Orbital Debris Assessment for SpaceICE

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This document is a university-generated placeholder for the NASA-generated Orbital Debris Assessment for the CubeSats on the ELaNa-24 mission, per NASA-STD 8719.14A (FCC). The official NASA-generated report will be provided at a later date.

Credit is provided to NASA for the outline and formatting of this report, which is based on a NASA-generated ODAR for the ongoing, unrelated ELaNa-19 mission. [1]

Table 1 summarizes the compliance status of the SpaceICE satellite, which is fully compliant with all applicable requirements. Listed requirements are per NASA-STD 8719.14A, and particular requirements were selected for analysis based on their inclusion in a previous NASA ODAR. [1]

Table 1: Orbital Debris Requirement Compliance Matrix

Requirement	Compliance Assessment	Comments
4.3-1a	Not applicable	No planned debris release in LEO
4.3-1b	Not applicable	No planned debris release in LEO
4.3-2	Not applicable	No planned debris release near GEO
4.4-1	Compliant	On-board energy source (battery) incapable of debris-producing failure
4.4-2	Compliant	See Section 4 for policy regarding battery disconnect
4.4-3	Not applicable	No planned breakups
4.4-4	Not applicable	No planned breakups
4.5-1	Compliant	See Section 5
4.5-2	Not applicable	Per NASA ELaNa-19 report [1]
4.6-1(a)	Compliant	Expected lifetime of 2 years
4.6-1(b)	Not applicable	No planned storage orbit
4.6-1(c)	Not applicable	No planned direct retrieval
4.6-2	Not applicable	No planned space structures near GEO
4.6-3	Not applicable	No planned space structures between LEO and GEO
4.6-4	Not applicable	Entirely passive post-mission disposal
4.7-1	Compliant	No components surviving re-entry; See Section 7
4.8-1	Not applicable	No planned tether systems

Section 1: Program Management and Mission Overview

Responsible senior scientific/management personnel are as follows:

SpaceICE: Dunand, David (Principle Investigator)

Table 2: Program Milestone Schedule

Task	Date
CubeSat Mission Readiness Review	June 24-30, 2018
CubeSat delivery	July 15, 2018
CubeSat integration with LV	Late 2018
Launch date	Late 2018

Section 2: Spacecraft Description

Table 3 outlines the general attributes of the SpaceICE CubeSat.

Table 3: SpaceICE Generic Attributes

Quantity	Size	Name	Mass (kg)
1	3U (10 cm x 10 cm x 34 cm)	SpaceICE	3.44

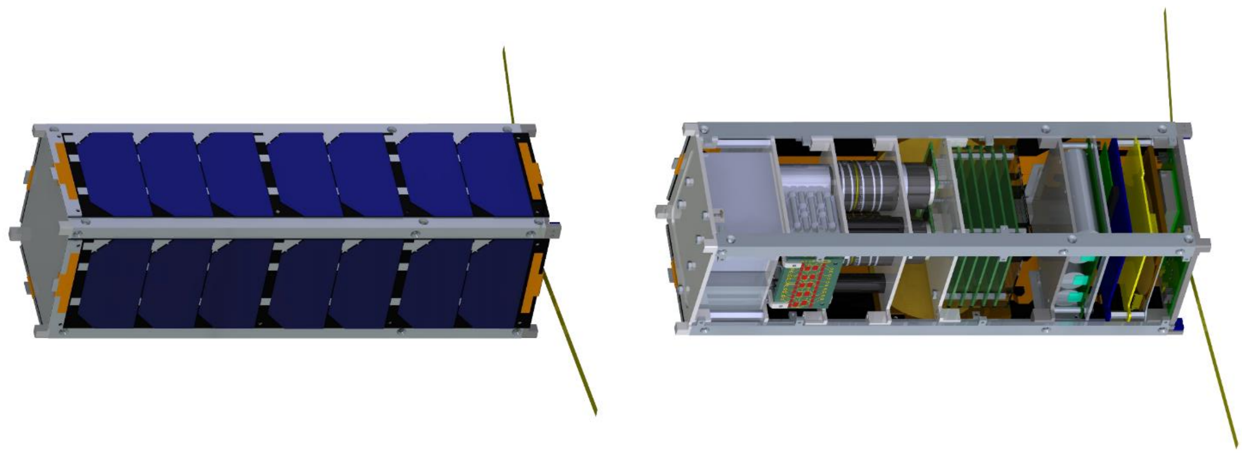

Figure 1: SpaceICE External View (Left) & Internal View (Right)

OVERVIEW

The SpaceICE mission aims to investigate the influence of gravity during directional solidification for the purpose of improving terrestrially-based materials fabricated using the freeze-casting technique. The scientific payload consists of two aqueous particle suspension samples and one aqueous solution sample which will be repeatedly solidified (and melted) over the course of the mission. Scientific instrumentation includes: cameras for imaging the solidification process and thermocouples for in-situ temperature data acquisition during solidification. Data products include images and temperature data.

CONOPS

Following a successful launch and orbit insertion of the satellite, communication will be initiated to verify satellite functionality. Next, a detumbling maneuver utilizing magnetic torque coils will commence. Once the satellite is stable, a 30-day status check period begins where the spacecraft operates in an idle mode, performs systems checks, and awaits an updated science schedule. When the system checks have passed and the spacecraft has verified its science schedule, the science mission phase begins.

