Agile MicroSat
Orbital Debris Assessment Report
Final

November 12, 2020

Lincoln Laboratory
Massachusetts Institute of Technology
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REVISION HISTORY

Revision	Description of Change	Author	Date
1.0	Preliminary draft	J. Tadiello	09/26/2020
2.0	Revision of DAS Section 9 calculations	J. Tadiello	10/25/2020
3.0	Revision of Section 2	D. Cousins	11/05/2020
4.0	Final, including Revision of Section 4, AMS-1 name used throughout	D. Cousins	11/12/2020

SUBMITTED BY

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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.

A self-assessment of the ODAR is provided below in accordance with the assessment format provided in Section 9A.2 of NASA-STD-8719.14.

Rqmt #	Rqmt Description	Compliance Assessment	Comments
4.3-1.a	25 year limit	Compliant	No debris released in LEO
4.3-1.b	<100 object x year limit	Compliant	No debris released in LEO
4.3-2	GEO +/- 200km	Compliant	No debris released near GEO
4.4-1	<0.001 Explosion Risk	Compliant	On-board energy source (batteries) incapable of debris –producing failure
4.4-2	Passivate Energy Sources	Compliant	On-board energy source (batteries) incapable of debris –producing failure
4.4-3	Limit BU Long term Risk	Compliant	No planned breakups
4.4-4	Limit BU Short term Risk	Compliant	No planned breakups
4.5-1	10cm Impact Risk	Compliant	
4.5-2	Post-mission Disposal Risk	Compliant	
4.6-1a	Disposal Method	Compliant	
4.6-1b	Disposal Method	Compliant	Planned atmospheric reentry
4.6-1c	Disposal Method	Compliant	No planned retrieval
4.6.2	GEO Disposal	Compliant	LEO orbit only
4.6-3	MEO Disposal	Compliant	LEO orbit only
4.6-4	Disposal Reliability	Compliant	
4.7-1	Ground Population Risk	Compliant	
4.8-1	Tether Risk	Compliant	No tethers used

This document does not contain proprietary, or export controlled information.

See page 2 of this document for revision history.

DAS v3.1.0 was utilized in assessing the requirements described within this document.

Section 1: Program Management and Mission Overview

a. Identification of the HQ Mission Directorate sponsoring the mission and the Program Executive

The Agile Micro Satellite is sponsored by Department of Defense, Under Secretary of Defense for Research and Engineering under provisions of Air Force Contract No. FA8702-15-D-0001 to MIT Lincoln Laboratory.

b. Identification of the responsible program/project manager and senior scientific and management personnel

Principal Investigator: Andrew Stimac
Program Manager: Daniel Cousins

c. Identification of any foreign government or space agency participation in the mission

No foreign government or space agency participation.

d. Schedule of mission design and development milestones

AMS-1 spacecraft Critical Design Review was completed 28 April 2020.
SpaceFlight Inc launch services were contracted and orbit parameters manfest 23 September 2020.

AMS-1 spacecraft shipment for launch integration planned for October 2021.
SpaceX launch window opening planned for December 2021.

e. Brief description of the mission

The AMS-1 project objectives are primarily Space Research and secondarily Earth Exploration Satellite. The overall research goal of the AMS-1 mission is to demonstrate significant orbit lowering maneuvers with a 3-axis stabilized 6U cubesat. Maneuvers of this type will enable future improved satellite-based Earth remote sensing missions. Both manual ground based and autonomous on board maneuver guidance will be performed by AMS-1. The autonomous altitude correction consists of both an altitude maintenance thruster control scheme as well as an attitude correction fault management element. Two additional payloads are manifested on the satellite. A visible wavelength Camera payload will space qualify a commercially available CMOS sensor under consideration for future LEO missions. An optical Beacon module will serve as a reference signal for a ground based adaptive optics system that is evaluating novel atmospheric correction schemes.

Upon deployment from at its initial altitude, AMS-1 spacecraft will be remain in the stowed solar panel configuration for 30 minutes. The spacecraft will then release solar panels into the operational configuration and autonomously enter a sun-safe attitude orientation and be ready for initial ground contact. The spacecraft will then spend a period of 4 weeks performing payload operations and thruster calibration. The AMS-1 spacecraft will normally maintain a Low Drag – Sun Track attitude orientation where the minimum cross sectional area will be oriented towards the velocity vector and the solar panels will roll about the velocity vector orienting the solar panels towards the sun.
Once calibrated, the spacecraft will be commanded from the mission operation center to begin a series of in-plane orbit altitude lowering maneuvers over a period of approximately 4 months. Once the spacecraft reaches a final operational minimum altitude, the spacecraft will continue to use the thruster to compensate for atmospheric drag in order to maintain altitude for a period of one months. At selected points within the AMS-1 mission, the spacecraft will conduct ground controlled Beacon and Camera payload operations while pointing at Earth fixed ground targets.

f. Identification of the anticipated launch vehicle and launch site

Launch Vehicle: Space X Falcon 9
Launch Site: Cape Canaveral Air Station, FL USA

g. Identification of the proposed launch date and mission duration

Proposed launch window: 01-31 Dec 2021
Nominal mission duration: 6 months

h. Description of the launch and deployment profile, including all parking, transfer, and operational orbits with apogee, perigee, and inclination

The AMS-1 spacecraft will be dispensed into orbit from a SHERPA transfer stage manufactured by SpaceFlight Inc. using a CubeSat dispenser manufactured by Innovative Solutions in Space, Inc

The AMS-1 spacecraft will dispense into Low-Earth-Orbit, circular, 98 degree inclination, sun-synchronous with Local Time of Descending Node 1030.

