than approximately 3 millimeters, the probability of impact for GNOMES-2 increases above the 0.01 threshold at any possible orbit altitude (between 525 and 650 km) over 7 years because of the increased amount of debris of this size in the LEO environment. Debris of this size could potentially cause critical damage to GNOMES-2 in the event of an impact; however, this depends much upon the impact location, angle, and relative velocity between the impacting objects.

To manage this risk, the GNOMES have been designed to be tolerant of small-particle impacts, with particular care to minimize the vulnerability of critical systems. Vital components, such as the communications radios, propulsion system, and payload components are provided with physical protection in the velocity direction by the satellite bus structure and science antenna panels with minimal external exposure. These protective layers serve as shielding that

[4] To calculate this value (part (i) in the footnote above) using NASA DAS, PlanetiQ generated the collision probability of operations for 18 months at the injection orbit plus the associated de-orbit period and then subtracted the collision probability for the associated de-orbit period, which was estimated in NASA DAS using an operational duration of 0.01 years at the injection orbit.

[5] DAS v. 2.1.1 was used for this analysis, as the Debris Impacts vs. Debris Diameter tool was removed in DAS v. 3.0.1 because of the length of time needed to run the simulation.

will either prevent small debris and meteoroids from reaching critical components or break up incoming particles prior to penetrating to the satellite's interior.

During orbital maneuvers using the propulsion system (orbit raise and inclination burns, periodic orbit maintenance, and end-of-life disposal acceleration), the satellite will orient itself to provide propulsion in either the velocity or cross-track directions. In these orientations, the vital spacecraft components are still protected by the external structure and should not pose any higher risk of collision than the nominal orientation.

In summary, the GNOMES-2 orbit exhibits a low probability of impact for debris larger than one centimeter and are well within the NASA stated requirement of 0.01. Protective design measures are taken to reduce the risk of catastrophic failure due to impacts with debris smaller than one centimeter.

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

Description of spacecraft disposal option selected: Responsible disposal of post-mission hardware is the most practical and effective means of preserving the orbital environment for future use. With this in mind, PlanetiQ plans to deorbit GNOMES-2 upon completion of its mission (nominally planned for 7 years or until the end of operational life). At its operational altitude of 650 km, GNOMES-2 will de-orbit naturally, without need for propulsive maneuvers, by atmospheric re-entry within 18 years.

The on-board propulsion system will be used to obtain the nominal 650 km circular orbit from the launch injection altitude, and to perform orbit maintenance to remain in its intended orbit for 7 years. After completion of its mission, the perigee altitude of GNOMES-2 will be lowered using the propulsion system to facilitate a more rapid, uncontrolled re-entry into the atmosphere. Re-entry will occur, however, within 18 years after mission completion with or without propulsion.

Identification of all systems or components required to accomplish any postmission disposal operation, including passivation and maneuvering: Without orbit maintenance, the satellite will reenter Earth's atmosphere naturally at altitudes 650 km and lower.

Plan for any spacecraft maneuvers required to accomplish postmission disposal: At the end of mission lifetime, GNOMES-2 will be moved into an elliptical orbit to sufficiently slow the orbital velocity to re-enter the Earth's atmosphere. A target perigee of 200 km, requiring ≤100 m/s of ΔV, will allow for de-orbit operations to complete in less than two months. A quick descent reduces the likelihood of interference with other objects in similar orbits.

Sufficient fuel is being budgeted on GNOMES-2 to perform maneuvers to accelerate disposal. The Enpulsion propulsion system uses two FEEP thrusters and an indium-based fuel with an Isp of 4200 seconds for the de-orbit phase of the mission. Thus, from the rocket equation[6], the minimum necessary disposal reserve for each 36 kg satellite is 0.09 kg.

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[6] $\Delta v = Isp \cdot g \cdot \ln\left(\frac{M_{total}}{M_{dry}}\right)$

Fuel levels will be closely monitored throughout the mission to ensure sufficient fuel remains for deorbit operations. With conservative propellant loading of 0.2125 kg per thruster, there should be sufficient indium fuel on-board each GNOMES for orbital placement, station keeping, maneuvering, and end-of-life disposal.

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

Spacecraft mass: 36 kg (reentry mass)
Average cross-sectional area: 0.60 m^2
Area to mass ratio: 0.016 m^2/kg

If appropriate, preliminary plan for spacecraft controlled reentry: N/A

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

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

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

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

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

Compliance Statement: COMPLIANT
The disposal plan of GNOMES-2 is COMPLIANT using the atmospheric reentry option, by either accelerated reentry with perigee lowering using the onboard propulsion system, or decay from nominal operational orbit from natural forces. See DAS v.3.0.1 output in Section 9 for compliance status for the operational orbit.

Requirement 4.6-2. Disposal for space structures near GEO: A spacecraft or orbital stage in an orbit near GEO shall be maneuvered at EOM to a disposal orbit above GEO with a predicted minimum perigee of GEO + 200 km (35,986 km) or below GEO with an apogee of GEO – 200 km (35,586 km) for a period of at least 100 years after disposal.

Compliance Statement: COMPLIANT
No orbits are planned near GEO.

