ELVL-2019-0045522
March 27, 2019

Orbital Debris Assessment for the SOCRATES Mission per NASA-STD 8719.14A

Signature Page

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ELVL-2019-0045522

Reply to Attn of: VA-H1

March 27, 2019

TO: Scott Higginbotham, LSP Mission Manager, NASA/KSC/VA-C

FROM: Yusef Johnson, a.i. solutions/KSC/AIS2

SUBJECT: Orbital Debris Assessment Report (ODAR) for the SOCRATES CubeSat

REFERENCES:

A. *NASA Procedural Requirements for Limiting Orbital Debris Generation*, NPR 8715.6A, 5 February 2008
B. *Process for Limiting Orbital Debris*, NASA-STD-8719.14A, 25 May 2012
C. International Space Station Reference Trajectory, delivered May 2017
D. McKissock, Barbara, Patricia Loyselle, and Elisa Vogel. *Guidelines on Lithium-ion Battery Use in Space Applications*. Tech. no. RP-08-75. NASA Glenn Research Center Cleveland, Ohio
E. *UL Standard for Safety for Lithium Batteries, UL 1642*. UL Standard. 4th ed. Northbrook, IL, Underwriters Laboratories, 2007
F. Kwas, Robert. Thermal Analysis of ELaNa-4 CubeSat Batteries, ELVL-2012-0043254; Nov 2012
G. Range Safety User Requirements Manual Volume 3- Launch Vehicles, Payloads, and Ground Support Systems Requirements, AFSCM 91-710 V3.
H. HQ OSMA Policy Memo/Email to 8719.14: CubeSat Battery Non-Passivation, Suzanne Aleman to Justin Treptow, 10, March 2014
I. HQ OSMA Email:6U CubeSat Battery Non Passivation Suzanne Aleman to Justin Treptow, 8 August 2017

The intent of this report is to satisfy the orbital debris requirements listed in ref. (a) for the SOCRATES CubeSat, which will be deployed from the International Space Station. It serves as the final submittal in support of the spacecraft Safety and Mission Success Review (SMSR). Sections 1 through 8 of ref. (b) are addressed in this document; sections 9 through 14 fall under the requirements levied on the primary mission and are not presented here.

RECORD OF REVISIONS		
REV	**DESCRIPTION**	**DATE**
0	Original submission	March 2019

The following table summarizes the compliance status of the SOCRATES CubeSat to be deployed from the International Space Station. SOCRATES is fully compliant with all applicable requirements.

Table 1: Orbital Debris Requirement Compliance Matrix

Requirement	Compliance Assessment	Comments
4.3-1a	Not applicable	No planned debris release
4.3-1b	Not applicable	No planned debris release
4.3-2	Not applicable	No planned debris release
4.4-1	Compliant	On board energy source (batteries) incapable of debris-producing failure
4.4-2	Compliant	On board energy source (batteries) incapable of debris-producing failure
4.4-3	Not applicable	No planned breakups
4.4-4	Not applicable	No planned breakups
4.5-1	Compliant	
4.5-2	Not applicable	
4.6-1(a)	Compliant	Worst case lifetime 2.1 years
4.6-1(b)	Not applicable	
4.6-1(c)	Not applicable	
4.6-2	Not applicable	
4.6-3	Not applicable	
4.6-4	Not applicable	Passive disposal
4.6-5	Compliant	
4.7-1	Compliant	Non-credible risk of human casualty
4.8-1	Compliant	No planned tether release for SOCRATES

Section 1: Program Management and Mission Overview

SOCRATES is sponsored by the Human Exploration and Operations Mission Directorate at NASA Headquarters. The Program Executive is John Guidi. Responsible program/project manager and senior scientific and management personnel are as follows:

SOCRATES: Demoz Egziabher, Project Manager, University of Minnesota, Twin Cities

Program Milestone Schedule	
Task	**Date**
CubeSat Selection	October 30th, 2018
Delivery to Nanoracks	August 1st, 2019
Launch	October 19, 2019
Deployment	Q1 2020

Figure 1: Program Milestone Schedule

SOCRATES will be launched as a payload on the Antares launch vehicle executing the NG-12 mission. SOCRATES will be deployed from the International Space Station. SOCRATES is described in Table 2: Attributes.

