**Laboratory for Atmospheric and Space Physics**
**University of Colorado at Boulder**

# Orbital Debris Analysis for MinXSS2

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**Satellite Primary Serial Number: Flight Model 2**

| | Title | Name |
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## Revision History

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|---|---|---|---|
| 1 | 4/7/16 | Initial Release | All |
| 1.1 | 1/28/17 | Updated project description and launch date [SEP] | 3 |
| | | | |

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# 1. SCOPE

This report summarizes the analyses performed to assess orbital debris for the Miniature X-ray Solar Spectrometer (MinXSS) and its compliance with requirements established by the NASA Orbital Debris Program Office (NASA ODPO).

The analysis uses Debris Assessment Software provided by the NASA ODPO and follows the requirement structure of the Process for Limiting Orbital Debris, NASA-STD 8719.14A. The MinXSS analysis was performed using version DAS 2.0.2 provided by the Orbital Debris Program Office at NASA's Johnson Space Center (JSC). This analysis complies with the methodology described in section 1.1.3 of NS 8719.14A: "*1.1.3 This document, along with the associated current version of Debris Assessment Software (DAS) or the higher fidelity Object Reentry Survival Analysis Tool (ORSAT), provided by the NASA Orbital Debris Program Office (NASA ODPO) located at Johnson Space Center (JSC), shall be used by the program or project manager as the primary reference in conducting orbital debris assessments (Requirement 56244).*"

# 2. MISSION DESIGN

## 2.1 MISSION DESCRIPTION

The Miniature X-ray Solar Spectrometer (MinXSS) is a 3U CubeSat mission, developed by students, faculty and staff at the University of Colorado Boulder in the Laboratory for Atmospheric and Space Physics (LASP) and the Department of Aerospace Engineering Sciences (AES). Its purpose is to better understand the solar flare energy distribution within the soft X-rays (SXR) and its impact on Earth's ionosphere, thermosphere, and mesosphere (ITM). MinXSS is expected to have a 5 year mission life. The nominal orbit for MinXSS is a 550 x 550 km circular sun synchronous orbit with a 13:15 LTDN. The launch is scheduled for mid 2017 from Vandenberg AFB. The primary science payload is Amptek's commercial X123 X-ray Spectrometer with repackaged electronics to mitigate thermal effects due to the space environment. From the 550 x 550 km, ~97° inclination orbit, MinXSS takes daily spectral measurements of the solar soft X-rays. LASP will process and distribute the data daily through the LASP Interactive Solar IRradiance Datacenter (LISIRD). The mission's ground segment that includes mission operations, the UHF ground station operating at 437 MHz, science and engineering data processing, and data distribution are located at the University of Colorado Boulder Laboratory for Atmospheric and Space Physics (LASP) in Boulder, Colorado.

## 2.2 SPACECRAFT DESCRIPTION

MinXSS is a solar-pointing, 3-axis-controlled, 3U CubeSat that observes the solar soft X-ray spectrum (SXR) between 0.4 and 40 keV (0.03-3 nm) with 0.15 keV resolution (0.0001 nm at 0.03 nm to 1 nm at 3 nm). The spacecraft is designed for use in low earth orbit (LEO) with two deployable solar panels and a deployable UHF monopole antenna. There is a single, fixed solar array panel along the plus X axis. The total spacecraft mass is 3.52 kg with a volume of 10 cm x 34 cm x 10 cm in the stowed configuration. When fully deployed, the spacecraft's monopole

antenna extends 47 cm along the minus Z axis and all three solar panels are sun facing. A miniaturized star tracker is mounted such that its boresight is perpendicular to the plus X-axis of MinXSS and pointing 10° from the plus Y axis.

