AKASH SYSTEMS

October 25, 2018

Exhibit 6: Akash MCNAIR Orbital Debris Assessment Report (ODAR)

1. Scope

This report summarizes the analyses performed to assess orbital debris for Akash's MCNAIR satellite and its compliance with requirements established by the NASA Orbital Debris Program Office (OPDO). This report does not cover potential debris from the launch vehicle.

The analysis uses Debris Assessment Software provided by the NASA OPDO and follows the requirement structure of the Process for Limiting Orbital Debris, NASA-STD 8719.14A. The MCNAIR analysis was performed using version DAS 2.1.1 provided by the OPDO 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

A complete Mission Description is provided in Exhibit 1 of Akash's MCNAIR STA Application.

It is important to note that Akash has no plans to intentionally release debris during nominal satellite operations, that MCNAIR has been designed without propulsion and that MCNAIR has no pressure vessels are on-board. Before launch, Akash will designate a point of contact for receiving JSpOC conjunction assessments, and plans for collision avoidance activities will be developed if necessary. Additionally, MCNAIR does have the ability, upon receipt of a ground command, to orient itself at a given attitude in order to vary its cross-sectional area in the vector of motion.

In terms of foreign government or space agency participation, The Akash satellite, MCNAIR, has not received support of any form from any foreign government or space agency.

2.2 Spacecraft Description

MCNAIR is a 3-axis controlled, 12U CubeSat designed for use in a low earth orbit (LEO) with two deployed, non-articulating solar arrays. There is also a deployed Ka-band antenna and an S-band patch antenna. The total spacecraft mass (and dry mass) is 19.9 kg. The dimensions of the 12U spacecraft are 23.9 cm x 22.9 cm x 36.6 cm in the stowed configuration. This does not include the stowed Ka-band parabolic antenna, which is deployed from the nadir facing wall. When fully deployed, the Ka-band antenna extends approximately 5 cm in

height and 51 cm in diameter, the two deployed solar arrays have a structural dimension of 20 cm x 69.8 cm each (GaAs cells only cover 20 cm x 45 cm of the array).

The 3-axis inertial pointing system contains three reaction wheel assemblies, three torque rods, two miniaturized star trackers, and a processor board. The MCNAIR bus battery is capable of 100 Watt-hr, and has charge control, power distribution and fault protection. All of these components are housed in the Avionics box. The payload battery (for use by the Akash Transmitter) consists of 24 cells, providing 300 Watt-hr at 28V.

All sensors on MCNAIR are passive and there are no lasers, propellants, radioactive, pyrotechnic devices, pressure vessels, or other hazardous materials on board the spacecraft.

