Orbital Debris Assessment Report

Hiber 1 & Hiber 2

Revision nr1

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1 Introduction

1.1 Purpose

The scope of this document is to assess the different causes and risks related to orbital debris. Only the risks related to Hiber's satellite, and not the launcher, are being investigated in this report. This study was conducted in concordance with the requirements stated in NASA-STD-8719.14A.

In order to determine risk probabilities, NASA's DAS software, version 2.0, was used.

1.2 References

Ref #	Document	Version
1	NASA-STD-8719.14A	
2	DAS	2.0

Table 1: List of referenced documents

2 General Review

The following table summarizes the different requirements recommended by NASA. As can be seen, Hiber's spacecrafts meet all requirements.

Requirement #	Launch Vehicle				Spacecraft			Comments
	Compliant	Not Compliant	Incomplete	Standard Non Compliant	Compliant or N/A	Not Compliant	Incomplete	
4.3-1.a			X		X			No intentional debris released
4.3-1.b			X		X			No intentional debris released
4.3-2			X		X			No intentional debris released
4.4-1			X		X			
4.4-2			X		X			No passivation
4.4-3			X		X			No intentional breakup
4.4-4			X		X			No intentional breakup
4.5-1			X		X			
4.5-2			X		X			
4.6-1.a			X		X			
4.6-1.b			X		X			
4.6-1.c			X		X			
4.6-2			X		X			
4.6-3			X		X			
4.6-4			X		X			
4.7-1			X		X			
4.8-1			X		X			No tether system

Table 2 : ODAR review check sheet

3 Orbital Debris Assessment

3.1 Program Management and Mission Overview

• **Identification of the Headquarters Mission Directorate sponsoring the mission and the Program Executive**

• **Identification of the responsible program/project manager and senior scientific and management personnel**

• **Identification of any foreign government or space agency participation in the mission and a summary of NASA's responsibility under the governing agreement(s)**

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

• Brief description of the mission : The first two 6U satellites of the Hiber constellation will be deployed on a 600 km high circular orbit. The rest of the constellation is composed of 3U satellites, which will not be studied here but in a separate report as their design differ.

• Identification of the anticipated launch vehicle and launch site

• Identification of the proposed launch date and mission duration

• Description of the launch and deployment profile, including all parking, transfer, and operational orbits with apogee, perigee, and inclination : the satellites will be deployed on a 600-km circular orbit, with a 97.8° inclination. They will then naturally decay because of atmospheric drag forces.

• Reason for selection of operational orbit(s) (such as ground track, SSO, GEO sync, instrument resolution, co-locate with other spacecraft, …) : this orbit was chosen because it is sun-synchronous.

• Identification of any interaction or potential physical interference with other operational spacecraft (Note: This does not include potential for RF interaction unless it affects the risk of generating orbital debris.) : None

3.2 Spacecraft Description

• Physical description of the spacecraft, including spacecraft bus, payload instrumentation, and all appendages, such as solar arrays, antennas, and instrument or attitude control booms: The spacecraft is a typical 6U CubeSat, with outside dimensions of 100 mm x 200 mm x 340.5 mm. There are two large solar panels (200 mm x 340.5 mm) and two smaller ones (100 mmx 340.5 mm), which will deploy once in orbit. Two antennas (550 mm long) serve for TTC, and two other ones (one 330 mm long deployable antenna and one patch antenna) for payload functionalities.

