Lambdasat Formal Orbital Debris Assessment Report (ODAR)

In accordance with NPR 8715.6A, this report is presented as compliance with the required reporting format per NASA-STD-8719.14, APPENDIX A.

Report Revision: A (2/14/2014)

DAS Software used in this analysis: Debris Assessment Software (DAS) Version 2.0.2

RECORDS OF REVISIONS				
Rev	**Date**	**Affected Pages**	**Description of Change**	**Author(s)**
A	2/14/2014	All	Initial Release	Periklis Papadopoulos, Simon Kanis

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Self assessment and OSMA assessment of the ODAR using the format in Appendix A.2 of NASASTD8719.14:

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.

The following table is in accordance with the assessment format from Appendix A.2 of NASA-STD-8719.14.

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, Note 1
4.3-1.b			X		X			No Debris Released in LEO, Note 1
4.3-2			X		X			No Debris Released in LEO, Note 1
4.4-1			X		X			Note 1
4.4-2			X		X			Note 1
4.4-3			X		X			No planned breakups, Note 1
4.4-4			X		X			No planned breakups, Note 1
4.5-1			X		X			Note 1
4.5-2					X			
4.6-1(a)			X		X			Note 1
4.6-1(b)			X		X			Note 1
4.6-1(c)			X		X			Note 1
4.6-2			X		X			Note 1
4.6-3			X		X			Note 1
4.6-4			X		X			Note 1
4.6-5			X		X			Note 1
4.7-1			X		X			Note 1
4.8-1					X			No tethers used.

Notes:

1. The primary payload belongs to the Lambdasat team. All of the other portions of the launch stack are non-NASA, non-Lambdasat related and Lambdasat is not the lead.

Assessment Report Format:

In this document is used the format from NASA-STD-8719.14, in AppendixA.1 to report all the necessary information for the Lambdasat satellite.

Mission Description:

The Lambdasat is a small satellite which follows the established requirements of 1U nanosatellites (cubesat) which are defined in the CubeSat Design Specification rev.12 published on August 1st, 2009 by the California Polytechnic State University. It demonstrates technology for two-way communication with the ground systems for operations. It carries a new science experiment which measures the radiation effects on the grapheme material in real environment in Low Earth Orbit (LEO). Another technology that carries is an AIS receiver for tracking all the vessels inside its footprint around the globe. The communication consist of an Iridium Short Burst Data (SBD) modem which is the 9602 and makes use of the Iridium constellation, and in parallel, the use of two of UHF receiver and transmitter for uploading commands and downloading additional data (in coordination with the Iridium modem). All these electronics are placed and operated by one power system and a main computer which have designed and built for the specific satellite (Lambdasat). They provide rad hard effectiveness for the satellite.

In addition, the Lambdasat is planned to be deployed from the International Space Station (ISS) on June 1 – Jun 30. The planned operations to put the satellite in orbit are the same with those from similar satellites which have been deployed form the ISS in the past.

The satellite will fly on Orbital-2, stowed inside NRCSD (Nanoracks Cubesat Deployer). The satellite is stowed in a common transfer bag (soft stow) during the launch. Once it arrives in the ISS, it will be placed into the NRCSD (Nanoracks Cubesat Deployer) and will remain there until its deployment. This mechanism is a cubical launcher which with the support of a spring will eject the satellite out to the space.

The orbit of Lambdasat will be at 413.2 Km apogee and 381.3 km perigee on an inclination from the equator of 51.6 degrees. The deployer from the ISS will provide to the satellite a velocity of 5cm/sec at an angle of 45 degrees relative to the NRSD into a circular orbit initially approximately 300 or 400 km relative to Earth's surface.

One very important requirement which follows strictly the Lambdasat is that all the electronics are off during the launch and there is a 40 minute timer which will turn on the operations of the satellite after the launch. His orbital lifetime will be for approximately 74.095 days after launch and will get burned at the final phase of its mission.

Launch vehicle and launch site: Orbital-2, KDC

Proposed launch date: May 1

Mission duration: Until de-orbit

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

Lambdasat will be transferred to the ISS with a launch vehicle of Orbital-2. It will be carried in a soft stow bag by a crew member and will be inserted to the NRCSD (Nanoracks Cubesat Deployer). The design and built of Lambdasat follows all the established requirements based on the CubeSat Design Specification rev.12 published on August 1st, 2009 by the California Polytechnic State University with JEM requirements ant the NR-SRD-029: Interface Control Document Between NanoRacks CubeSats And NanoRacks CubeSat Deployer. The deployer mechanism will launch the satellite at a velocity of 5 m/sec and at an angle of 45 degrees relative to the NRCSD (Nanoracks Cubesat Deployer) into a circular orbit approximately 300-400 km relative to the Earth's surface.