Over the mission, the AMS-1 spacecraft will make in-plane maneuvers to lower it's altitude.

Nominal Initial Deployment Altitude: 500 km
Maximum Initial Deployment Altitude: 550 km

i. Description of the spacecraft's maneuver capability, including both attitude and orbit control.

The AMS-1 mission is equipped with a thruster manufactured by Enpulsion GmbH operating by the Field-Emission Electric Propulsion effect to provide up to 5000 Ns total impulse. AMS-1 will maneuver only in-plane to either increase or decrease orbital velocity and corresponding change to altitude. After the initial deployment, the AMS-1 spacecraft will maneuver to lower the orbital altitude over a four month period utilizing short duration, low impulse thrusting events at orbital apogee/perigee. Upon reaching the final operational orbit, the AMS-1 spacecraft will continuously thrust to maintain that orbital altitude.

Minimum Final Operating Altitude: 275 km

j. Reason for selection of operational orbit

Operational sun synchronous orbit chosen to optimize power generation while in the Low drag sun track attitude orientation. Mid or low inclination orbits are not sufficient for adequate power generation and corresponding minimum maintainable altitude. Mid-morning LTAN is needed for sunlit ground illumination scenes for Camera operation and dark sky night scenes for Beacon operation.
k. Identification of any interaction or potential physical interference with other operational spacecraft

The AMS-1 spacecraft will traverse the International Space Station orbital altitude range. The real-time orbital location of the AMS-1 spacecraft will be monitored by GlobalStar simplex telemetry by the AMS-1 mission operations center. AMS-1 spacecraft maneuvers through this altitude range will be carefully monitored and coordinated with the use of Air Force Space Control Network radar assets.

Section 2: Spacecraft Description

a. Physical description of the spacecraft

AMS-1 is a 6U XL cubesat configuration. The stowed configuration of the satellite complies with the 6UXL standard chassis rail envelope of 365 mm x 266 mm x 100 mm. Payloads are interior to this volume. After dispensing from the launch vehicle transfer stage into orbit, the latched solar panels are be deployed utilizing a spring/latch mechanism resulting in the operational on-orbit configuration. The tip-to-tip extent of the deployed solar panels is 1.415 meter. Radio communications and GPS patch antennas are mounted to the sides of the spacecraft and do not deploy.

b. Illustration of the spacecraft in the mission operation configuration

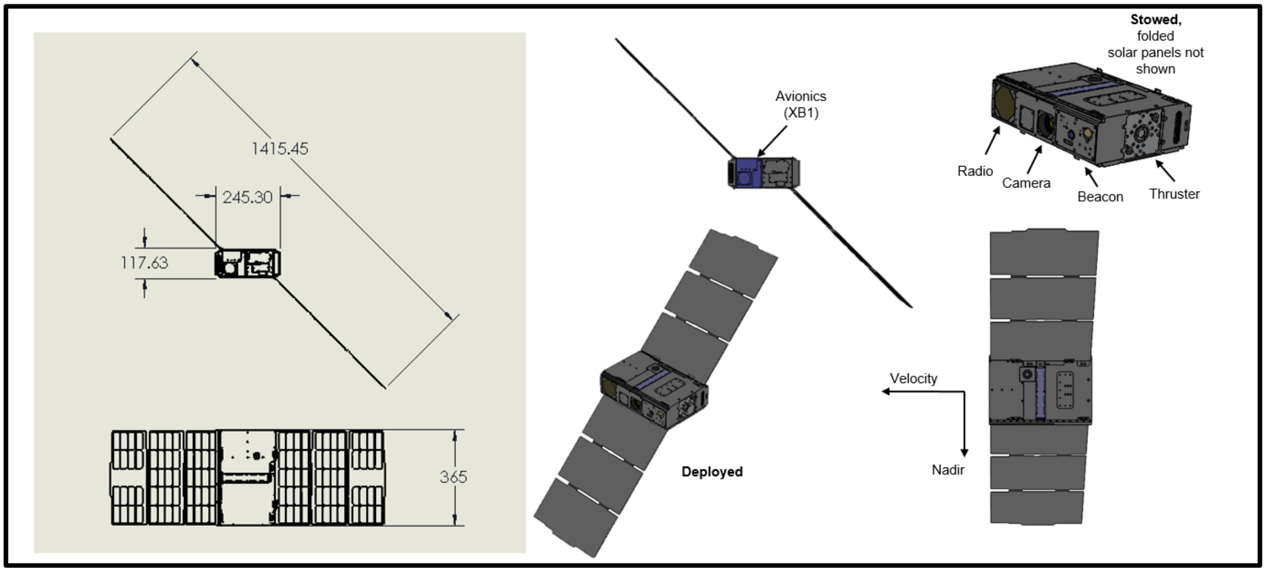


Figure 1. AMS-1 Spacecraft on-orbit configuration. Dimensions shown in mm.