• Detailed illustration of the entire spacecraft in the mission operation configuration with clear overall dimensional markings and marked internal component locations :

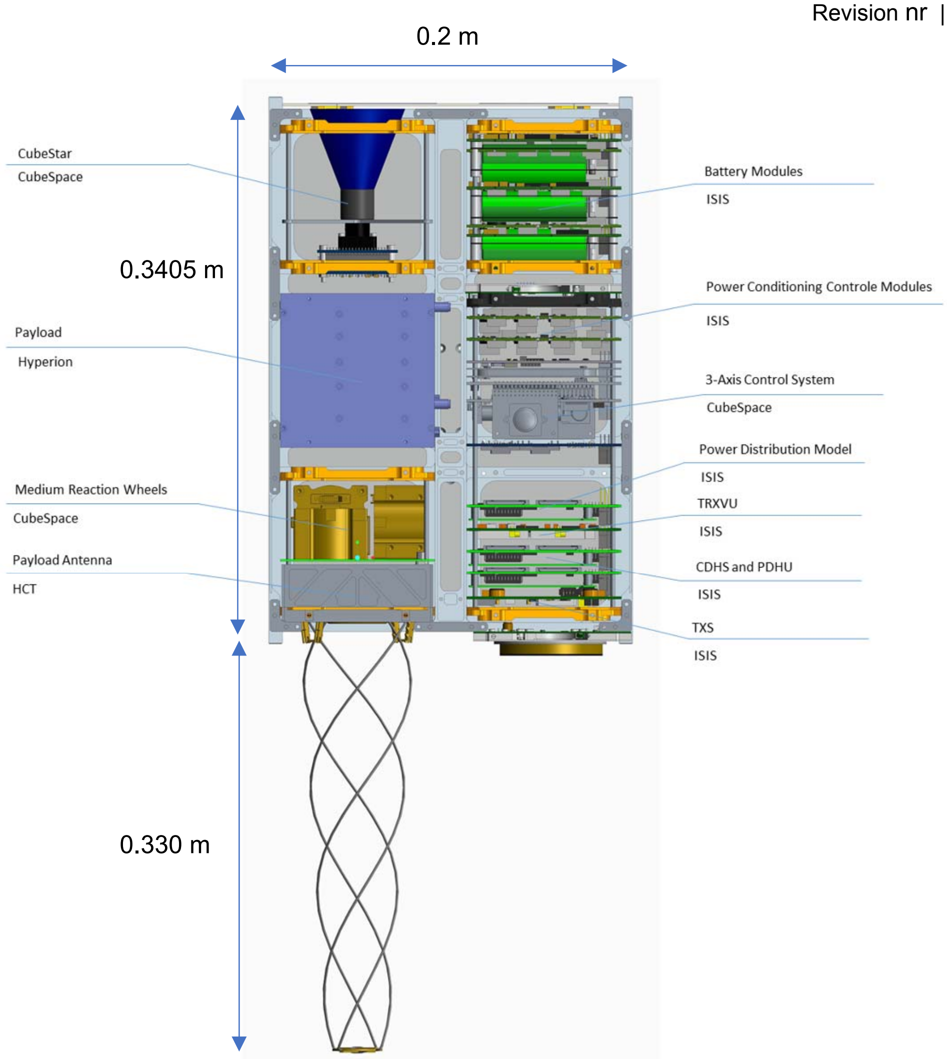

Figure 1 : Hiber's satellite

• **Total spacecraft mass at launch, including all propellants and fluids** : 7.23 kg

• **Dry mass of spacecraft at launch, excluding solid rocket motor propellants :** 7.23 kg

• **Description of all propulsion systems (cold gas, mono-propellant, bi-propellant, electric, nuclear) :** NA

• **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. Description of all fluid systems, including size, type, and qualifications of fluid containers such as propellant and pressurization tanks, including pressurized batteries :** NA

• **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 satellite is controlled via 3 reaction wheels and 3 magnetorquers. The normal attitude of the spacecraft consists of the long axis nadir-aligned, and the 3U face velocity-aligned. This is the naturally stable attitude of the satellite.

• **Description of any range safety or other pyrotechnic devices :** NA

• **Description of the electrical generation and storage system :** Li-ion battery cells provide energy, and are recharged by GaAs solar cells.

• Identification of any other sources of stored energy not noted above : NA

• Identification of any radioactive materials on board or make a positive statement that there are no radioactive materials onboard : there are no radioactive materials onboard.