Requirement 4.6-3. <u>Disposal for space structures between LEO and GEO:</u> a. A spacecraft or orbital stage shall be left in an orbit with a perigee greater than 2000 km above the Earths' surface and apogee less than 500 km below GEO. b. A spacecraft or orbital stage shall not use nearly circular disposal orbits near regions of high value operational space structures, such as between 19,200 km and 20,700 km.
Compliance Statement: COMPLIANT No orbits planned between LEO and GEO

Requirement 4.6-4. <u>Reliability of postmission disposal operations in Earth orbit:</u> NASA space programs and projects shall ensure that all postmission disposal operations to meet Requirements 4.6-1, 4.6-2, and/or 4.6-3 are designed for a probability of success as follows: a. Be no less than 0.90 at EOM b. For controlled reentry, the probability of success at the time of reentry burn must be sufficiently high so as not to cause a violation of Requirement 4.7-1 pertaining to limiting the risk of human casualty.
Compliance Statement: COMPLIANT GNOMES-2 will reenter without disposal operations from its operational altitude of 650 km. The on-board propulsion system allows for altitude adjustments after launch, as well as deorbit acceleration through lowering of the perigee altitude.

7 ODAR Section 7: Assessment of Spacecraft Reentry Hazards

Detailed description of spacecraft components by size, mass, material, shape, and original location on the space vehicle, if the atmospheric reentry option is selected: See DAS v.3.0.1 output in Section 9 for itemized list of spacecraft components used for reentry analysis.

Summary of objects expected to survive an uncontrolled reentry, using NASA Debris Assessment Software (DAS), NASA Object Reentry Survival Analysis Tool (ORSAT), or comparable software: The only components predicted to survive reentry are the single, large solar panel, a tungsten and a tantalum emitter in the propulsion system (labeled Emitter 1 and Emitter 2 in the output), and the coarse sun sensors, but all are predicted to have less than 15 Joules of kinetic energy. The total debris casualty area from the surviving components was estimated as 0 m^2.

Calculation of probability of human casualty for the expected year of uncontrolled reentry and the spacecraft orbital inclination: The risk of human casualty for GNOMES-2 re-entering the atmosphere was calculated in DAS v.3.0.1 to be 1 in 100,000,000.

Assessment of spacecraft compliance with Requirement 4.7-1:

Requirement 4.7-1. <u>Limit the risk of human casualty:</u> 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). b. 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. c. 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).
Compliance Statement: COMPLIANT Analysis performed using DAS v.3.0.1 shows that the risk of human casualty from surviving debris is 1:100,000,000. All components have 15 Joules of energy or less, or completely disintegrate before the Earth's surface upon reentry.

7.1 ODAR Section 7A: Assessment of Spacecraft Hazardous Materials

Summary of the hazardous materials contained on the spacecraft using all columns and the format in paragraph 4.7.5: N/A, no hazardous materials on the spacecraft.

8 ODAR Section 8: Assessment for Tether Missions

Type of tether; e.g., momentum or electrodynamics: There are no tethers in the GNOMES mission.

Description of tether system, including (1) tether length, diameter, materials, and design (single strand, ribbon, multi-strand mesh), at a minimum and (2) end-mass size and mass: N/A

Determination of minimum size of object that will cause the tether to be severed: N/A

Tether mission plan, including duration and postmission disposal: N/A

Probability of tether colliding with large space objects: N/A

Probability of tether being severed during mission or after postmission disposal: N/A

Maximum orbital lifetime of a severed tether fragment: N/A

Assessment of compliance with Requirement 4.8-1:

Requirement 4.8-1. Mitigate the collision hazards of space tethers in Earth or Lunar orbits: Intact and remnants of severed tether systems in Earth and lunar orbit shall meet the requirements limiting the generation of orbital debris from on-orbit collisions (Requirements 4.5-1 and 4.5-2) and the requirements governing postmission disposal (Requirements 4.6-1 through 4.6-4) to the limits specified in those paragraphs.
Compliance Statement: COMPLIANT There are no tethers in the GNOMES-2 mission.