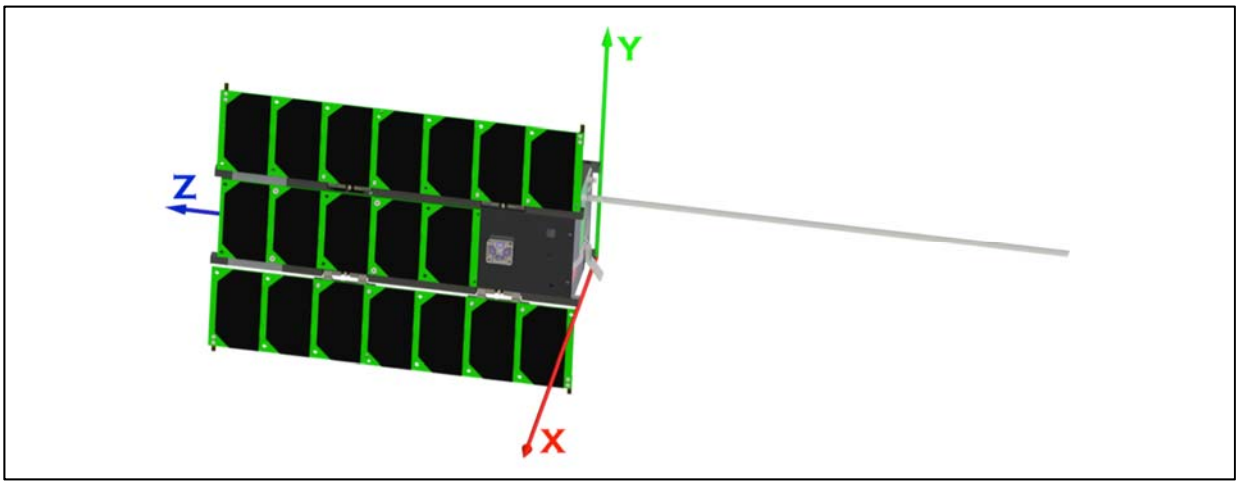


**Figure 1, MinXSS with the solar arrays and monopole antenna deployed.**

The 3 axis inertial pointing system (from Blue Canyon Technologies) contains 3 reaction wheel assemblies, 3 torque rods, a miniaturized star tracer, and a processor board all self contained in a ½ U unit that is attached to plus Z side of the main body of the spacecraft. The MinXSS battery pack is comprised of four 2 amp-hour lithium polymer batteries connected in series and parallel to make an 8.4 Volt battery pack with a 4 amp-hour capacity.

All sensors and components on MinXSS are passive. There are no lasers, radiation sources, propellants, pressure vessels, or other hazardous materials on board the spacecraft.

## 3. ORBIT LIFETME

NASA requires the disposal of spacecraft through one of three methods; 1) atmospheric reentry within 25 years of Mission completion or 30 years from launch, maneuver the spacecraft for a controlled reentry, 2) maneuver the spacecraft into a storage orbit, or 3) direct retrieval. MinXSS will meet NS 8719.14 through atmospheric reentry within 25 years mission completion *[(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: a. Atmospheric reentry option:*

*(1) Leave the space structure in an orbit in which natural forces will lead to atmospheric reentry within 25 years after the completion of mission but no more than 30 years after launch; or…*].

For the orbit lifetime analysis, MinXSS uses the orbital parameters determined by the primary payload - 550 km SSO with and LTDN of 13:15. DAS software is used to calculate the cross sectional area of the spacecraft for random tumbling and an electronic scale was used to measure accurately the fully integrated spacecraft mass.

A 0.06 $m^2$ cross sectional area and 3.52 kg result in an area-to-mass ratio of 0.0172 for MinXSS in the fully deployed configuration (the area-to-mass ratio is 0.012 with the solar arrays stowed and would reenter in 7.2 years). The inputs to the calculation and the orbit history are shown in Figure2, MinXSS Orbit Lifetime/Dwell Time and Orbit Decay.