3. Orbit Lifetime

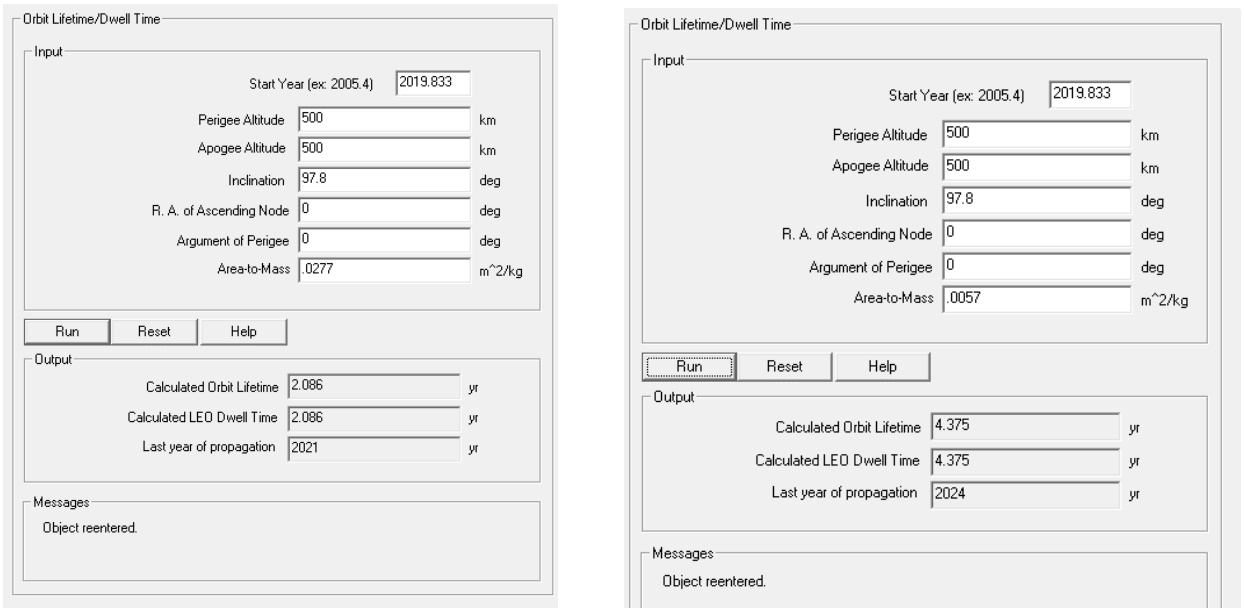
NASA requires the disposal of spacecraft through one of three methods; 1) atmospheric reentry within 25 years of Mission completion or 30 years from launch, maneuver the spacecraft for a controlled reentry, 2) maneuver the spacecraft into a storage orbit, or 3) direct retrieval. MCNAIR will meet NS 8719.14 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 orbital lifetime analysis, an initial orbit of 500 x 500 km altitude and 97.8 degrees inclination was input into the DAS software. The software was also used to calculate the cross sectional area of the spacecraft for random tumbling and a detailed mass budget was used to accurately estimate the fully integrated spacecraft mass. Random tumbling was selected because neither the nadir direction nor the velocity vector will be maintained throughout the duration of the mission. When MCNAIR is in view of the earth station it will track the earth station, and when not in view of the earth station, MCNAIR will orient itself to align its arrays with the sun. A deployed configuration, in which both the solar arrays and the Ka-band antenna deploy, as well as a stowed configuration, in which neither the solar arrays nor the Ka-band antenna deploy, were analyzed. The stowed configuration is highly unlikely, and would only exist if the event of an anomaly. Table 1 provides a summary of the geometry and orbital lifetime calculations for both configurations.

Table 1. Summary of Geometry and Orbital Lifetime

Configuration	Cross Sectional Area (m^2)	Area-to-Mass Ratio (m^2/kg)	Orbital Lifetime (years)
Stowed	0.1131	0.0057	4.375
Deployed	0.5511	0.0277	2.086

The inputs to the orbit lifetime calculation for a (a) fully deployed and (b) fully stowed configuration are shown in Figure 1 (a,b).



(a) Fully Deployed (b) Fully Stowed

Figure 1(a,b). Inputs and Outputs to the Orbital Lifetime / Dwell Time Calculation for a (a) fully deployed configuration and (b) fully stowed configuration

The worst-case orbit dwell time is 4.375 years (stowed configuration), which only happens in the event of an anomaly, meeting requirement 8719.14 (atmospheric reentry within 25 years of mission completion or 30 years from launch). However, it is important to note that the plan is to re-enter in the fully deployed configuration, which has an orbital lifetime of 2.086 years.

Due to the uncertainty in cubesat launch availability, additional sun synchronous orbits were analyzed. Re-entry within 25 years occurs up to an altitude of 598 km for the worst-case stowed configuration (which only happens in the event of an anomaly). Therefore, we will ensure that the cubesat is not deployed above 598 km.

4. Orbital Debris Requirements

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 performed with DAS 2.1.1 Requirements Assessment tools were successfully run with the exception of collision hazards from space tethers. There are no tethers on MCNAIR.