The orbit of the Lambdasat is going to end with the burn of the satellite. The satellite is going to be affected from the gravity of Earth , because it uses only a passive magnetic system and not an active system. It means that no propulsion is used and also, it does not actively change orbits.

The same orbit has been used again from other cubesats and the likelihood of any impact with the ISS is very minimal.

The Lambdasat orbit parameters:

Apogee: 413.2 km

Perigee: 381.3 km

Inclination: 51.6 degrees

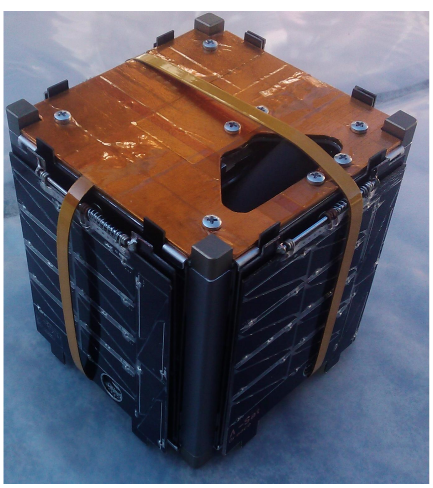

Figure 1: Satellite in initial state

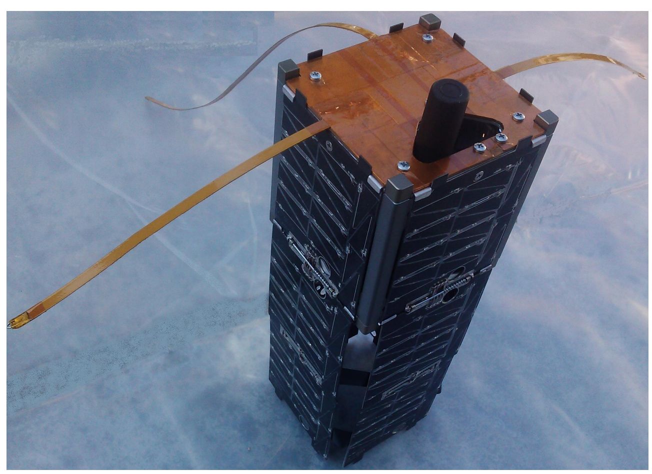

Figure 2: Satellite with deployed antennas and solar panels

The orbital lifetime of the Lambdasat depends in a passive magnetic system and has no propulsion. This does not allow the satellite to change its orbit actively. The Earth's gravity will decrease the altitude of the satellite until it slow down due to atmospheric friction and disintegrate on atmospheric re-entry approximately 74.095 days after the deployment from the ISS.

Interaction or potential physical interference with other operational Spacecraft:

The Lambdasat once enters the ISS will inserted in the NRCSD (Nanoracks Cubesat Deployer). No operations by any crew member are planned before the deployment. The most important risks of the satellite are the power supplier, the RF interference and the possibility of impacting the ISS after the deployment. The last risk is considered minimal due to previous launches of cubesats from the ISS. The power supplier of the Lambdasat is a lithium battery which is certified by the ISS program and has flight heritage. The radio-frequency noise generated by the satellite has a timer which allows any RF operations after the desired time as described in the requirements at NR-SRD-029: Interface Control Document Between NanoRacks CubeSats And NanoRacks CubeSat Deployer.

ODAR Section 1: Program Management and Mission Overview

Program Executive: Dr. Periklis Papadopoulos

Program/project Manager: Simon Kanis

Senior Scientist: Dr. Periklis Papadopoulos

Senior Management: Dr. Periklis Papadopoulos

Foreign government or space agency participation: N/A

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

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

Mission Preliminary Design Review: October 15, 2013

Mission Critical Design Review: December 12, 2013

PSRP: TO be scheduled by NanoRacks

Launch: May 1, 2014

Release from ISS, Begin Operation: June 1 – 30, 2014

ODAR Section 2: Spacecraft Description

Physical description of the spacecraft: Lambdasat is a 1U nanosatellite which meets all the requirements defined in the CubeSat Design Specification rev.12 published on August 1st, 2009 by the California Polytechnic State University and the NR-SRD-029: Interface Control Document Between NanoRacks CubeSats And NanoRacks CubeSat Deployer. The dimensions are 10cm X 10cm X 10cm and the total mass at launch is 1275 grams.

Lambdasat consists of:

- The main computer.
- The power system which uses the ISS approved Canon BP-930 battery.
- The graphene board for the grapheme experiment.
- The AIS receiver for locating and tracking the vessels around the globe.
- The UHF receiver.
- The UHF transmitter (stensat radio beacon).
- The Iridium Short Burst Data modem 9602.
- The deployable antennas (two monopole antennas for UHF receiver, transmitter and AIS receiver and one omni antenna for the Iridium modem) and deployable solar panels (3U surface of deployed solar panels).
- The 1U skeletonized frame from Pumpkin.
- Deployment switches.
- One magnet and two hysteresis rods.