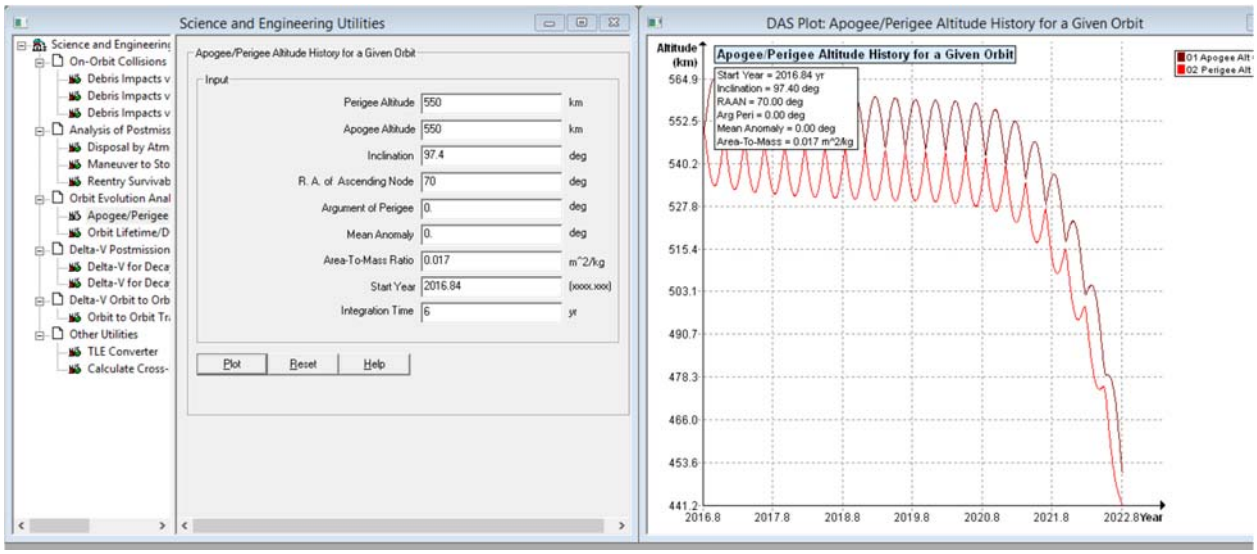


**Figure 2, MinXSS Orbit Lifetime/Dwell Time and Orbit Decay**

Assuming an October, 2016 launch, the orbit dwell time is 6.3 years and meets 8719.14 disposal requirements through atmospheric reentry within 25 years of mission completion or 30 years from launch.

## 4. ORBITAL DEBRIS REQUIREMENTS

The requirements associated with the risk of human casualty from reentering space hardware are contained in NS 8719.14A, 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)…. ]*

All analyses contained in the DAS 2.0.2 Requirements Assessment tools were successfully performed. MinXSS does not contain tethers.

### 4.1 MODEL CONSTRUCTION

In the calculation to determine the risk of human casualty, the arrangement of each space structure element is defined to realistically assess its reentry survival potential. The model is based on la successive set of layered shells with a parent-child relationship. Based on empirical and theoretical values, the outermost structure (i.e. the “parent” object) is assumed to break apart at an altitude of 78 km. The first level of “child” objects is exposed at this point. The objects are

then subjected to the various forces of the reentry model. If a child object is destroyed ("demises") due to the reentry forces, it does not affect the final casualty area calculation. If a child object contains further levels of children, those children are exposed at the same altitude at which their immediate parent is destroyed.

### 4.1.1 MinXSS Components and Object Tree

MinXSS components and their physical properties are inserted into the object tree with sub-items (child objects) nested to match the mechanical design of the system. The object tree contains 34 objects and nests to the third level of child objects. The root level ($0^{th}$) object for the object tree is MinXSS. The first level of child objects contains the MinXSS structure, the ADCS structure, and items that reside on the outside of the spacecraft such as: solar array hinge pieces, solar arrays, and the antenna. The second level of child objects contains components inside the two level 1 structures and consists of housings encasing other components, electronics boards, batteries, wire harness, fasteners, and connectors. The third level of child objects contains components housed inside the level 2 cases and consists of instrument electronics boards, reaction wheel components, and torque rod cores.