SOCRATES weighs approximately 3.6 kg.

Section 2: Spacecraft Description

Table 2: outlines the generic attributes of the spacecraft.

Table 2: SOCRATES Attributes

CubeSat Names	CubeSat Quantity	CubeSat size (mm^3)	CubeSat Masses (kg)
SOCRATES	1	340.5 x 100 x 100	3.6

The following pages describe the SOCRATES CubeSat.

SOCRATES– University of Minnesota, Twin Cities – 3U

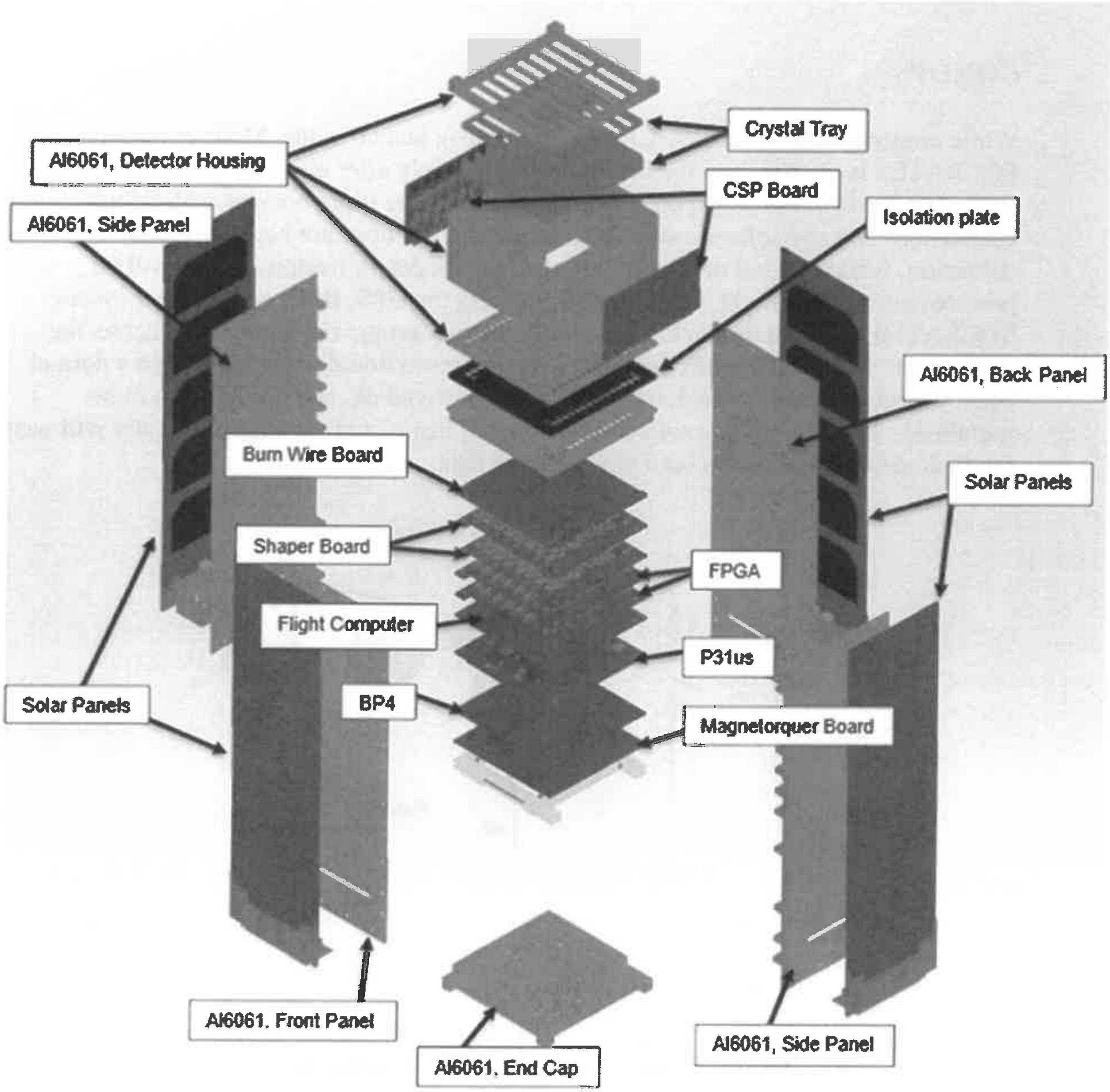

Figure 2: SOCRATES assembled view (w/o solar panels)