4.1 Model Construction

In order to calculate the risk of human casualty, the MCNAIR components and their physical properties were input into the object tree with sub-items (child objects) nested to match the

mechanical design of the system. All of the component information (level, quantity, mass, dimensions) are provided in Appendix A. The root level (0th) object for the object tree is the MCNAIR structure. The next level of child objects includes the:

- Cubesat Structure (includes mass for fixtures and harnesses)
- Avionics box (includes the bus battery, reaction wheels, torque rods, star trackers, deployment switches, and sun sensor)
- Solar Array Structure
- Solar Arrays (GaAs)
- Payload Batteries
- Deployable Antenna
- Akash Transmitter

4.2 Orbital Debris Analysis Results

A summary of the orbital debris analyses results is shown in Figure 2, and applies to both the stowed configuration and the deployed configuration. MCNAIR is compliant with NS 8719.14A – Process for Limiting Orbital Debris. There are no tethers on MCNAIR.

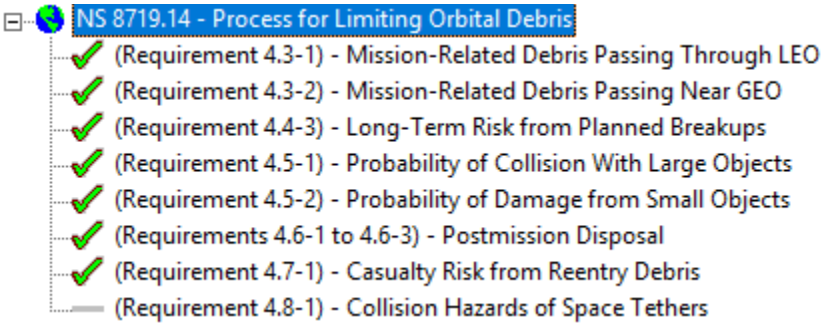


Figure 2. MCNAIR Compliance with Orbital Debris Requirements

Numerical results for the risk of human casualty for the total mission is shown in Figure 3. The risk of human casualty is "1:100000000" and the total casualty area is 0 m^2. Therefore, the spacecraft and all of its internal components oblate with a risk to human casualty that is compliant with Requirement 4.7-1, which states that *"For uncontrolled reentry, the risk of human casualty from surviving debris shall not exceed 0.0001 (1:10,000)"*.

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Output

Object Name	Compliance Status	Risk of Human Casualty	SubComponent Object	Demise Altitude (km)	Total Debris Casualty Area ...	Kinetic Energy (J)
MCNAIR	Compliant	1:100000000			0.00	
			Structure	66.8	0.00	0
			Avionics	64.3	0.00	0
			Solar Array Str...	77.7	0.00	0
			Solar Arrays	77.9	0.00	0
			Payload Battery	65.5	0.00	0

Messages

MCNAIR Requirement 4.7-1 Compliant

Figure 3. MCNAIR Risk of Human Casualty

5. Summary

An orbital debris analysis found the MCNAIR 12U 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. On October 1, 2019, MCNAIR will be launched into a 500 km altitude, 97.8 degree inclination orbit and spacecraft disposal is accomplished through atmospheric reentry. The spacecraft is estimated to reenter in 4.375 years (fully stowed configuration) and 2.086 years (fully deployed configuration) 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 to the users guide to provide a realistic reentry model and used the standard materials database provided in the application.

MCNAIR meets all applicable requirements for the process of limiting orbital debris.

6. Appendix

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10 24 2018; 17:55:04PM
Processing Requirement 4.3-2: Return Status: Passed
=============== End of Requirement 4.3-2 ===============


10 24 2018; 17:55:49PM Requirement 4.4-3:  Compliant
=============== End of Requirement 4.4-3 ===============


10 24 2018; 18:01:12PM Processing Requirement 4.5-1: Return Status: Passed
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Run Data
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INPUT

Space Structure Name = MCNAIR
Space Structure Type = Payload
Perigee Altitude = 500.000000 (km)
Apogee Altitude = 500.000000 (km)
Inclination = 97.800000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Final Area-To-Mass Ratio = 0.027700 (m^2/kg)
Start Year = 2019.833000 (yr)
Initial Mass = 19.900000 (kg)
Final Mass = 19.900000 (kg)
Duration = 0.500000 (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 = 0.000002
Returned Error Message: Normal Processing
Date Range Error Message: Normal Date Range
Status = Pass