Total satellite mass at launch, including all propellants and fluids: 1275 grams

Dry mass of satellite at launch, excluding solid rocket motor propellants: 1275 grams

Description of all propulsion systems (cold gas, mono-propellant, bi-propellant, electric, nuclear): No propulsion for Lambdasat.

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. Lambdasat 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: Lambdasat uses passive magnetic system. The magnets are aligned along the length of the spacecraft so the spacecraft aligns in accordance with the Earth's magnetic field. This means that the satellite cross section represented to the direction of flight varies with location within the Earth's magnetic field as well as varying due to nutation (coning rotation). The variable tilt toward earth caused by local magnetic inclination should have little on orbit decay. Variable magnetic declination effects (angles away from true north) should average out with minimal or no effect.

Description of any range safety or other pyrotechnic devices: The Lambdasat utilizes a resistor (heating element) for use in antenna deployment. The resistor is wound in a coil shape with a braided nylon cord strung through its center. The resistor wire itself is then crimped into barrel pins as the two ends and soldered to the ground plane of the satellite. The resistor cutter is in series with a power resister and has its own software controlled power source dedicated to the action of antenna deployment. The coil is placed inside of a ceramic tube to protect the local structure and elements as well as improve efficient delivery of heat to the nylon wire. This method and design was used successfully on NanoSail D2 and TechedSat.

Description of the electrical generation and storage system: The power will be generated using solar panels and Lithium Ion Batteries. The battery that will be used is a Canon BP-930. This battery is approved by the ISS for flight. The dimensions of the battery are 4 x 7 x 3.8cm and the weight is 0.18kg.

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 (>1mm) expected to be released from the spacecraft any time after launch, including object dimensions, mass and material: No any intentional releases.

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

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

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

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

N/A.

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

N/A.

Assessment of spacecraft compliance with Requirements 4.3-1 and 4.3-2 (per DAS v2.0)

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.

Potential causes of spacecraft breakup during deployment and mission operations: There is not a potential scenario of spacecraft breakup during deployment and mission operations.

Summary of failure modes and effects analyses of all credible failure modes which may lead to an accidental explosion: The only potential accidental explosion could be caused from the battery. The battery contains two protection circuits, one internal and one external. The external protection circuit is responsible for overcharging, short circuit and overheating. The battery safety systems discussed in the FMEA (see requirement 4.4-1 below) describe these faults..

Detailed plan for any designed spacecraft breakup, including explosions and intentional collisions: There is not a possible scenario of planned spacecraft breakup.

List of components which shall be passivated at End of Mission (EOM) including method of passivation and amount which cannot be passivated: None.

Rationale for all items which are required to be passivated, but cannot be due to their design: The Lambdasat will be operational during only its orbital life time. This lifetime has been calculated to 74.095 days. No postmission passivation will be performed after the mission. The satellite will terminate its mission after the burn in the atmosphere.

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:

Payload Pressure Vessel Failure: The payload should be considered to be “sealed container” because the maximum payload pressure is 14.7 PSIa. This pressure is considered to be insufficient to cause catastrophic failure.

Battery explosion:

Effect: All failure modes below might result in battery explosion with the possibility of orbital debris generation. This is an unlikely scenario since the flight heritage of this battery type and its approval from the ISS. In an unlikely scenario of battery rupture, the small mass of the battery will be limited for debris inside the vessel. due to the lack of penetration energy.

Probability: It is believed to be less than 0.1% given that multiple independent (not common mode) faults must occur for each failure mode to cause the ultimate effect explosion).

Failure mode 1: Battery Internal short circuit.

Mitigation 1: Complete proto-qualification and environmental acceptance tests of the Canon BP-930 battery by JSC ISS program. The acceptance tests are 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: Each cell includes a positive temperature coefficient (PTC) variable resistance device that ensures high rate discharge is limited to acceptable levels if thermal rise occurs in the battery.

Combined faults required for realized failure: The PTC must fail and spacecraft thermal design must be incorrect and external over current detection and protection must fail for this failure mode to occur.

Failure Mode 3: Overcharging and excessive charge rate.

Mitigation 3: The satellite is designed and built to provide battery protection in case of overcharged. This circuit has been protoqualification 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 150 mA, but because of the depoyable solar panels, the total charging current is 450mA. The maximum charge rate the battery can accept is 500mA. The battery is a proto-qualified Canon BP-930 from the JSC ISS program, and has four US18650S cells. The battery itself has two parallel strings of 2 cells connected in series, and thus having 4 cells. 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 only a single string from the battery was accepting charge. For this failure mode to become active one string must fail to accept a charge and the charge control circuit on the remaining string fails. 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) proto-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: The PTC must fail and an external load must fail/short-circuit and external over-current detection and disconnect function must fail 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 and ISS environmental stress screening fails to detect failed vents.