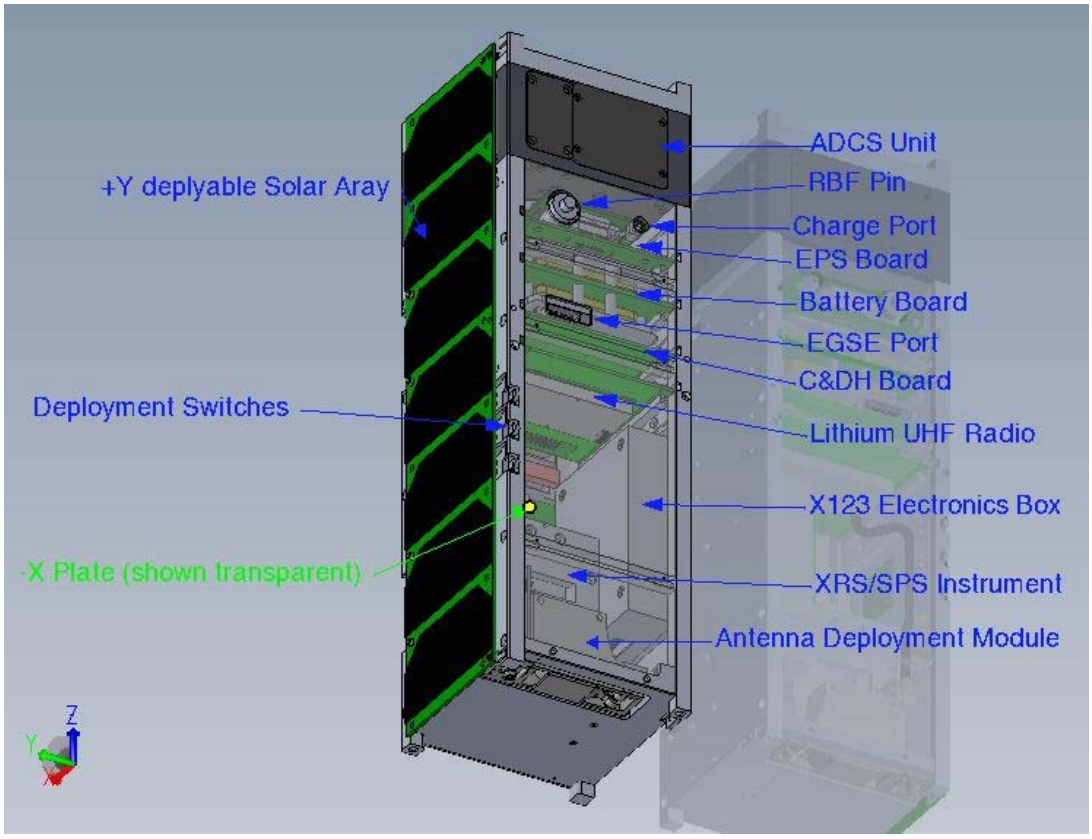


**Figure 3, MinXSS Major Components. The major components and internal laocationlocation are shown forffor the MinXSS spacecraft in the stowed configuration.**

### 4.1.2

Materials for each object are selected from the standard DAS materials database and no new materials were added. The material that is closest to the family of the exact material is selected

for items not contained in the database. The following properties were applied to MinXSS components:

1. electronic boards – fiberglass
2. wire harness – copper alloy
3. connectors – polymide
4. steel items - stainless steel (generic)
5. torque rods – copper alloy and iron (nested)
6. structures – aluminum 6061-T6
7. fasteners - steel A-286
8. solar arrays – fiberglass
9. plastic parts - polymide
10. internal casings - aluminum 6061-T6
11. Heavy metal – Tungsten (the exact material property for the detector aperture)

The analysis uses measured values for most items and subassemblies contained in the object tree. The mass for all major structures, electronics boards, the integrated ADCS unit, and the total mass of the system are measured values. The mass for connectors, wire harness, and fasteners are derived though analysis.

Object sizes are measured values and the thickness of the electronics boards is increased (usually by about a factor of 2 to account for electronic parts) so the volume is consistent with the mass and density of the item.

## 4.2 Orbital Debris Analysis Results

A summary of the results of orbital debris analyses that were performed are shown in Figure 4, MinXSS Compliance with Orbital Debris Requirements. MinXSS is compliant with NS 8719.14A – Process for Limiting Orbital Debris. There are no tethers on MinXSS.

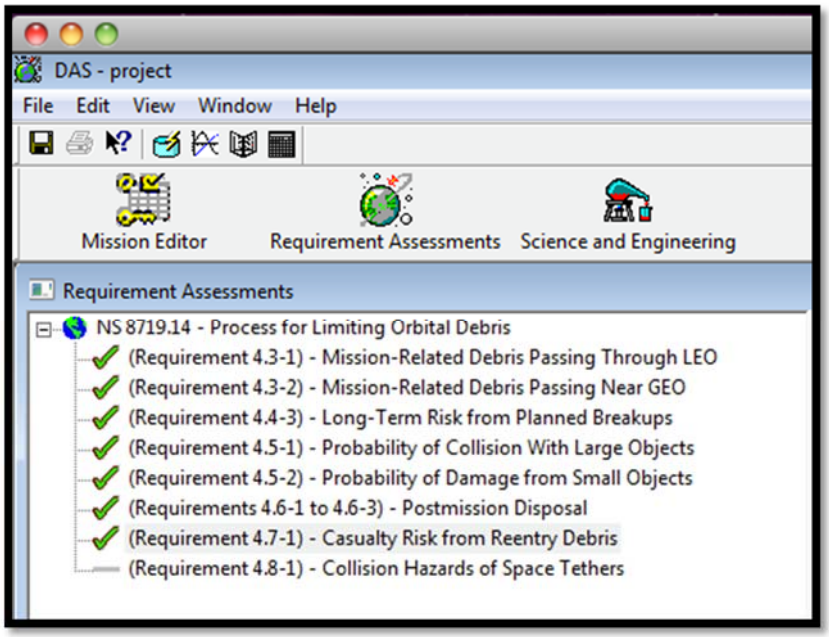


**Figure 4, MinXSS Compliance with Orbital Debris Requirements. The green checkmarks in the requirements assessment window indicate MinXSS is compliant with that particular requirement.**