c. Total spacecraft mass at launch, including all propellants and fluids

AMS-1 spacecraft has a maximum launch mass of 12.6 kg (Maximum Expected Value).

d. Dry mass of spacecraft at launch (minus all consumables and propellants),

If the total thruster fuel capacity was not loaded, the spacecraft mass would be reduced by 0.22 kg to a final mass of 12.4 kg (MEV).

e. Identification of all fluids planned to be on board (including any planned future in-space transfers), excluding fluids in sealed heat pipes.

There are no pressurized fluids, gases used as propellants, pressurized batteries or sealed heat pipes on the AMS-1 spacecraft.

The thruster uses indium metal as propellant, which is in a solid state at normal Earth and on-orbit temperatures. Prior to a thrusting event, the indium fuel is heated above 156 C into a molten state for electric propulsion as ionized particles.

The battery is composed of unpressurized lithium-ion battery cells.

f. Description of all propulsion systems

The propulsion system consists of an Enpulsion Nano model AR3 thruster module with thrust vector control and capable of producing thrust of 0.35 milli-Newtons. The indium fuel is unpressurized in both solid and molten states. Similar Enpulsion Nano models have spaceflight heritage starting in 2018 and presently operate on ICEYE spacecraft.

g. 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 AMS-1 mission includes a fully populated 3-axis attitude determination and control system including redundant star trackers, reaction wheels and torque rods. Flexible commanding allows for multiple pointing modes to be commanded as needed including Inertial stabilized, Sun-hold safe, Earth target fixed and Fine-reference pointed.

For the normal mission operations involving altitude lowering and maintenance at low altitude, the spacecraft will be oriented in fine reference pointed Low drag – Sun hold attitude mode where the minimum cross sectional area is oriented towards the velocity vector and the solar panels roll about the velocity vector to maximize solar illumination on the panels.

For normal mission operations involving radio communications and payload data collection, the spacecraft will be body stabilized and oriented to maintain pointing toward a fixed Earth target during an overpass. At the completion of the overpass, the spacecraft will return to Low-drag Sun-hold orientation described above.

h. Description of any range safety or other pyrotechnic devices

The spacecraft employs three independent deployment switches to fully inhibit the spacecraft power system while stowed in the dispenser onboard the launch vehicle. In this stowed configuration for launch, there is no potential for powered radio transmission of the AMS-1 spacecraft.

After dispensing into orbit, two linearly actuated hold down mechanisms are used for the deployment of the solar panels. The mechanisms are non-pyrotechnic.

i. Description of the electrical generation and storage system

The spacecraft power management system stores energy storage via a lithium-ion 10.2 A-hr battery manufactured by Blue Canyon Technologies. The battery is configured of 3 strings of 3 cells providing overall voltage range between 10.8 and 12.3 V. The cells are lithium manganese nickel chemistry and model 18650MJ1 manufactured by LG Chem. Individual cells are 3.5A-hr capacity at 3.635 V nominal. Cells are not pressure vessels. Power is generated by a solar array consisting of SolAero ZTJ photovoltaic cells configured as 14, 8-cell strings in series.

Battery cells are UN38.3 safety certified. The power management system incorporates both low-side and high-side battery inhibits.

j. Identification of any other sources of stored energy not noted above

There are no sources of stored energy on-board other than the battery.

k. Identification of any radioactive materials on board

No radioactive materials are onboard AMS-1 spacecraft.

l. Description of any planned proximity operations or docking with other spacecraft

There are no planned proximity operations or docking with other spacecraft.

Section 3: Assessment of Spacecraft Debris Released during Normal Operations

a. Identification of any object (>1 mm) expected to be released from the spacecraft any time after launch

There are no planned intentional releases of objects from AMS-1 during any mission phase. The AMS-1 does not incorporate any shrouds or covers to be removed on deployment. The solar panel arrays are stowed using a torsion spring that has been compressed for launch and restrained through the use of two linearly actuated latch mechanisms that produces no shrapnel. The solar arrays deploy when the linear actuators retract a latch that is constraining the panels releasing the stored tension in the springs.

b. Rationale/necessity for release of each object

N/A

c. Time of release of each object, relative to launch time

N/A

d. Release velocity of each object with respect to spacecraft

N/A

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

N/A

f. Calculated orbital lifetime of each object, including time spent in LEO

N/A

g. Assessment of spacecraft compliance with Requirements 4.3-1 and 4.3-2

Requirement 4.3-1: Debris passing through LEO – released debris with diameters of $\geq$ 1mm

a. Requirement 4.3-1a: 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. Requirement 4.3-1b: The total object-time product shall be no larger than 100 object-years per mission. For the purpose of this standard, satellites smaller than a 1U standard CubeSat are treated as mission-related debris and thus are bound by this definition to collectively follow the same 100 object-years per mission deployment limit.