9 DAS v.2.1.1 Output

Requirement 4.5-1

Injection orbit: 525 km SSO for 18 months

```
06 04 2020; 08:58:00AM    Processing Requirement 4.5-1:    Return Status : Passed

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

        **INPUT**

                Space Structure Name = GNOMES-2 Injection Orbit
                Space Structure Type = Payload
                Perigee Altitude = 525.000 (km)
                Apogee Altitude = 525.000 (km)
                Inclination = 97.500 (deg)
                RAAN = 0.000 (deg)
                Argument of Perigee = 0.000 (deg)
                Mean Anomaly = 0.000 (deg)
                Final Area-To-Mass Ratio = 0.0160 (m^2/kg)
                Start Year = 2021.000 (yr)
                Initial Mass = 36.000 (kg)
                Final Mass = 36.000 (kg)
                Duration = 1.500 (yr)
                Station-Kept = True
                Abandoned = True

        **OUTPUT**

                Collision Probability = 3.4106E-06
                Returned Message: Normal Processing
                Date Range Message: Normal Date Range
                Status = Pass

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

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

De-orbit from 650 km SSO (processed orbit scenario of 0.01 years)

06 05 2020; 14:54:44PM Processing Requirement 4.5-1: Return Status : Passed

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

INPUT

Space Structure Name = GNOMES-2
Space Structure Type = Payload
Perigee Altitude = 650.000 (km)
Apogee Altitude = 650.000 (km)
Inclination = 98.000 (deg)
RAAN = 0.000 (deg)
Argument of Perigee = 0.000 (deg)
Mean Anomaly = 0.000 (deg)
Final Area-To-Mass Ratio = 0.0160 (m^2/kg)
Start Year = 2021.000 (yr)
Initial Mass = 36.000 (kg)
Final Mass = 36.000 (kg)
Duration = 0.100 (yr)
Station-Kept = True
PMD Perigee Altitude = 650.000 (km)
PMD Apogee Altitude = 650.000 (km)
PMD Inclination = 98.000 (deg)
PMD RAAN = 0.000 (deg)
PMD Argument of Perigee = 0.000 (deg)
PMD Mean Anomaly = 0.000 (deg)

OUTPUT

Collision Probability = 3.9795 E-05
Returned Message: Normal Processing
Date Range Message: Normal Date Range
Status = Pass

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

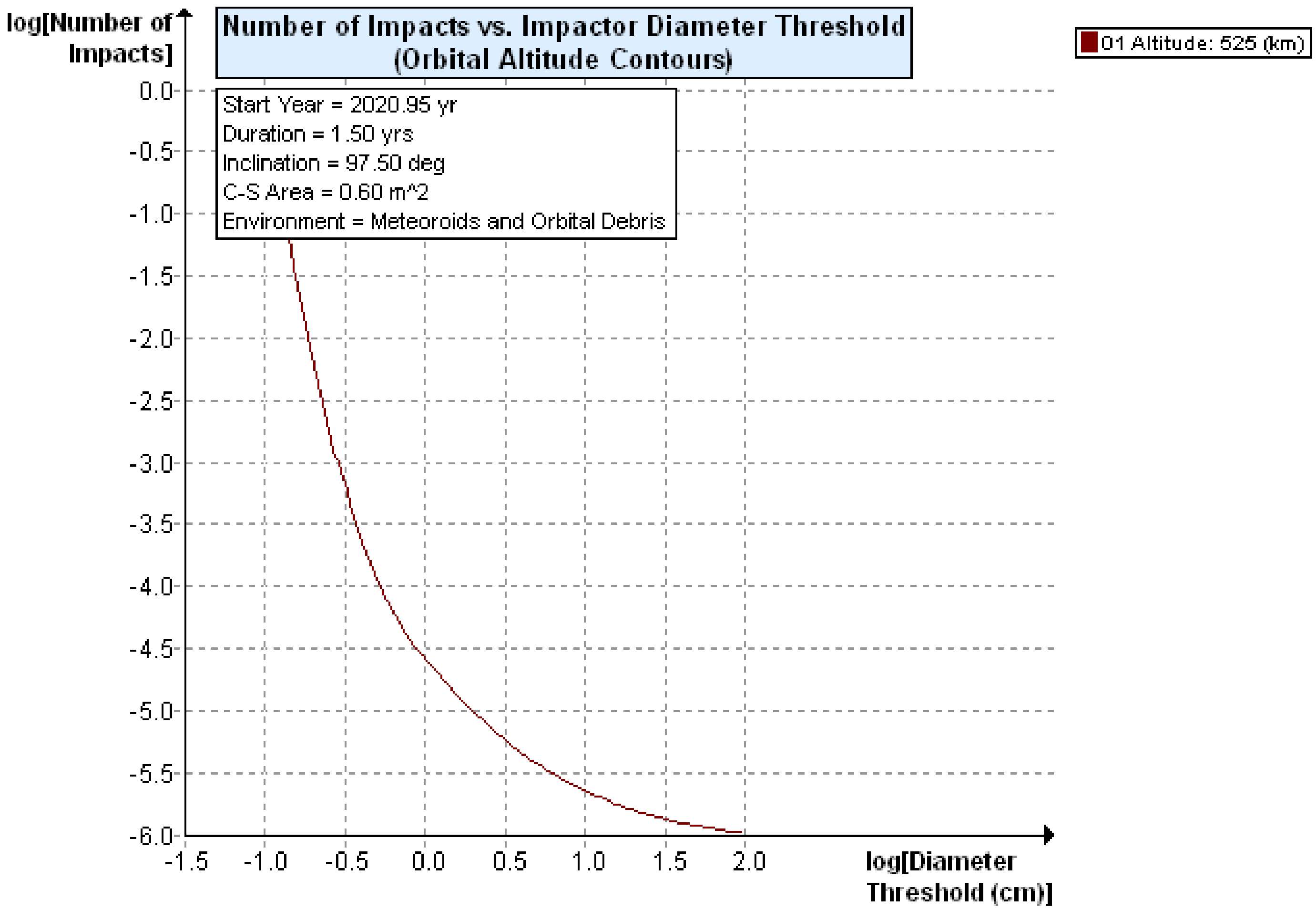
===============End of Requirement 4.5-1===============

Sun synchronous operational: 650 km SSO (worst-case) and including de-orbit

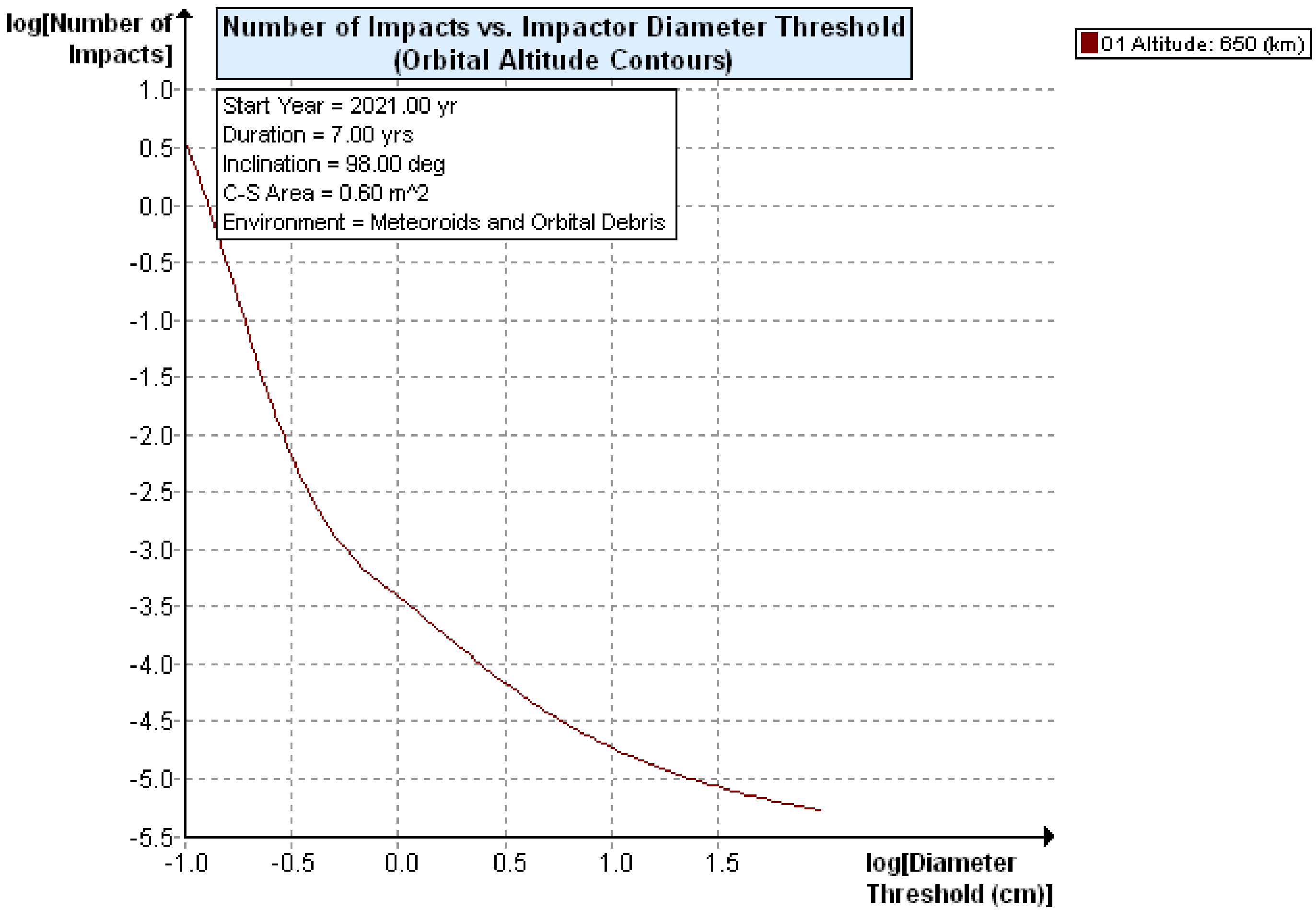
```
06 04 2020; 11:33:40AM     Processing Requirement 4.5-1:     Return Status : Passed