During the science mission phase, the satellite's payload will conduct a series of experiments designed to investigate freeze-casting in the micro-gravity environment of Low Earth Orbit (LEO). Freeze-casting is a directional solidification technique that is used to fabricate porous materials with anisotropic, aligned pore structures. The SpaceICE mission aims to improve terrestrial fabrication of these materials by better understanding the role of gravity during the solidification process. To accomplish this, the spacecraft houses three cylindrical Pyrex containers which contain aqueous ceramic solutions. These containers will leverage a combination of thermoelectric coolers (TECS), electrical heaters, and thermocouples to repeatedly freeze, thaw, and measure the temperature throughout the freeze-casting process. Three cameras will capture still images of the experiment in order to observe the particle suspensions in various states. At the conclusion of a successful freeze-casting cycle, the satellite will begin recharging its batteries and package both science and health monitoring data for downlink.

The science mission phase will conclude after 26 weeks of successful experiments and science data retrieval, at which point the spacecraft enters the training and education phase for the remainder of its orbital lifetime. This final phase of the mission lifecycle is to be utilized as a platform for students at Northwestern University, the University of Illinois, and Bradley University to gain hands-on experience operating the spacecraft, planning experiments, and analyzing data.

MATERIALS

Satellite structure and solar panels are made from AL60601-T6. All aluminum is anodized, and the rails are Type III hard anodized. PCBs are made from FR-4, copper, and small electrical components. SpaceICE's payload has the same material make-up as the bus, with the addition of Kovar caps, Pyrex containers, and a water and TiO_2 solution.

HAZARDS

There are no hazardous systems on board. There are no pressure vessels nor thrusters nor any chemical reactants.

BATTERIES

The electrical power storage system consists of four lithium-ion batteries with over-charge, over-discharge, and over-current protection circuitry. The batteries are LG Chem Lithium-Ion INR18650 MJ1 cells.

Section 3: Assessment of Spacecraft Debris Released during Normal Operations

This section is not applicable, as no releases are planned on the SpaceICE mission.

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

There are NO plans for designed spacecraft breakups, explosions, or intentional collisions on the SpaceICE mission.

Per a previous NASA-generated ODAR for 3U-scale CubeSats [1],

> "The probability of battery explosion is very low, and, due to the very small mass of the satellites and their short orbital lifetimes the effect of an explosion on the far-term LEO environment is negligible."
>
> "The CubeSats batteries still meet Req. 56450 (4.4-2) by virtue of the HQ OSMA policy regarding CubeSat battery disconnect stating: 'CubeSats as a satellite class need not disconnect their batteries if flown in LEO with orbital lifetimes less than 25 years.'"

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

A detailed assessment of the components to be flown on the SpaceICE mission was performed. The assessment used DAS 2.1.1, a conservative tool used by the NASA Orbital Debris Office. With the orbit parameters of a circular, 500-km orbit with an inclination of 98.8°, the software returns an average 0.00000 probability of collision.

Section 6: Assessment of Spacecraft Post Mission Disposal Plans and Procedures

SpaceICE will naturally decay from orbit within 25 years after end of the mission, satisfying requirement 4.6-1a detailing the spacecraft disposal option.

Planning for spacecraft maneuvers to accomplish post mission disposal is not applicable. Disposal is achieved via passive atmospheric reentry.

An assessment was run using STK 10, an orbital analysis tool. With the orbit parameters of a circular orbit with an altitude of 500 km, inclination of 98.8°, and a mass of 4 kg, the software returns the satellite will deorbit in 2 years.

Section 7: Assessment of Spacecraft Reentry Hazards

A detailed assessment of the components to be flown on the SpaceICE mission was performed.

Reentry analysis followed the same methodology as a previous NASA-generated ODAR for 3U-scale CubeSats [1]:

> "The assessment used DAS 2.1.1, a conservative tool used by the NASA Orbital Debris Office to verify Requirement 4.7-1. The analysis is intended to provide a bounding analysis for characterizing the survivability of a CubeSat's component during re-entry. For example, when DAS shows a component surviving reentry it is not taking into account the material ablating away or charring due to oxidative heating. Both physical effects are experienced upon reentry and will decrease the mass and size of the real-life components as the reenter the atmosphere, reducing the risk they pose still further."
>
> "The following steps are used to identify and evaluate a components potential reentry risk relative to the 4.7-1 requirement of having less than 15 J of kinetic energy and a 1:10,000 probability of a human casualty in the event the survive reentry."

1) "Low melting temperature (less than 1000 °C) components are identified as materials that would never survive reentry and pose no risk to human casualty. This is confirmed through DAS analysis that showed materials with melting temperatures equal to or below that of copper (1080 °C) will always demise upon reentry for any size component up to the dimensions of a 1U CubeSat."
2) "The remaining high temperature materials are shown to pose negligible risk to human casualty through a bounding DAS analysis of the highest temperature components, stainless steel (1500°C). If a component is of similar dimensions and has a melting temperature between 1000 °C and 1500°C, it can be expected to possess the same negligible risk as stainless steel components. See following tables."

The results for reentry analysis of SpaceICE high melting temperature materials are shown in Table 4 below. Based on this analysis, no components will survive re-entry.

Table 4: SpaceICE High Melting Temperature Material Analysis

CubeSat	High Temp Component	Material	Mass (g)	Demise Alt (km)	KE (J)
SpaceICE	SpaceICE Antenna	Stainless Steel (generic)	4.400	0	0
SpaceICE	Fasteners	Stainless Steel (generic)	100.000	77.7	0
SpaceICE	Thermocouple	Stainless Steel (generic)	1.000	77	0
SpaceICE	Sample Container Plug	Kovar	8.000	73.8	0
SpaceICE	Sample Container Cap	Kovar	8.000	71.7	0

Section 8: Assessment for Tether Missions

There are NO plans for any tethers on the SpaceICE mission.

References

[1] NASA, "Orbital Debris Assessment for The CubeSats on the ELaNa-XIX Mission per NASA-STD 8719.14A (FCC) Rev E," 2018, https://apps.fcc.gov/els/GetAtt.html?id=207464&x=.