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 nonconductive 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 6.7 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.

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 post mission 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: The Lambdasat will only be on orbit for 74 days based on the DAS analysis shown in this report, and it is planned to operate until deorbiting. No postmission passivation will be performed, as the satellite will break up on re-entry at the end of the mission.

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 OnOrbit Collisions

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

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

Large Object Impact and Debris Generation Probability: 0.000000; COMPLIANT.

Requirement 4.5-2. Limiting debris generated by collisions with small objects whenoperating 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

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: 1275 grams

Cross-sectional Area: 0.015 m^2

Area to mass ratio: 0.024634 (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 Lambdasat satellite reentry is COMPLIANT using Method "a." Lambdasat will re-enter approximately 74 days after launch with orbit history as shown in Figure 3 (analysis assumes an approximate random tumbling behavior).

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 Lambdasat is compliant with the requirement. It predicts that no components reach the ground, except the solar cells. The only thing that would reach the ground are the solar cells, but it is still compliant. The risk of human casualty according to the DAS program is 1:0. 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. Impact kinetic energy is less than 15 J in order and also compliant (the solar cells have an impact kinetic energy of 5.49 J). Finally, there are no titanium components that will be used on Lambdasat, which also is a reason why no components reach the ground

LambdaSat (1275g) Nominal Deployment

Duration: 0.203 yr (74.095 days)

Altitude Plot:

Figure 3: Altitude Plot

DAS Requirement Results:
02 08 2014; 21:23:04PM Processing Requirement 4.3-1: Return Status : Not Run

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

=============== End of Requirement 4.3-1 ===============
02 08 2014; 21:23:07PM Processing Requirement 4.3-2: Return Status : Passed

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

=============== End of Requirement 4.3-2 ===============
02 08 2014; 21:23:09PM Requirement 4.4-3: Compliant

=============== End of Requirement 4.4-3 ===============
02 08 2014; 21:23:11PM Processing Requirement 4.5-1: Return Status : Passed

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

INPUT

Space Structure Name = LambdaSat
Space Structure Type = Payload
Perigee Altitude = 361.000000 (km)
Apogee Altitude = 437.000000 (km)
Inclination = 51.600000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Final Area-To-Mass Ratio = 0.024634 (m^2/kg)
Start Year = 2014.000000 (yr)
Initial Mass = 1.275000 (kg)
Final Mass = 1.275000 (kg)
Duration = 0.203000 (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 08 2014; 21:23:14PM Requirement 4.5-2: Compliant
02 08 2014; 21:23:15PM Processing Requirement 4.6 Return Status : Passed

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

INPUT

Space Structure Name = LambdaSat

Space Structure Type = Payload

Perigee Altitude = 361.000000 (km)
Apogee Altitude = 437.000000 (km)
Inclination = 51.600000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Area-To-Mass Ratio = 0.024634 (m^2/kg)
Start Year = 2014.000000 (yr)
Initial Mass = 1.275000 (kg)
Final Mass = 1.275000 (kg)
Duration = 0.203000 (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 = 361.000000 (km)
Suggested Apogee Altitude = 437.000000 (km)
Returned Error Message = Reentry during mission (no PMD req.).

Released Year = 2014 (yr)
Requirement = 61
Compliance Status = Pass

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

=============== End of Requirement 4.6 ===============
02 08 2014; 21:24:25PM *********Processing Requirement 4.7-1
Return Status : Passed

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

name = LambdaSat
quantity = 1
parent = 0
materialID = 8
type = Box
Aero Mass = 1.275000
Thermal Mass = 1.275000

Diameter/Width = 0.104000
Length = 0.302000
Height = 0.104000

name = PowerBoard
quantity = 1
parent = 1
materialID = 77
type = Box
Aero Mass = 0.010000
Thermal Mass = 0.010000
Diameter/Width = 0.092000
Length = 0.108000
Height = 0.005000

name = Main Computer
quantity = 1
parent = 1
materialID = 77
type = Box
Aero Mass = 0.010000
Thermal Mass = 0.010000
Diameter/Width = 0.092000
Length = 0.108000
Height = 0.005000

name = Board Graphene Experiment
quantity = 1
parent = 1
materialID = 77
type = Box
Aero Mass = 0.061000
Thermal Mass = 0.061000
Diameter/Width = 0.092000
Length = 0.108000
Height = 0.005000

name = Battery
quantity = 1
parent = 1
materialID = 39
type = Box
Aero Mass = 0.181000
Thermal Mass = 0.181000
Diameter/Width = 0.040000
Length = 0.070000
Height = 0.038000