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

10 24 2018: 18:02:38PM Requirement 4.5-2: Compliant

10 24 2018; 18:02:40PM
Processing Requirement 4.6 Return Status: Passed

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

INPUT

Space Structure Name = MCNAIR
Space Structure Type = Payload

Perigee Altitude = 500.000000 (km)
Apogee Altitude = 500.000000 (km)

```
      Inclination = 97.800000 (deg)
      RAAN = 0.000000 (deg)
      Argument of Perigee = 0.000000 (deg)
      Mean Anomaly = 0.000000 (deg)
      Area-To-Mass Ratio = 0.027700 (m^2/kg)
      Start Year = 2019.833000 (yr)
      Initial Mass = 19.900000 (kg)
      Final Mass = 19.900000 (kg)
      Duration = 0.500000 (yr)
      Station Kept = False
      Abandoned = True
      PMD Perigee Altitude = 486.318697 (km)
      PMD Apogee Altitude = 510.406166 (km)
      PMD Inclination = 97.779004 (deg)
      PMD RAAN = 188.760527 (deg)
      PMD Argument of Perigee = 51.901028 (deg)
      PMD Mean Anomaly = 0.000000 (deg)

**OUTPUT**

      Suggested Perigee Altitude = 486.318697 (km)
      Suggested Apogee Altitude = 510.406166 (km)
      Returned Error Message = Passes LEO reentry orbit criteria.

      Released Year = 2021 (yr)
      Requirement = 61
      Compliance Status = Pass
============== End of Requirement 4.6 ==============


10 24 2018; 18:02:49PM *********Processing Requirement 4.7-1
      Return Status :  Passed

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

name = MCNAIR
quantity = 1
parent = 0
materialID = 5
type = Box
Aero Mass = 19.900000
Thermal Mass = 19.900000
Diameter/Width = 0.400000
Length = 0.400000
Height = 0.400000

name = Structure
quantity = 1
parent = 1
materialID = 8
```

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```
type = Box
Aero Mass = 6.730000
Thermal Mass = 6.730000
Diameter/Width = 0.239000
Length = 0.370000
Height = 0.229000

name = Avionics
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 3.200000
Thermal Mass = 3.200000
Diameter/Width = 0.100000
Length = 0.200000
Height = 0.100000

name = Solar Array Structure
quantity = 2
parent = 1
materialID = 27
type = Flat Plate
Aero Mass = 0.550000
Thermal Mass = 0.550000
Diameter/Width = 0.213000
Length = 0.698000

name = Solar Arrays
quantity = 2
parent = 1
materialID = 24
type = Flat Plate
Aero Mass = 0.030000
Thermal Mass = 0.030000
Diameter/Width = 0.200000
Length = 0.450000

name = Payload Battery
quantity = 1
parent = 1
materialID = 5
type = Box
Aero Mass = 2.100000
Thermal Mass = 2.100000
Diameter/Width = 0.100000
Length = 0.150000
Height = 0.100000

name = Deployable Antenna
quantity = 1
```

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```
parent = 1
materialID = 8
type = Cylinder
Aero Mass = 1.500000
Thermal Mass = 1.500000
Diameter/Width = 0.100000
Length = 0.500000

name = Akash Transmitter
quantity = 1
parent = 1
materialID = 8
type = Box
Aero Mass = 5.000000
Thermal Mass = 5.000000
Diameter/Width = 0.200000
Length = 0.300000
Height = 0.100000

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

name = MCNAIR
Demise Altitude = 77.999687
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Structure
Demise Altitude = 66.824486
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Avionics
Demise Altitude = 64.349579
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Solar Array Structure
Demise Altitude = 77.687889
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Solar Arrays
Demise Altitude = 77.911682
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
```

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```
************************************
name = Payload Battery
Demise Altitude = 65.515236
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Deployable Antenna
Demise Altitude = 73.317383
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Akash Transmitter
Demise Altitude = 63.468834
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************

=============== End of Requirement 4.7-1 ===============
10 24 2018; 18:07:02PM Project Data Saved To File
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