3.3 Assessment of Spacecraft Debris Released during Normal Operations

No object will be released intentionally.

3.4 Assessment of Spacecraft Intentional Breakups and Potential for Explosions

• Identification of all potential causes of spacecraft breakup during deployment and mission operations : there is no credible scenario which would lead to a spacecraft breakup.

• Summary of failure modes and effects analyses of all credible failure modes which may lead to an accidental explosion :
The only potential source of explosion on the satellite is from the Li-ion battery cells. Explosion can be due to overheating or venting.

Metal scraps (left during manufacturing), shocks, damages, over-discharging and overcharging, fast charging and use of batteries outside of recommended temperatures could lead to these events.

• Detailed plan for any designed spacecraft breakup, including explosions and intentional collisions : NA

• List of components which are passivated at EOM. List includes method of passivation and amount which cannot be passivated : no items will be passivated. The batteries don't need to be passivated because, as the failure mode analysis shows, they don't present a high or credible risk for the mission.

• Rationale for all items which are required to be passivated, but cannot be due to their Design : NA

• **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)*

The following failure modes were assessed regarding the battery cells. They can all potentially lead to explosion.

Failure mode	Effects of failure	Causes of failure	Recommended action
Short circuit	Overheating	Metal scraps, shock, physical damage, over-discharge, overcharge, external system failure	Quality check, vibration test, shock test, charge and discharge cycling tests, discharge and overcharge protection, short circuit protection on external circuits

Overcharging	Overheating	No overcharging protection	Overcharging protection Charge cycling test
Overpressure	Venting	Ultra-fast charging	Nominal charging
Lithium plating on anode	Physical damage / venting / short circuit	Use below recommended temperatures	Thermal analysis Thermal cycling tests
Gas generation	Venting	Use above recommended temperatures	Thermal analysis Thermal cycling tests

Table 3 : Battery failure modes

The above-mentioned tests and analysis were conducted and it was concluded that the probability of a failure mode was less than 0.001.

Requirement 4.4-2 : Passivate to limit probability of accidental explosion after EOM : NA

Requirement 4.4-3 : Limiting the long-term risk to other space systems from planned breakups : NA

Requirement 4.4-4: Limiting the short-term risk to other space systems from planned breakups : NA

3.5 Assessment of Spacecraft Potential for On-Orbit Collisions

• **Calculation of spacecraft probability of collision with space objects larger than 10 cm in diameter during the orbital lifetime of the spacecraft (compliance with requirement 4.5-1) :**
Probability for one satellite : 0

Probability for both satellites : 0

Hiber's satellites are compliant with requirement 4.5-1.

• **Calculation of spacecraft probability of collision with space objects, including orbital debris and meteoroids, of sufficient size to prevent post-mission disposal (compliance with requirement 4.5-2)** : Post-mission disposal is done naturally, via drag forces. Therefore, there are no vital systems needed to ensure it. Similarly, no systems will be passivated, so once again there will be no vital systems needed to ensure it.

3.6 Assessment of Spacecraft Post-mission Disposal Plans and Procedures

• **Description of spacecraft disposal option selected** : the spacecraft will decay because of atmospheric drag and de-orbit naturally via atmospheric re-entry

• **Identification of all systems or components required to accomplish any post mission disposal operation, including passivation and maneuvering** : NA

• **Plan for any spacecraft maneuvers required to accomplish post mission disposal** : NA

• **Calculation of area-to-mass ratio after post mission disposal, if the controlled reentry option is not selected :** The mass of the satellite will be 7.23 kg at the end of life.
At the end of life, the satellite won't be controlled anymore and will automatically align its longest axis with nadir. This means the cross-sectional area will be either 0.03405 m2 or 0.0681 m2, depending on which side is oriented with the velocity axis.

This means the area to mass ratio will vary between 4.71 x 10-3 m2/kg and 9.42 x 10-3 m2/kg.