name = Stensat
quantity = 1
parent = 1
materialID = 77
type = Flat Plate
Aero Mass = 0.020000
Thermal Mass = 0.020000
Diameter/Width = 0.045000
Length = 0.080000

name = Iridium Modem
quantity = 1
parent = 1
materialID = 5
type = Box
Aero Mass = 0.030000
Thermal Mass = 0.030000
Diameter/Width = 0.041000
Length = 0.045000
Height = 0.013000

name = UHF Receiver
quantity = 1
parent = 1
materialID = 5
type = Box
Aero Mass = 0.008000
Thermal Mass = 0.008000
Diameter/Width = 0.019300
Length = 0.039600
Height = 0.004320

name = AIS Receiver
quantity = 1
parent = 1
materialID = 5
type = Box
Aero Mass = 0.070000
Thermal Mass = 0.070000
Diameter/Width = 0.062000
Length = 0.069900
Height = 0.012700

name = Antenna 1
quantity = 1
parent = 1
materialID = 23
type = Box

Aero Mass = 0.000500
Thermal Mass = 0.000500
Diameter/Width = 0.006000
Length = 0.171000
Height = 0.001000

name = Antenna 2
quantity = 1
parent = 1
materialID = 23
type = Box
Aero Mass = 0.000500
Thermal Mass = 0.000500
Diameter/Width = 0.006000
Length = 0.172000
Height = 0.001000

name = Antenna 3
quantity = 1
parent = 1
materialID = 23
type = Box
Aero Mass = 0.001000
Thermal Mass = 0.001000
Diameter/Width = 0.006000
Length = 0.463000
Height = 0.001000

name = Iridium Antenna
quantity = 1
parent = 1
materialID = 5
type = Box
Aero Mass = 0.025000
Thermal Mass = 0.025000
Diameter/Width = 0.017000
Length = 0.040000
Height = 0.017000

name = Solar Cells
quantity = 4
parent = 1
materialID = -1
type = Box
Aero Mass = 0.078000
Thermal Mass = 0.078000
Diameter/Width = 0.082000
Length = 0.300000

Height = 0.002000

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

name = LambdaSat
Demise Altitude = 77.998019
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = PowerBoard
Demise Altitude = 77.920926
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Main Computer
Demise Altitude = 77.920926
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Board Graphene Experiment
Demise Altitude = 77.510847
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Battery
Demise Altitude = 77.485215
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Stensat
Demise Altitude = 77.628082
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Iridium Modem
Demise Altitude = 74.503113
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = UHF Receiver

Demise Altitude = 75.899511
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = AIS Receiver
Demise Altitude = 73.484449
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Antenna 1
Demise Altitude = 77.941222
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Antenna 2
Demise Altitude = 77.941230
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Antenna 3
Demise Altitude = 77.960058
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Iridium Antenna
Demise Altitude = 74.082066
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Solar Cells
Demise Altitude = 0.000000
Debris Casualty Area = 2.029199
Impact Kinetic Energy = 5.492338

****

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

Requirements 4.7-1b and 4.7-1c below are non-applicable requirements because Lambdasat 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 according to the DAS program is 1:0, so there is no risk because almost all the components won't reach the ground. Impact kinetic energy has to be less than 15 J in order to be compliant (the solar cells have an impact kinetic energy of 5.49 J).

ODAR Section 8: Assessment for Tether Missions

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

Appendix A: Data Sheet of Battery Canon BP-930

MATERIAL SAFETY DATA SHEET

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MSDS#:BA0035-01-090218

SECTION 1 IDENTIFICATION OF THE SUBSTANCE/MIXTURE AND OF THE COMPANY/UNDERTAKING

Product Name:	Lithium Ion Battery
Product Code:	BP-930
Company Name:	Canon Inc.
Address:	30-2, Shimomaruko 3-Chome, Ohta-ku, Tokyo 146-8501, Japan
Use of the Product:	Battery for Video camera
Supplier:	
Address:	
Phone number:	

With regard to air transport, the International Civil Aviation Organization (ICAO) Packing Instruction 965 Part 1 complies with the Recommendation as is; further, the International Air Transport Association (IATA) adopts ICAO Packing Instruction 965 Part 1. In addition, the regulations of the US Department of Transportation for land, sea and air transportation are based on the UN Recommendations.

SECTION 2 MATERIALS AND INGREDIENTS INFORMATION

IMPORT ANT NOTE: The battery pack uses four US 18650S lithium-ion rechargeable cells and control circuit on the PWB. The cells are connected in 2 parallel strings of 2 cells in series. The battery pack should not be opened or burned since the following ingredients contained within the cells could be harmful under some circumstance if exposed or misused. The cells contain neither metallic lithium nor lithium alloy.