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

        **INPUT**

                Space Structure Name = GNOMES-2
                Space Structure Type = Payload
                Perigee Altitude = 650.000 (km)
                Apogee Altitude = 650.000 (km)
                Inclination = 98.000 (deg)
                RAAN = 0.000 (deg)
                Argument of Perigee = 0.000 (deg)
                Mean Anomaly = 0.000 (deg)
                Final Area-To-Mass Ratio = 0.0160 (m^2/kg)
                Start Year = 2021.000 (yr)
                Initial Mass = 36.000 (kg)
                Final Mass = 36.000 (kg)
                Duration = 7.000 (yr)
                Station-Kept = True
                PMD Perigee Altitude = 200.000 (km)
                PMD Apogee Altitude = 650.000 (km)
                PMD Inclination = 98.000 (deg)
                PMD RAAN = 0.000 (deg)
                PMD Argument of Perigee = 0.000 (deg)
                PMD Mean Anomaly = 0.000 (deg)

        **OUTPUT**

                Collision Probability = 1.8253E-05
                Returned Message: Normal Processing
                Date Range Message: Normal Date Range
                Status = Pass

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

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

Requirement 4.5-2

Injection orbit: 525 km SSO for 18 months



Sun synchronous operational: 650 km SSO



Requirement 4.6-1

Sun synchronous operational: 650 km SSO

```
06 04 2020; 10:10:11AM    Processing Requirement 4.6       Return Status : Passed

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

        **INPUT**

                Space Structure Name = GNOMES-2
                Space Structure Type = Payload

                Perigee Altitude = 650.000000 (km)
                Apogee Altitude = 650.000000 (km)
                Inclination = 98.000000 (deg)
                RAAN = 0.000000 (deg)
                Argument of Perigee = 0.000000 (deg)
                Mean Anomaly = 0.000000 (deg)
                Area-To-Mass Ratio = 0.016000 (m^2/kg)
                Start Year = 2021.000000 (yr)
                Initial Mass = 36.000000 (kg)
                Final Mass = 36.000000 (kg)
                Duration = 7.000000 (yr)
                Station Kept = True
                Abandoned = True
                PMD Perigee Altitude = 650.000000 (km)
                PMD Apogee Altitude = 650.000000 (km)
                PMD Inclination = 98.000000 (deg)
                PMD RAAN = 0.000000 (deg)
                PMD Argument of Perigee = 0.000000 (deg)
                PMD Mean Anomaly = 0.000000 (deg)

        **OUTPUT**

                Suggested Perigee Altitude = 650.000000 (km)
                Suggested Apogee Altitude = 650.000000 (km)
                Returned Error Message = Passes LEO reentry orbit criteria.

                Released Year = 2045 (yr)
                Requirement = 61
                Compliance Status = Pass

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

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

Requirement 4.7-1

Sun synchronous operational: 650 km SSO

06 04 2020; 10:10:19PM *********Processing Requirement 4.7-1
Return Status: Passed

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

name = GNOMES-2
quantity = 1
parent = 0
materialID = 5
type = Box
Aero Mass = 36.000000
Thermal Mass = 36.000000
Diameter/Width = 0.700000
Length = 0.800000
Height = 0.600000

name = Front Plate
quantity = 1
parent = 1
materialID = 8
type = Flat Plate
Aero Mass = 1.000000
Thermal Mass = 1.000000
Diameter/Width = 0.364490
Length = 0.548894

name = Back Plate
quantity = 1
parent = 1
materialID = 8
type = Flat Plate
Aero Mass = 1.000000
Thermal Mass = 1.000000
Diameter/Width = 0.364490
Length = 0.548894

name = Top Plate
quantity = 1
parent = 1
materialID = 8
type = Flat Plate
Aero Mass = 0.800000
Thermal Mass = 0.800000
Diameter/Width = 0.255778
Length = 0.548894

name = Bottom Plate
quantity = 1
parent = 1
materialID = 8
type = Flat Plate
Aero Mass = 0.800000
Thermal Mass = 0.800000
Diameter/Width = 0.255778
Length = 0.548894

name = Lightband Fasteners
quantity = 12
parent = 1
materialID = -4
type = Cylinder
Aero Mass = 0.029484
Thermal Mass = 0.029484
Diameter/Width = 0.050930
Length = 0.026416

name = Solar Panel Honeycomb
quantity = 1
parent = 1
materialID = -11
type = Flat Plate
Aero Mass = 0.703730
Thermal Mass = 0.703730
Diameter/Width = 0.700000
Length = 0.800000

name = Solar Panel Face Sheet
quantity = 1
parent = 1
materialID = 16
type = Flat Plate
Aero Mass = 0.472640
Thermal Mass = 0.472640
Diameter/Width = 0.700000
Length = 0.800000

name = Solar Cells
quantity = 1
parent = 1
materialID = 27
type = Flat Plate
Aero Mass = 0.500000
Thermal Mass = 0.500000
Diameter/Width = 0.700000
Length = 0.800000

name = Solar Array Drive Gearbox
quantity = 1
parent = 1
materialID = 5
type = Cylinder
Aero Mass = 1.180000
Thermal Mass = 1.180000
Diameter/Width = 0.097800
Length = 0.066870

name = Flexure arm
quantity = 2
parent = 1
materialID = -5
type = Box
Aero Mass = 0.217724
Thermal Mass = 0.217724
Diameter/Width = 0.036222
Length = 0.036222
Height = 0.036222

name = Nut
quantity = 4
parent = 1
materialID = 65
type = Cylinder
Aero Mass = 0.000862