The AMS-1 spacecraft has no intentional releases of debris.
Compliant Statement: COMPLIANT

Requirement 4.3-2: Debris passing near GEO:

The AMS-1 spacecraft orbit is not GEO nor does traverse through GEO.
Compliant Statement: COMPLIANT

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

a. Identification of all potential causes of spacecraft breakup during deployment and mission operations

There is no credible deployment or operational scenarios that would result in AMS-1 spacecraft breakup during normal deployment and operation

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

There is no credible failure modes that would result in AMS-1 spacecraft breakup during normal deployment and operation

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

There are no planned breakups of the AMS-1 spacecraft.

d. List of components which are passivated at EOM. List includes method of passivation and amount which cannot be passivated.

When the AMS-1 mission is completed, the battery system will be passivated by completely discharging the battery.

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

N/A

f. 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

No credible AMS-1 spacecraft failure modes exist that results in explosion.
Compliant Statement: COMPLIANT

Requirement 4.4-2: Design for passivation after completion of mission operations while in orbit

When the AMS-1 mission is completed, the battery system will be disconnecting the battery charge circuit and passivated by completely discharging the battery.
Compliance Statement: COMPLIANT.

Requirement 4.4-3. Limiting the long-term risk to other space systems from planned breakups.
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 10cm 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 remains in Earth orbit longer than one year.

The AMS-1 mission does not generate debris on orbit.
Compliant Statement: COMPLIANT

Requirement 4.4-4: Limiting the short-term risk to other space systems from planned breakups for Earth orbital missions:

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}.

The AMS-1 mission has no planned explosions or intentional collision.
Compliant Statement: COMPLIANT

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

a. Calculation of spacecraft probability of collision with space objects larger than 10 cm in diameter during the orbital lifetime of the spacecraft.

b. Calculation of spacecraft probability of collision with space objects, including orbital debris and meteoroids, of sufficient size to prevent postmission disposal.

c. Assessment of spacecraft compliance with Requirements 4.5-1 and 4.5-2

Requirement 4.5-1. Limiting debris generated by collisions with large objects when 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 does not exceed 0.001. For spacecraft and orbital stages passing through the protected region +/- 200 km and +/-15 degrees of geostationary orbit, the probability of accidental collision with space objects larger than 10 cm in diameter shall not exceed 0.001 when integrated over 100 years from time of launch.

Analysis performed using DAS v.3.0.1 shows that probability for collision of the AMS-1 spacecraft at 4.3211E-07. See Section 9 DAS Analysis output for itemized list of spacecraft components used for collision analysis.
Compliance Statement: COMPLIANT

Requirement 4.5-2. Limiting debris generated by collisions with small objects when operating in Earth 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 maneuver requirements does not exceed 0.01.

Analysis performed using DAS v.3.0.1 shows that probability for PMD failure at 1.0049E-5 for the AMS-1 spacecraft and the probability of penetration for the patch antenna at 1.0049E-5
See Section 9 DAS Analysis output for itemized list of spacecraft components used for collision analysis.
Compliance Statement: COMPLIANT

d. Detailed description and assessment of the efficacy of any planned debris avoidance capability intended to help in meeting the requirements of requirement 4.5-1, including any plans to move to less congested altitudes, as well as any tracking enhancements (GPS, laser retroreflector, e.g.) that may assist in reducing the covariance of collision estimates.

While not required to comply with debris limits, the AMS-1 spacecraft provides real-time simplex telemetry through GlobalStar relay of the spacecraft current position, velocity and status. Such data mitigates the risk of losing track of the spacecraft during orbital maneuvers. Data will be proved to Spacetrack.org to enhance track custody of the AMS-1 spacecraft.

Section 6: Assessment of Spacecraft Postmission Disposal Plans and Procedures

a. Description of spacecraft disposal option selected

Due to the nature of the experiment, the final operational orbit of the AMS-1 mission will be such that natural passive orbital decay will be < 1 year without the need for propulsive maneuvers.

b. Identification of all systems or components required to accomplish any postmission disposal maneuvers. Plan for any spacecraft maneuvers required to accomplish postmission disposal

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

Per DAS v3.0.1 analysis, the AMS-1 spacecraft

12.6 kg, 0.586 m2 CD*Aref, area to mass ratio = 0.0464 m2/kg in on-orbit nominal deployed solar panel configuration
12.6 kg, 0.0792 m2 CD*Aref, area to mass ratio = 0.0063 m2/kg in stowed solar panel configuration

d. If appropriate, preliminary plan for spacecraft controlled reentry

N/A

e. 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 2,000 km shall be disposed of by one of the following three methods:

a. Atmospheric reentry option:

(1) Leave the space structure in an orbit in which natural forces will lead to atmospheric reentry within 25 years after the completion of mission or

(2) 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 above 2000 km and ensure its apogee altitude will be below 19,700 km, both for a minimum of 100 years.