Cathode:	Lithium-Cobalt Dioxides	(active material)
	Polyvinyldiene Fluoride	(binder)
	Graphite	(conductive material)
Anode:	Graphite	(active material)
	Polyvinyldiene Fluoride	(binder)
Electrolyte:	Organic Solvent	(non-aqueous liquid)
	Lithium Salt	
Others:	Heavy metals such as Mercury, Cadmium, Lead, and Chromium are not used in the cells.	
Enclosure:	Plastic (PC)	

SECTION 3 FIRE HAZARD DATA

In case of fire, use CO_2 or dry chemical extinguishers.

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SECTION 4 HEALTH HAZARD DATA

Under normal condition of use, these chemicals are contained in sealed can. Risk of exposure occurs only if the cells are mechanically abused.

Inhalation:	Contents of an opened cell can cause respiratory irritation. Remove to fresh air immediately and call a doctor.
Skin Contact:	Contents of an opened cell can cause skin irritation. Wash skin with soap and water.
Eye Contact:	Contents of an opened cell can cause eye irritation. Immediately flush eyes thoroughly with water for at least 15 minutes. Seek medical attention.

SECTION 5 PRECAUTIONS FOR SAFE HANDLING AND USE

Storage:	Store within the recommended limit of -20 degrees C to 45 degrees C (-4 degrees F to 113 degrees F), well-ventilated area. Do not expose to high temperature (60 degrees C/140 degrees F). Since short circuit can cause burn hazard or safety vent to open, do not store with metal jewelry, metal covered tables, or metal belt.
Handling:	Do not disassemble, remodel, or solder. Do not short + and - terminals with a metal. Do not open the battery pack.
Charging:	Charge within the limits of 0 degrees C to 40 degrees C (32 degrees F to 104 degrees F) temperature. Charge with specified charger designed for this battery pack.
Discharging:	Discharge within the limits of -10 degrees C to 50 degrees C (14 degrees F to 122 degrees F) temperature.
Disposal:	Dispose in accordance with applicable federal, state and local regulation.
Caution:	Attach the cover to the battery pack to prevent short circuits. Do not disassemble. Do not incinerate. Do not expose to temperature above 140 degrees F.

SECTION 6 SPECIAL PROTECTION INFORMATION

Respiratory Protection:	Not necessary under normal use.
Ventilation:	Not necessary under normal use.
Eye Protection:	Not necessary under normal use.
Protective Gloves:	Not necessary under normal use.