• **If appropriate, preliminary plan for spacecraft controlled reentry** : NA

• **Assessment of spacecraft compliance with Requirements 4.6-1 through 4.6-4**

Requirement 4.6-1 : Disposal for space structures passing through LEO : compliant

Requirement 4.6-2 : Disposal for space structure near GEO : NA

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

Requirement 4.6-4 : Reliability of post-mission disposal operations in earth orbit

Because the disposal operation is natural and will happen automatically, it is entirely reliable.

3.7 Assessment of Spacecraft Reentry Hazards

• **Detailed description of spacecraft components by size, mass, material, shape, and original location on the space vehicle, if the atmospheric reentry option is selected**

Group	Name	Quantity	Material	Shape	Mass (kg)	Diam / width (m)	Length (m)	Height (m)
EPS	PCCM + PDM	1	FR4 (fiberglass)	Box	0.429	0.100	0.100	0.050
	BM	3	Li-ion	Box	0.220	0.100	0.100	0.033
	depSPA s	2	GaAs	Box	0.279	0.100	0.3405	0.00015
	depSPA l	2	GaAs	Plate	0.557	0.200	0.3405	0.00015
CDHS	iOBC	1	FR4	Box	0.096	0.100	0.100	0.014
PDHS	PDHU	1	FR4	Box	0.099	0.100	0.100	0.014
	TXS-2	1	FR4	Box	0.068	0.090	0.096	0.033
	S-Patch	1	Ceramic	Cylinder	0.420	0.084	x	0.0148
TTC	TRXVU	1	FR4	Box	0.077	0.090	0.096	0.015
	ANTs + cover plate	1	Aluminum	Box	0.204	0.098	0.098	0.007
AOCS	RW	3		Box	0.153	0.046	0.046	0.0315
	ADCS Board	1	FR4	Box	0.278	0.090	0.096	0.075
	STR	1	PCB, camera, lens, baffle	Box	0.067	0.035	0.050	0.100
	CSS	10			0.015			
	MTM	1			0.015			
	MTM (red)	1			0.071			
Payload	HCT	1	NiTinol	Cylinder	0.290	0.100	0.100	0.330
	BEE	1	FR4 RO4350	Box	0.500	0.100	0.100	0.100
MECH	Structure	1	Aluminum 6061 (Endurosat)	Box	1.155	0.100	0.200	0.3405
MISC	IGIS	1			0.105			
	MISC	1			0.500			

Table 4 : Description of spacecraft components

Location : all components are inside the spacecraft, except for the antennas and the solar arrays.

• **Summary of objects expected to survive an uncontrolled reentry, using NASA Debris Assessment Software (DAS), NASA Object Reentry Survival Analysis Tool (ORSAT), or**

comparable software : No object is expected to survive reentry.

• Calculation of probability of human casualty for the expected year of uncontrolled reentry and the spacecraft orbital inclination (compliance with requirement 4.7-1) :
Casualty : 0

The casualty probability is compliant with requirement 4.7-1, which demands a probability lower than 1/10 000.

Note : this is compliant with the requirements but not all the systems were modeled (see table above, systems in orange) due to lack of information, and some were modeled using approximations.

3.8 Assessment of Spacecraft Hazardous Materials

• **Summary of the hazardous materials contained on the spacecraft :**

Chemical and commercial name of the material	Description of how it is a hazard to humans	Estimated state, quantity, activity, pressure at launch	Estimated state, quantity, pressure on orbit	Estimated state, quantity, pressure at EOM	Estimated state, quantity, pressure at end of passivation	Estimated state, quantity, pressure to survive reentry
Li-ion battery cell Panasonic NCR18650A	Toxic gases released when exploding	Solid 0.66 kg	Solid 0.66 kg	Solid 0.66 kg	Solid 0.66 kg	None

Table 5 : Hazardous materials found on spacecraft

3.9 Assessment for Tether Missions

There are no tether systems in the mission.