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

The nominal disposal plan of AMS-1 is by natural atmospheric reentry of the spacecraft in the operational solar panel configuration from final operational orbit at 275 km altitude. After thrust employed by the AMS-1 spacecraft to actively compensate for drag and maintain 275 km altitude is suspended, the spacecraft will begine to tumble and naturally lose orbital energy into the atmosphere and re-enter.

Per DAS v3.0.1 analysis, the orbital lifetime for the nominal disposal plan is 0.011 year lifetime (4 days)

The contingency disposal plan of AMS-1 is by natural atmospheric reentry of the spacecraft in the operational solar panel configuration from initial deployment orbit at 550 km altitude if for any reason the spacecraft is unable to execute propulsive orbit lowering maneuvers.

Per DAS v3.0.1 analysis, the orbital lifetime for the contingency disposal plan is 0.706 year lifetime (8.47 months)

The worst case disposal plan of AMS-1 relies on natural atmospheric reentry from initial deployment orbit of 550 km altitude assuming the solar panels never deploy and the spacecraft remains in the stowed configuration.

Per DAS v3.0.1 analysis, the orbital lifetime for the worst case disposal plan is 10.875 year lifetime

Compliance Statement: COMPLIANT

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

The AMS-1 spacecraft orbit is not GEO nor does traverse through GEO.
Compliance Statement: COMPLIANT

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

No orbits are planned between LEO and MEO or MEO and GEO.
Compliance Statement: COMPLIANT

Requirement 4.6-4. Reliability of postmission disposal maneuver operations in Earth orbit:

NASA space progrAMS-1 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, and

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.

AMS-1 will reenter without disposal operations from its minimum final operational altitude of 275 km.
Compliance Statement: COMPLIANT

Section 7: Assessment of Spacecraft Reentry Hazards

a. 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 Section 9 DAS Analysis output for itemized list of spacecraft components used for reentry analysis

b. Summary of objects expected to survive an uncontrolled reentry, using NASA DAS

Two spacecraft components, reaction wheels and solar arrays, are predicted by DAS v3.0.1 to survive reentry. See Section 9 DAS Analysis for component predicted Debris Casualty Area and Impact Kinetic Energy.

c. Calculation of probability of human casualty for the expected year of uncontrolled reentry and the spacecraft orbital inclination

The risk of human casualty for AMS-1 re-entering the atmosphere is calculated in DAS v.3.0.1 to be 1 in 26100.

d. Assessment of spacecraft compliance with Requirement 4.7-1

Analysis performed using DAS v.3.0.1 shows that the risk of human casualty from surviving debris is < 1:10000. All components completely disintegrate before the Earth's surface upon reentry or have 150.96 Joules of energy or less.
Compliance Statement: COMPLIANT