Thermal Mass = 0.000862
Diameter/Width = 0.008000
Length = 0.003900

name = Washers
quantity = 4
parent = 1
materialID = 65
type = Cylinder
Aero Mass = 0.000726
Thermal Mass = 0.000726
Diameter/Width = 0.008500
Length = 0.002900

name = Split Spool Release Mech
quantity = 2
parent = 1
materialID = 54
type = Cylinder
Aero Mass = 0.074000
Thermal Mass = 0.074000
Diameter/Width = 0.031750
Length = 0.024000

name = Solar Array Drive Motor
quantity = 1
parent = 1
materialID = 58
type = Box
Aero Mass = 0.320000
Thermal Mass = 0.320000
Diameter/Width = 0.042420
Length = 0.048000
Height = 0.042420

name = RO Antenna Frame Fixed
quantity = 2
parent = 1
materialID = 8
type = Box
Aero Mass = 0.500000
Thermal Mass = 0.500000
Diameter/Width = 0.257050
Length = 0.435000
Height = 0.021267

name = RO Antenna Frame Rotating
quantity = 2
parent = 1
materialID = 8
type = Box
Aero Mass = 0.500000
Thermal Mass = 0.500000
Diameter/Width = 0.257050
Length = 0.435000
Height = 0.021267

name = RO Antenna Panels Fixed
quantity = 2
parent = 1
materialID = 5
type = Box
Aero Mass = 0.780364
Thermal Mass = 0.780364
Diameter/Width = 0.254000
Length = 0.431800
Height = 0.003556

name = RO Antenna Panels Rotating
quantity = 2
parent = 1
materialID = 5
type = Box
Aero Mass = 0.775828
Thermal Mass = 0.775828
Diameter/Width = 0.254000
Length = 0.431800
Height = 0.003556

name = RO Antenna Patches Fixed
quantity = 16
parent = 1
materialID = -6
type = Box
Aero Mass = 0.113900
Thermal Mass = 0.113900
Diameter/Width = 0.073660
Length = 0.073660
Height = 0.010000

name = RO Antenna Patches Rotating
quantity = 16
parent = 1
materialID = -6
type = Box
Aero Mass = 0.113900
Thermal Mass = 0.113900
Diameter/Width = 0.073660
Length = 0.073660
Height = 0.010000

name = RO Antenna Wiring
quantity = 4
parent = 1
materialID = 19
type = Cylinder
Aero Mass = 0.050000
Thermal Mass = 0.050000
Diameter/Width = 0.004064
Length = 0.500000

name = RO Deployment Mechanism
quantity = 2
parent = 1
materialID = -2
type = Box
Aero Mass = 0.040000
Thermal Mass = 0.040000
Diameter/Width = 0.013000
Length = 0.175440
Height = 0.013000

name = RO Deployment Plungers
quantity = 4
parent = 1
materialID = -2
type = Cylinder
Aero Mass = 0.020000
Thermal Mass = 0.020000
Diameter/Width = 0.031750
Length = 0.019050

name = RO Antenna Hinges
quantity = 4
parent = 1
materialID = -2
type = Box
Aero Mass = 0.100000
Thermal Mass = 0.100000
Diameter/Width = 0.042670
Length = 0.127000
Height = 0.025400

name = POD Antenna
quantity = 2
parent = 1
materialID = -6
type = Box
Aero Mass = 0.213188
Thermal Mass = 0.213188
Diameter/Width = 0.101600
Length = 0.127000
Height = 0.013335

name = POD Wiring
quantity = 2
parent = 1
materialID = 19
type = Cylinder
Aero Mass = 0.075000
Thermal Mass = 0.075000
Diameter/Width = 0.003302
Length = 1.000000

name = Propulsion Module
quantity = 2
parent = 1
materialID = 5
type = Box
Aero Mass = 0.480000
Thermal Mass = 0.279000
Diameter/Width = 0.100000
Length = 0.100000
Height = 0.082500

name = Reservoir
quantity = 2
parent = 28
materialID = 54
type = Cylinder
Aero Mass = 0.184000
Thermal Mass = 0.184000
Diameter/Width = 0.056000
Length = 0.045000

name = Emitter 1
quantity = 2
parent = 28
materialID = 67
type = Box
Aero Mass = 0.002000
Thermal Mass = 0.002000
Diameter/Width = 0.016000
Length = 0.016000
Height = 0.000780

name = Emitter 2
quantity = 2
parent = 28
materialID = -1
type = Box
Aero Mass = 0.015000
Thermal Mass = 0.015000
Diameter/Width = 0.032000
Length = 0.032000
Height = 0.001000

name = Prop Electronics Board
quantity = 2
parent = 1
materialID = -9
type = Box
Aero Mass = 0.200000
Thermal Mass = 0.200000
Diameter/Width = 0.100000
Length = 0.100000
Height = 0.018650

name = Pyxis Payload
quantity = 1
parent = 1
materialID = 5
type = Box
Aero Mass = 5.600000
Thermal Mass = 2.000000
Diameter/Width = 0.175900
Length = 0.180300
Height = 0.162600

name = Payload Fasteners
quantity = 100
parent = 33
materialID = -4
type = Cylinder
Aero Mass = 0.001000
Thermal Mass = 0.001000
Diameter/Width = 0.004000
Length = 0.015000

name = Printed Wiring Assemblies
quantity = 7
parent = 33
materialID = 50
type = Box
Aero Mass = 0.500000

Thermal Mass = 0.500000
Diameter/Width = 0.150000
Length = 0.150000
Height = 0.020000

name = Oscillator
quantity = 1
parent = 1
materialID = 5
type = Box
Aero Mass = 0.146400
Thermal Mass = 0.146400
Diameter/Width = 0.050000
Length = 0.050000
Height = 0.030000

name = XB1 Avionics Module
quantity = 1
parent = 1
materialID = 5
type = Box
Aero Mass = 3.450000
Thermal Mass = 3.088000
Diameter/Width = 0.127000
Length = 0.165100
Height = 0.104140

name = XB1 Controller Board
quantity = 1
parent = 37
materialID = 50
type = Box
Aero Mass = 0.050000
Thermal Mass = 0.050000
Diameter/Width = 0.097000
Length = 0.097000
Height = 0.005000

name = Power Board
quantity = 1
parent = 37
materialID = 50
type = Box
Aero Mass = 0.050000
Thermal Mass = 0.050000
Diameter/Width = 0.097000
Length = 0.097000
Height = 0.005000

name = Configuration Board
quantity = 1
parent = 37
materialID = 50
type = Box
Aero Mass = 0.050000
Thermal Mass = 0.050000
Diameter/Width = 0.097000
Length = 0.097000
Height = 0.005000

name = Software Radio Board
quantity = 1
parent = 37
materialID = 50
type = Box