Numerical results for the risk of human casualty for the total mission is shown in Figure 5, Risk of Human Casualty. The risk

of human casualty is “1:0” (or zero) and the total casualty area is 0.00m$^2$. The spacecraft and all of its internal components oblate at attitude of approximately 71 km with the exception of the Tungsten aperture over the detector which has a debris casualty area of 0.38 m$^2$ and a kinetic energy of 2 Joules. The casualty assessment calculated by DAS only considers objects with more than 15 Joules of kinetic energy. The kinetic energy of the Tungsten aperture is less than 15 Joules, resulting in a total casualty area of 0.00 m$^2$ for MinXSS-2.

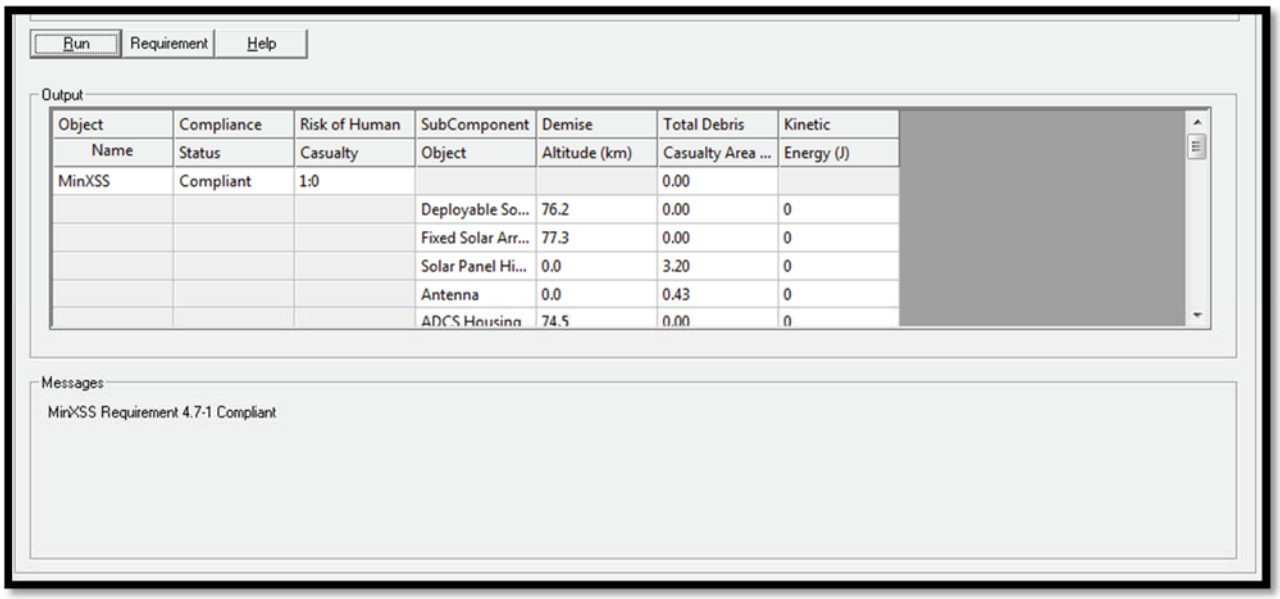


**Figure 5, Risk of Human Casualty**

MinXSS is compliant with the requirements contained in NS 8719.14A for orbit lifetime and orbital debris requirements.

## 5.0 SUMMARY

An orbital debris analysis found the MinXSS 3U CubeSat mission to be compliant with the applicable requirements for spacecraft disposal and risk to human casualty contained in NASA STD 8719.14A. The analysis uses Debris Assessment Software provided by the NASA ODPO and follows the requirement structure of the Process for Limiting Orbital Debris, NASA-STD 8719.14A. The current launch date for MinXSS is October 2016 and spacecraft disposal is accomplished through atmospheric reentry. The spacecraft is estimated to reenter in 6.3 years and is compliant with the requirement to reenter within 25 years after mission completion or 30 years after launch.

The inputs to the DAS object tree (spacecraft model) were nested according the users guide to provide a realistic reentry model and used the standard materials database provided in the application. MinXSS meets all applicable requirements for the process of limiting orbital debris. The total risk of human casualty is zero and the total debris casualty area is zero.