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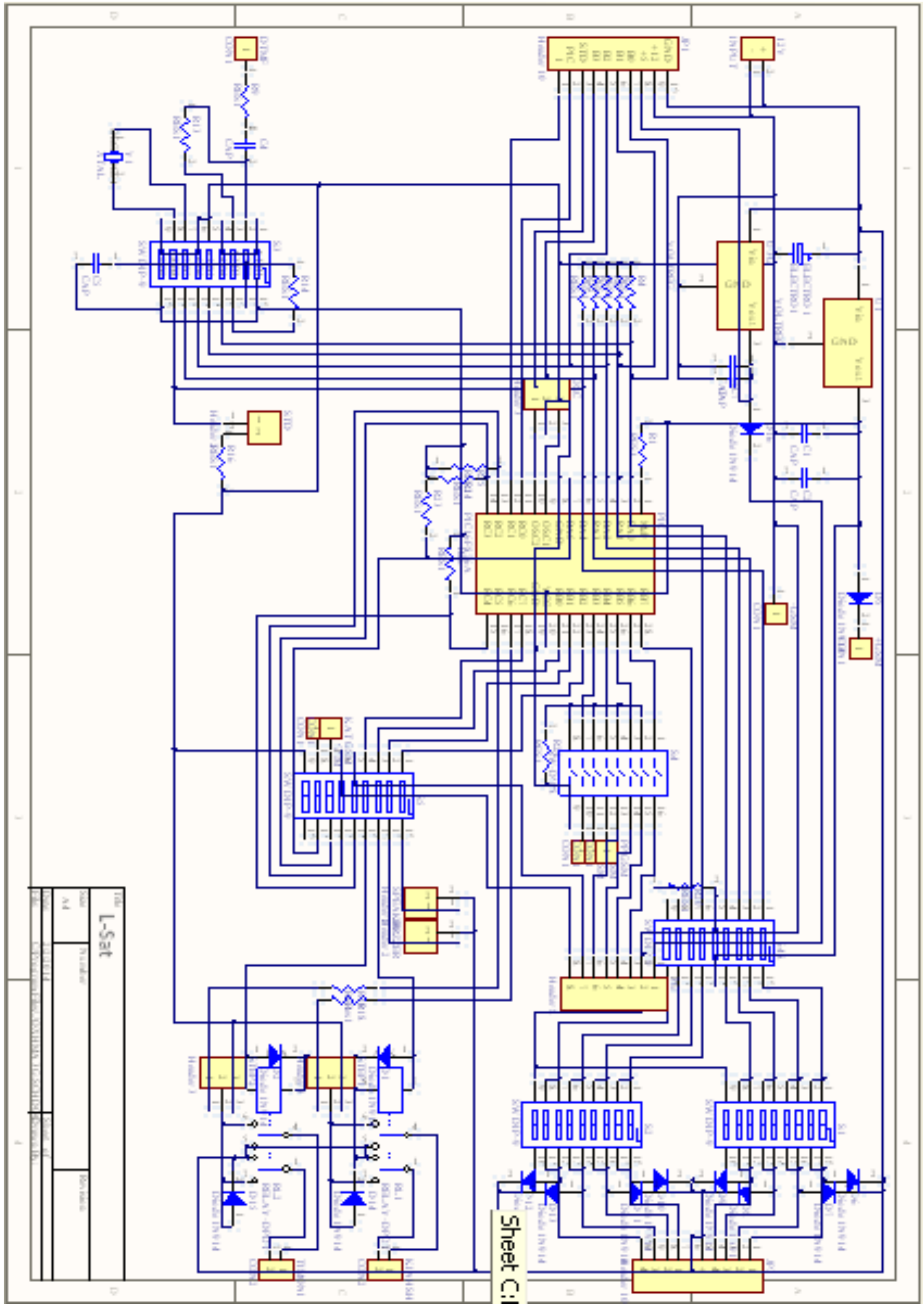
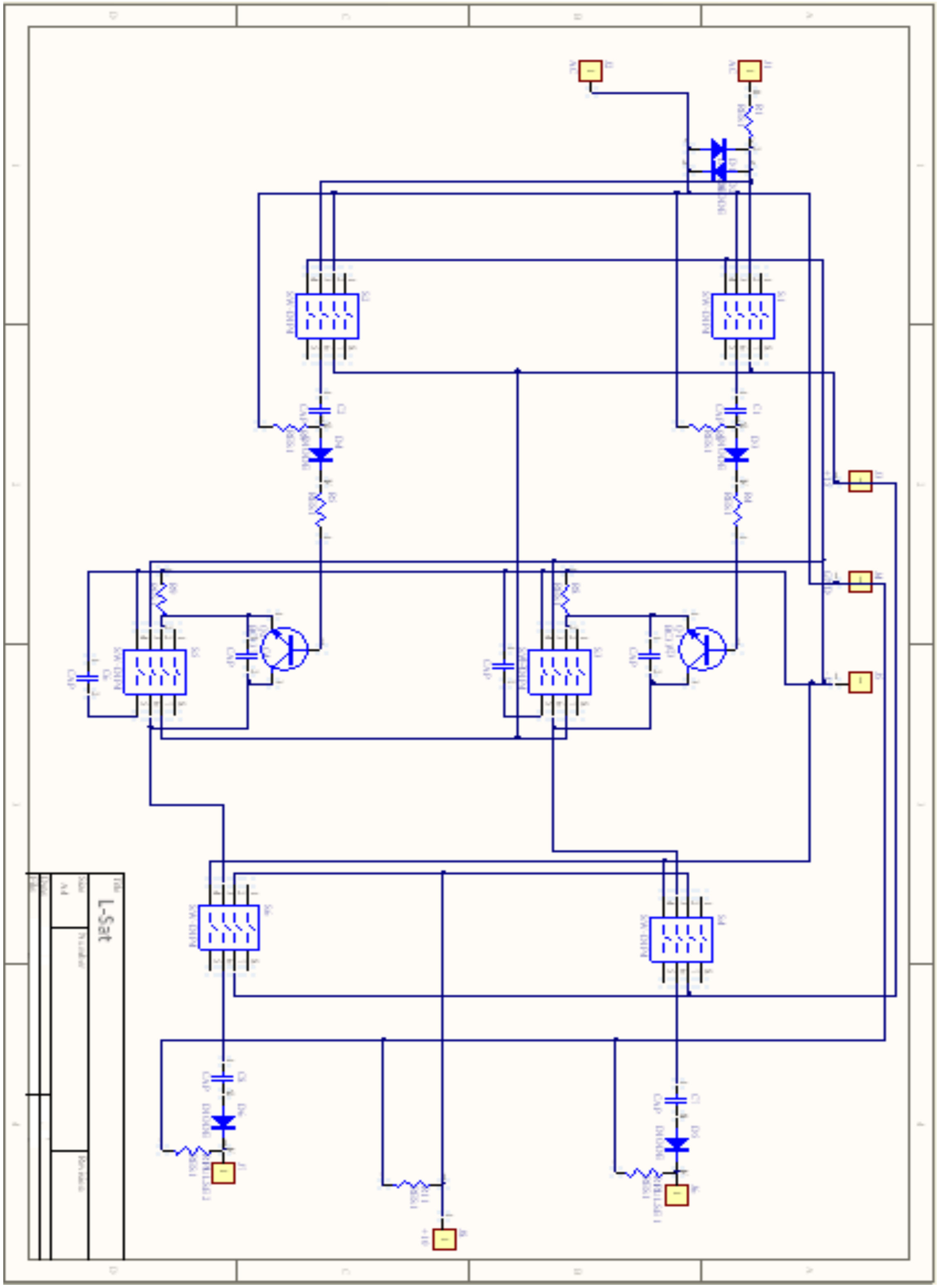