Section 7A: Assessment of Spacecraft Hazardous Materials

a. Summary of the hazardous materials contained on the spacecraft

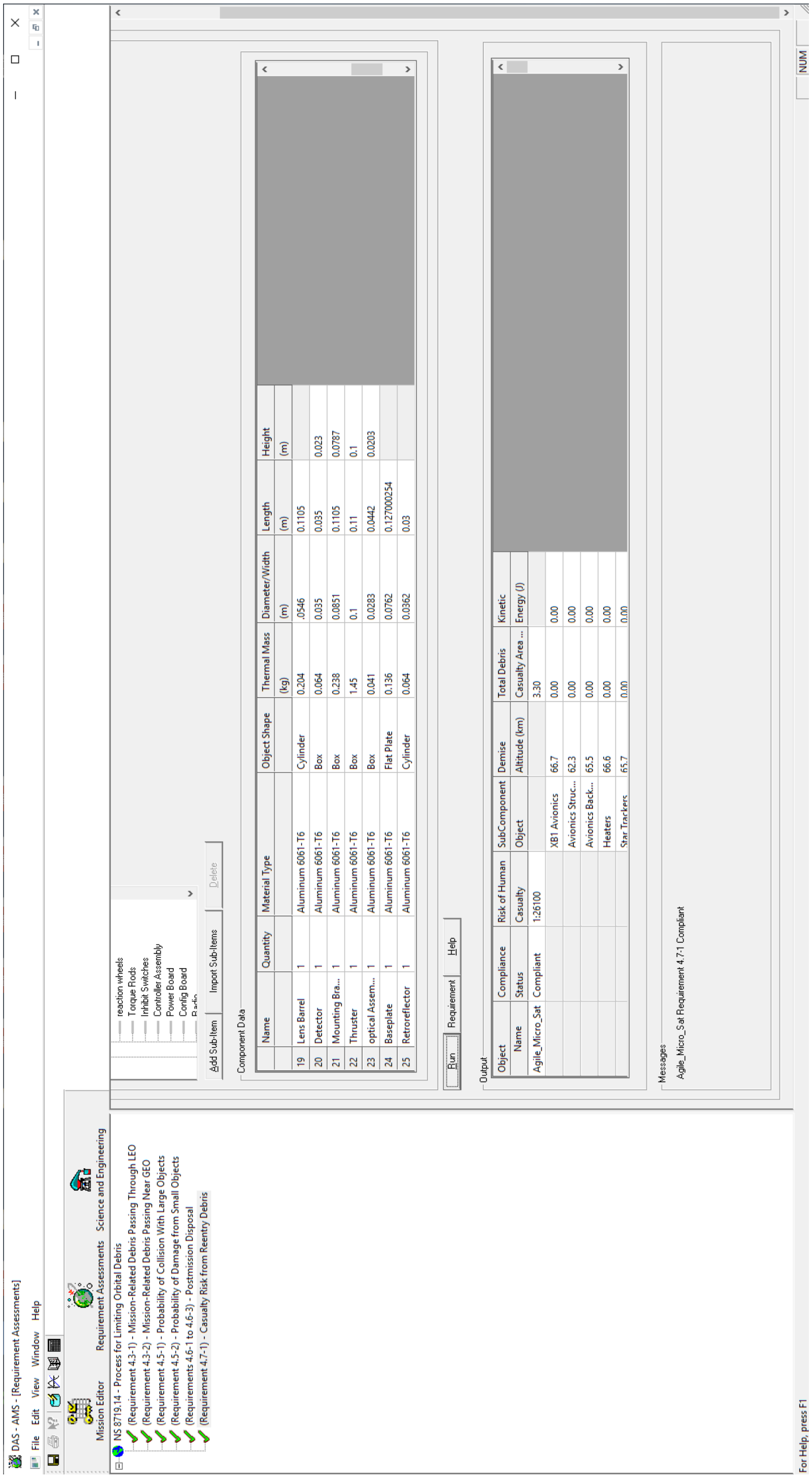
There are no hazardous materials on the AMS-1 spacecraft.

Section 8: Assessment for Tether Missions

a. Type of tether; e.g., momentum or electrodynamics
b. Description of tether system
c. Determination of minimum size of object that could sever the tether
d. Tether mission plan, including duration and postmission disposal
e. Probability of tether colliding with large space objects
f. Probability of tether being severed during mission or after postmission disposal
g. Maximum orbital lifetime of a severed tether fragment
h. Assessment of compliance with Requirement 4.8-1

The AMS-1 does not utilize a Tether system.

Section 9. DAS v.3.0.1 Analysis for AMS-1 Spacecraft



10 19 2020; 15:17:28PM   Processing Requirement 4.3-1:   Return Status : Not Run

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

=============== End of Requirement 4.3-1 ===============
10 19 2020; 15:17:31PM   Processing Requirement 4.3-2: Return Status : Passed

=====================
No Project Data Available
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=============== End of Requirement 4.3-2 ===============
10 19 2020; 15:26:14PM   Processing Requirement 4.5-1:   Return Status : Passed

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

INPUT

Space Structure Name = Agile_Micro_Sat
Space Structure Type = Payload
Perigee Altitude = 550.000 (km)
Apogee Altitude = 550.000 (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 = 0.0197 (m^2/kg)
Start Year = 2022.001 (yr)
Initial Mass = 12.626 (kg)
Final Mass = 12.626 (kg)
Duration = 0.500 (yr)
Station-Kept = False
PMD Perigee Altitude = -1.000 (km)
PMD Apogee Altitude = -1.000 (km)
PMD Inclination = 0.000 (deg)
PMD RAAN = 0.000 (deg)
PMD Argument of Perigee = 0.000 (deg)
PMD Mean Anomaly = 0.000 (deg)

OUTPUT

Collision Probability = 4.3211E-07
Returned Message: Normal Processing
Date Range Message: Normal Date Range
Status = Pass

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

=============== End of Requirement 4.5-1 ===============
10 19 2020; 15:29:29PM   Requirement 4.5-2: Compliant

==
Spacecraft = Agile_Micro_Sat

Critical Surface = Patch Antenna
===

INPUT

Apogee Altitude = 550.000 (km)
Perigee Altitude = 550.000 (km)
Orbital Inclination = 98.000 (deg)
RAAN = 0.000 (deg)
Argument of Perigee = 0.000 (deg)
Mean Anomaly = 0.000 (deg)
Final Area-To-Mass = 0.0197 (m^2/kg)
Initial Mass = 12.626 (kg)
Final Mass = 12.626 (kg)
Station Kept = No
Start Year = 2022.001 (yr)
Duration = 0.500 (yr)
Orientation = Fixed Oriented
CS Areal Density = 0.892 (g/cm^2)
CS Surface Area = 0.0225 (m^2)
Vector = (-1.000000 (u), 0.000000 (v), 0.000000 (w))
CS Pressurized = No