Aero Mass = 0.100000
Thermal Mass = 0.100000
Diameter/Width = 0.097000
Length = 0.097000
Height = 0.010000

name = GPS Receiver Board
quantity = 1
parent = 37
materialID = 50
type = Box
Aero Mass = 0.062000
Thermal Mass = 0.062000
Diameter/Width = 0.097000
Length = 0.097000
Height = 0.005000

name = Backplane
quantity = 1
parent = 37
materialID = 50
type = Box
Aero Mass = 0.050000
Thermal Mass = 0.050000
Diameter/Width = 0.097000
Length = 0.097000
Height = 0.005000

name = Reaction Wheel Box
quantity = 1
parent = 1
materialID = 5
type = Box
Aero Mass = 2.181000
Thermal Mass = 1.350000
Diameter/Width = 0.099870
Length = 0.099870
Height = 0.099870

name = Reaction Wheel Housing
quantity = 3
parent = 44
materialID = 5
type = Box
Aero Mass = 0.082000
Thermal Mass = 0.064000
Diameter/Width = 0.064520
Length = 0.069090
Height = 0.024890

name = Electronics Board
quantity = 3
parent = 45
materialID = 50
type = Box
Aero Mass = 0.018000
Thermal Mass = 0.018000
Diameter/Width = 0.060000
Length = 0.060000
Height = 0.005000

name = Flywheel
quantity = 3
parent = 44
materialID = -7
type = Cylinder
Aero Mass = 0.195000
Thermal Mass = 0.195000
Diameter/Width = 0.065000
Length = 0.020000

name = Torque Rods
quantity = 3
parent = 1
materialID = 62
type = Cylinder
Aero Mass = 0.345000
Thermal Mass = 0.345000
Diameter/Width = 0.022230
Length = 0.127000

name = Star Tracker Housing
quantity = 2
parent = 1
materialID = 5
type = Box
Aero Mass = 0.310000
Thermal Mass = 0.266000
Diameter/Width = 0.054610
Length = 0.100080
Height = 0.050040

name = Star Tracker Lens
quantity = 2
parent = 49
materialID = -10
type = Box
Aero Mass = 0.044000
Thermal Mass = 0.044000
Diameter/Width = 0.027000
Length = 0.039000
Height = 0.026000

name = Coarse Sun Sensor
quantity = 3
parent = 1
materialID = -8
type = Box
Aero Mass = 0.008000
Thermal Mass = 0.008000
Diameter/Width = 0.026670
Length = 0.026670
Height = 0.006350

name = GPS Antenna
quantity = 1
parent = 1
materialID = -9
type = Box
Aero Mass = 0.016000
Thermal Mass = 0.016000
Diameter/Width = 0.047000
Length = 0.047000

Height = 0.008000

name = X-band Antenna
quantity = 1
parent = 1
materialID = -6
type = Box
Aero Mass = 0.013608
Thermal Mass = 0.013608
Diameter/Width = 0.050800
Length = 0.050800
Height = 0.002794

name = S-band Antenna
quantity = 1
parent = 1
materialID = -6
type = Box
Aero Mass = 0.049895
Thermal Mass = 0.049895
Diameter/Width = 0.076200
Length = 0.076200
Height = 0.004445

name = TT&C Wiring
quantity = 2
parent = 1
materialID = 19
type = Cylinder
Aero Mass = 0.025000
Thermal Mass = 0.025000
Diameter/Width = 0.004064
Length = 0.609600

name = Battery Modules
quantity = 3
parent = 1
materialID = 5
type = Box
Aero Mass = 0.669000
Thermal Mass = 0.147000
Diameter/Width = 0.081990
Length = 0.105540
Height = 0.043690

name = Battery Cells
quantity = 24
parent = 56
materialID = 54
type = Cylinder
Aero Mass = 0.049000
Thermal Mass = 0.049000
Diameter/Width = 0.018400
Length = 0.065200

name = Battery Side PWB
quantity = 3
parent = 56
materialID = 50
type = Box
Aero Mass = 0.030000
Thermal Mass = 0.030000
Diameter/Width = 0.040000
Length = 0.075000
Height = 0.010000

name = Battery Top PWB
quantity = 3
parent = 56
materialID = 50
type = Box
Aero Mass = 0.050000
Thermal Mass = 0.050000
Diameter/Width = 0.040000
Length = 0.100000
Height = 0.010000

name = Battery Bottom PWB
quantity = 3
parent = 56
materialID = 50
type = Box
Aero Mass = 0.050000
Thermal Mass = 0.050000
Diameter/Width = 0.040000
Length = 0.100000
Height = 0.010000

name = Fasteners
quantity = 200
parent = 1
materialID = 57
type = Cylinder
Aero Mass = 0.001000
Thermal Mass = 0.001000
Diameter/Width = 0.004000
Length = 0.015000

name = Harness Connectors
quantity = 31
parent = 1
materialID = 5
type = Box
Aero Mass = 0.003000
Thermal Mass = 0.003000
Diameter/Width = 0.010310
Length = 0.021970
Height = 0.007620

name = Cable Harness
quantity = 17
parent = 1
materialID = 19
type = Cylinder
Aero Mass = 0.063000
Thermal Mass = 0.063000
Diameter/Width = 0.006000
Length = 0.250000

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

name = GNOMES-2
Demise Altitude = 77.992752
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Front Plate
Demise Altitude = 74.628708
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Back Plate
Demise Altitude = 74.628708
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Top Plate
Demise Altitude = 74.863731
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Bottom Plate
Demise Altitude = 74.863731
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Lightband Fasteners
Demise Altitude = 73.905418
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Solar Panel Honeycomb
Demise Altitude = 76.512512
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Solar Panel Face Sheet
Demise Altitude = 0.000000
Debris Casualty Area = 1.817998
Impact Kinetic Energy = 6.506311

****
name = Solar Cells
Demise Altitude = 0.000000
Debris Casualty Area = 1.817998
Impact Kinetic Energy = 7.281438

****
name = Solar Array Drive Gearbox
Demise Altitude = 62.173599
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Flexure arm
Demise Altitude = 62.675838
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****

name = Nut
Demise Altitude = 75.498474