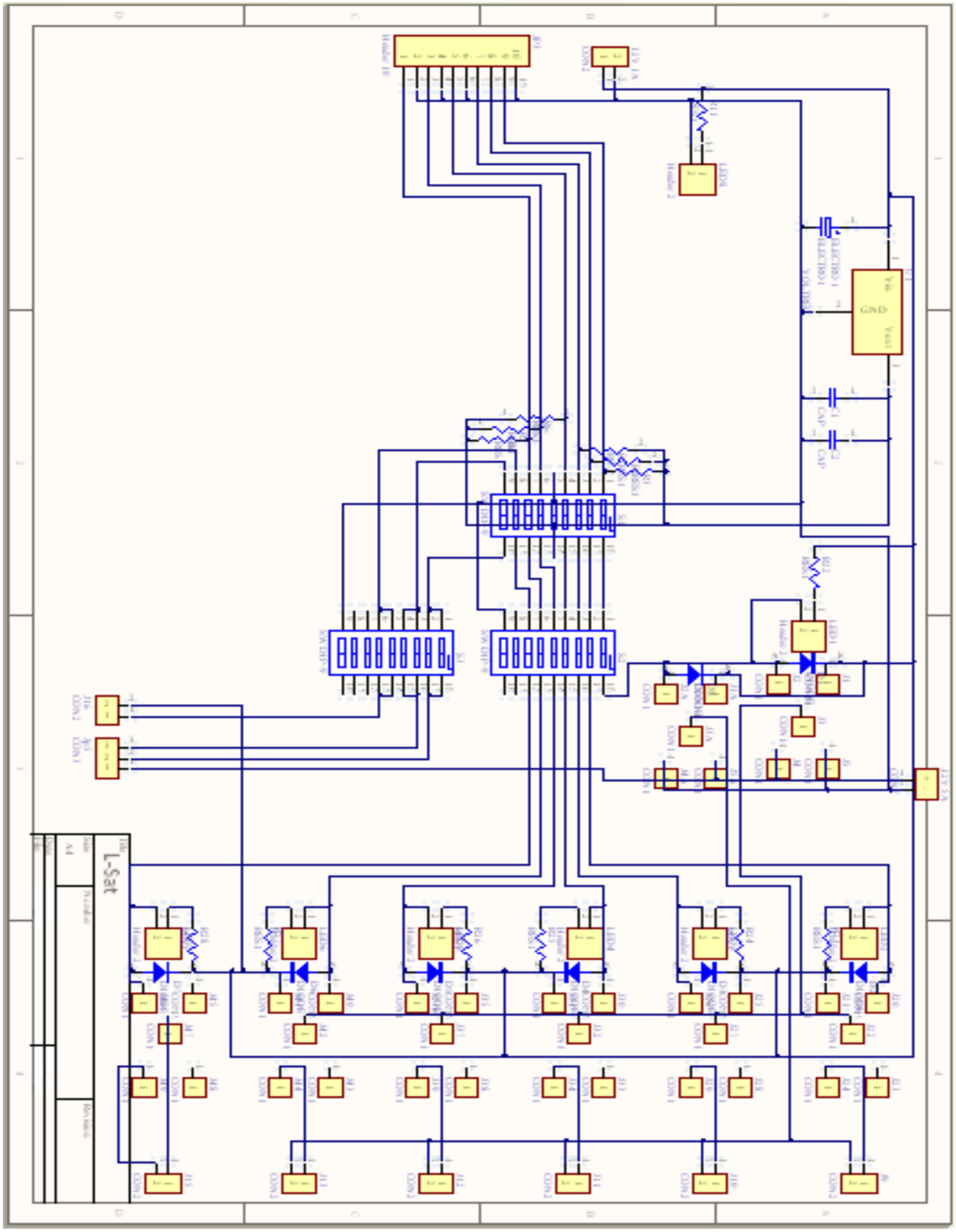
Appendix B: Wiring diagram – Schematics for Lambdasat Electronics


L-Sat




L-Sat