OUTPUT

Probability of Penetration = 1.0049E-05 (1.0049E-05)
Returned Error Message: Normal Processing
Date Range Error Message: Normal Date Range

=============== End of Requirement 4.5-2 ===============

10 19 2020; 15:29:34PM Processing Requirement 4.6 Return Status : Passed

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

INPUT

Space Structure Name = Agile_Micro_Sat
Space Structure Type = Payload

Perigee Altitude = 550.000000 (km)
Apogee Altitude = 550.000000 (km)
Inclination = 98.000000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Area-To-Mass Ratio = 0.019740 (m^2/kg)
Start Year = 2022.001000 (yr)
Initial Mass = 12.626000 (kg)
Final Mass = 12.626000 (kg)
Duration = 0.500000 (yr)
Station Kept = False
Abandoned = False
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 = -1.000000 (km)
Suggested Apogee Altitude = -1.000000 (km)
Returned Error Message = Passes LEO reentry orbit criteria.

Released Year = 2022 (yr)
Requirement = 61
Compliance Status = Pass

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

=============== End of Requirement 4.6 ===============
10 19 2020; 15:29:42PM *********Processing Requirement 4.7-1
Return Status : Passed

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

name = Agile_Micro_Sat
quantity = 1
parent = 0
materialID = 8
type = Box
Aero Mass = 12.626000
Thermal Mass = 12.626000
Diameter/Width = 0.239400
Length = 0.365500
Height = 0.103500

name = XB1 Avionics
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 7.517000
Thermal Mass = 3.759000
Diameter/Width = 0.100000
Length = 0.230000
Height = 0.100000

name = Avionics Structure
quantity = 1
parent = 2
materialID = 8
type = Box
Aero Mass = 1.370000
Thermal Mass = 1.370000
Diameter/Width = 0.100000
Length = 0.230000
Height = 0.100000

name = Avionics Backplane
quantity = 1
parent = 2
materialID = 19
type = Flat Plate
Aero Mass = 0.215000
Thermal Mass = 0.215000
Diameter/Width = 0.096000
Length = 0.225000

name = Heaters
quantity = 2
parent = 2
materialID = 19
type = Flat Plate
Aero Mass = 0.001500
Thermal Mass = 0.001500
Diameter/Width = 0.025000
Length = 0.025000

name = Star Trackers
quantity = 2
parent = 2
materialID = 8
type = Box
Aero Mass = 0.060500
Thermal Mass = 0.060500
Diameter/Width = 0.027000
Length = 0.090000
Height = 0.026000

name = reaction wheels
quantity = 3
parent = 2
materialID = 54
type = Box
Aero Mass = 0.195000
Thermal Mass = 0.195000
Diameter/Width = 0.056000
Length = 0.056000
Height = 0.023000

name = Torque Rods
quantity = 3
parent = 2
materialID = 19
type = Cylinder
Aero Mass = 0.118000
Thermal Mass = 0.118000
Diameter/Width = 0.020000
Length = 0.060000

name = Inhibit Switches
quantity = 1
parent = 2
materialID = 54

type = Box
Aero Mass = 0.029000
Thermal Mass = 0.029000
Diameter/Width = 0.040000
Length = 0.060000
Height = 0.008000

name = Controller Assembly
quantity = 1
parent = 2
materialID = 19
type = Flat Plate
Aero Mass = 0.059000
Thermal Mass = 0.059000
Diameter/Width = 0.090000
Length = 0.096000

name = Power Board
quantity = 1
parent = 2
materialID = 19
type = Flat Plate
Aero Mass = 0.139000
Thermal Mass = 0.139000
Diameter/Width = 0.090000
Length = 0.096000

name = Config Board
quantity = 1
parent = 2
materialID = 19
type = Flat Plate
Aero Mass = 0.054000
Thermal Mass = 0.054000
Diameter/Width = 0.090000
Length = 0.096000

name = Radio
quantity = 1
parent = 2
materialID = 8
type = Box
Aero Mass = 0.149000
Thermal Mass = 0.149000
Diameter/Width = 0.080000
Length = 0.094000
Height = 0.008000

name = Battery pack
quantity = 1
parent = 2
materialID = 8
type = Box
Aero Mass = 0.638000
Thermal Mass = 0.638000
Diameter/Width = 0.075000
Length = 0.085000