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Washers
Demise Altitude = 75.866310
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Split Spool Release Mech
Demise Altitude = 67.479347
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Solar Array Drive Motor
Demise Altitude = 62.292583
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = RO Antenna Frame Fixed
Demise Altitude = 75.857002
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = RO Antenna Frame Rotating
Demise Altitude = 75.857002
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = RO Antenna Panels Fixed
Demise Altitude = 73.954575
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = RO Antenna Panels Rotating
Demise Altitude = 73.987320
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = RO Antenna Patches Fixed
Demise Altitude = 67.083328
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = RO Antenna Patches Rotating
Demise Altitude = 67.083328
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = RO Antenna Wiring
Demise Altitude = 76.789162
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = RO Deployment Mechanism
Demise Altitude = 77.138893
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = RO Deployment Plungers
Demise Altitude = 76.372971
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = RO Antenna Hinges
Demise Altitude = 76.613762
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = POD Antenna
Demise Altitude = 67.117844
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = POD Wiring
Demise Altitude = 76.933983
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Propulsion Module
Demise Altitude = 74.299149
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Reservoir
Demise Altitude = 61.710861
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Emitter 1
Demise Altitude = 0.000000
Debris Casualty Area = 0.748075
Impact Kinetic Energy = 0.320897

****
name = Emitter 2
Demise Altitude = 0.000000
Debris Casualty Area = 0.776204
Impact Kinetic Energy = 4.670167

****
name = Prop Electronics Board
Demise Altitude = 75.367836
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Pyxis Payload
Demise Altitude = 69.182190
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Payload Fasteners
Demise Altitude = 68.323441
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Printed Wiring Assemblies
Demise Altitude = 67.461807
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Oscillator
Demise Altitude = 71.236099
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = XB1 Avionics Module
Demise Altitude = 59.676952
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = XB1 Controller Board
Demise Altitude = 59.252193
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Power Board
Demise Altitude = 59.252193
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Configuration Board
Demise Altitude = 59.252193
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Software Radio Board
Demise Altitude = 58.877937
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = GPS Receiver Board
Demise Altitude = 59.155251
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Backplane
Demise Altitude = 59.252193

Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Reaction Wheel Box
Demise Altitude = 64.939117
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Reaction Wheel Housing
Demise Altitude = 62.999302
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Electronics Board
Demise Altitude = 62.583893
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Flywheel
Demise Altitude = 58.585125
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Torque Rods
Demise Altitude = 62.821442
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Star Tracker Housing
Demise Altitude = 72.897102
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Star Tracker Lens
Demise Altitude = 68.657928
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Coarse Sun Sensor
Demise Altitude = 0.000000
Debris Casualty Area = 1.156863
Impact Kinetic Energy = 1.374079

****
name = GPS Antenna
Demise Altitude = 77.256851
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = X-band Antenna
Demise Altitude = 75.329117
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = S-band Antenna
Demise Altitude = 72.764351
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = TT&C Wiring
Demise Altitude = 77.490173
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Battery Modules
Demise Altitude = 75.476585
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Battery Cells
Demise Altitude = 68.820992
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Battery Side PWB
Demise Altitude = 75.016647
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Battery Top PWB
Demise Altitude = 74.867714
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Battery Bottom PWB
Demise Altitude = 74.867714
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Fasteners
Demise Altitude = 76.700813
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Harness Connectors
Demise Altitude = 76.875839
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Cable Harness
Demise Altitude = 75.748833
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

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