Height = 0.060000

name = GPS
quantity = 1
parent = 2
materialID = 8
type = Box
Aero Mass = 0.039000
Thermal Mass = 0.039000
Diameter/Width = 0.050000
Length = 0.090000
Height = 0.010000

name = Alignment cube
quantity = 1
parent = 2
materialID = 71
type = Box
Aero Mass = 0.003000
Thermal Mass = 0.003000
Diameter/Width = 0.010500
Length = 0.010500
Height = 0.010500

name = Spacecraft Structure
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 4.976000
Thermal Mass = 2.475000
Diameter/Width = 0.230000
Length = 0.260000
Height = 0.095000

name = Lens Assembly
quantity = 1
parent = 17
materialID = 8
type = Cylinder
Aero Mass = 0.250000
Thermal Mass = 0.250000
Diameter/Width = 0.049000
Length = 0.068300

name = Lens Barrel
quantity = 1
parent = 17
materialID = 8
type = Cylinder
Aero Mass = 0.204000
Thermal Mass = 0.204000
Diameter/Width = 0.054600
Length = 0.110500

name = Detector
quantity = 1

parent = 17
materialID = 8
type = Box
Aero Mass = 0.064000
Thermal Mass = 0.064000
Diameter/Width = 0.035000
Length = 0.035000
Height = 0.023000

name = Mounting Bracket
quantity = 1
parent = 17
materialID = 8
type = Box
Aero Mass = 0.238000
Thermal Mass = 0.238000
Diameter/Width = 0.085100
Length = 0.110500
Height = 0.078700

name = Thruster
quantity = 1
parent = 17
materialID = 8
type = Box
Aero Mass = 1.450000
Thermal Mass = 1.450000
Diameter/Width = 0.100000
Length = 0.110000
Height = 0.100000

name = optical Assembly
quantity = 1
parent = 17
materialID = 8
type = Box
Aero Mass = 0.041000
Thermal Mass = 0.041000
Diameter/Width = 0.028300
Length = 0.044200
Height = 0.020300

name = Baseplate
quantity = 1
parent = 17
materialID = 8
type = Flat Plate
Aero Mass = 0.136000
Thermal Mass = 0.136000
Diameter/Width = 0.076200
Length = 0.127000

name = Retroreflector
quantity = 1
parent = 17
materialID = 8
type = Cylinder

Aero Mass = 0.064000
Thermal Mass = 0.064000
Diameter/Width = 0.036200
Length = 0.030000

name = Beacon Board
quantity = 1
parent = 17
materialID = 19
type = Flat Plate
Aero Mass = 0.054000
Thermal Mass = 0.054000
Diameter/Width = 0.062200
Length = 0.069940

name = Solar Arrays
quantity = 2
parent = 1
materialID = 27
type = Flat Plate
Aero Mass = 0.597500
Thermal Mass = 0.597500
Diameter/Width = 0.240000
Length = 0.700000

name = Hold down release
quantity = 2
parent = 1
materialID = 8
type = Flat Plate
Aero Mass = 0.018500
Thermal Mass = 0.018500
Diameter/Width = 0.033000
Length = 0.187000

name = Patch Antenna
quantity = 1
parent = 1
materialID = 19
type = Flat Plate
Aero Mass = 0.205000
Thermal Mass = 0.205000
Diameter/Width = 0.096000
Length = 0.225000

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

name = Agile_Micro_Sat
Demise Altitude = 77.993332
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = XB1 Avionics
Demise Altitude = 66.665886
Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****
name = Avionics Structure
Demise Altitude = 62.297794
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Avionics Backplane
Demise Altitude = 65.491608
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Heaters
Demise Altitude = 66.564026
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Star Trackers
Demise Altitude = 65.657516
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = reaction wheels
Demise Altitude = 0.000000
Debris Casualty Area = 1.255951
Impact Kinetic Energy = 150.961105

****
name = Torque Rods
Demise Altitude = 63.743927
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Inhibit Switches
Demise Altitude = 65.070946
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Controller Assembly
Demise Altitude = 65.979889
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Power Board
Demise Altitude = 65.050858
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****

name = Config Board
Demise Altitude = 66.046654
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Radio
Demise Altitude = 64.193069
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Battery pack
Demise Altitude = 60.602772
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = GPS
Demise Altitude = 65.913704
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Alignment cube
Demise Altitude = 65.911400
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Spacecraft Structure
Demise Altitude = 71.414871
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Lens Assembly
Demise Altitude = 65.701569
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Lens Barrel
Demise Altitude = 68.350052
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Detector
Demise Altitude = 68.155357
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Mounting Bracket
Demise Altitude = 69.270264
Debris Casualty Area = 0.000000

Impact Kinetic Energy = 0.000000

****
name = Thruster
Demise Altitude = 60.380165
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = optical Assembly
Demise Altitude = 69.537292
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Baseplate
Demise Altitude = 68.800697
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Retroreflector
Demise Altitude = 68.013817
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Beacon Board
Demise Altitude = 70.035767
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Solar Arrays
Demise Altitude = 0.000000
Debris Casualty Area = 2.039707
Impact Kinetic Energy = 34.671440

****
name = Hold down release
Demise Altitude = 77.509285
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

****
name = Patch Antenna
Demise Altitude = 76.455116
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

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