Overview

The primary mission of SOCRATES is to measure the arrival time of hard x-rays and soft γ-ray photons for the purpose of signal-of-opportunity navigation in deep space. The secondary mission is to measure the x-ray photon energies and arrival times to study electron acceleration in solar flares. Both missions will be accomplished by the payload sensor known as the Cesium Iodide Thallium-doped Incident Energy Spectrometer (CITIES). CITIES uses signals emitted by x-ray pulsars to measure the range of a space vehicle relative to some pre-defined origin. Eventually (after technology maturation)

CITIES will be an integral part of a system used for three dimensional positioning and timing in deep-space or GPS/GSSN-denied operational scenarios.

CONOPS

While awaiting deployment, SOCRATES will be in launch mode. Mode exit occurs when SOCRATES is ejected from the deployer. Immediately after ejection, the satellite will enter Safe mode in the power on state. In safe mode, the flight computer initializes connections and any software structures necessary, but does not begin any data collection. After a period of 48 minutes, the attitude determination sensors will be powered on with the flight computer this includes the GPS, IMU, and magnetorquers. SOCRATES will then de-tumble using only the gyroscopic readings. Once stable, the solar panels will deploy, and begin charging the power board batteries. When a normal battery level has been reached, CITIES will be powered on, and the FPGA will be initialized. The default data collection mode will begin, and the flight computer will wait for a telemetry command to send any gathered data.

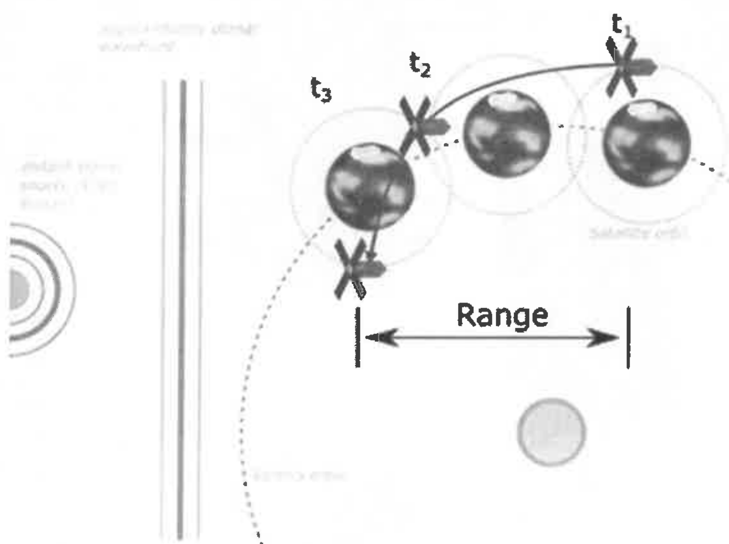

Figure 3: SOCRATES Data Collection depiction

The data collection mode for SOCRATES is schematically depicted in Figure 3. During the data collection mode, SOCRATES will make photon flux measurements to detect pulsar signals from which an estimate of the range between two time steps (e.g., t1 and t3 shown in the figure above) will be made. This will be done by time tagging and recording each x-ray photon received for the pulsars. The data will be saved on an onboard storage device until the appropriate time when the data can be transmitted to the ground. Once the data is received on the ground it will be compared to known pulsar signal profiles to make range estimates. The range estimates calculated from the pulsar signals will be compared to range estimates derived using the onboard GPS receivers and the known orbit model for SOCRATES. The difference between the two estimates will be used to assess the performance of CITIES as a ranging sensor.

The data transmissions to the ground will be timed when SOCRATES is in the service volume of the ground station network used for communications. SOCRATES will be relying on the Aerospace Corporations ground station network for uplink and downlink of data. The University of Minnesota has a contractual agreement in place with the Aerospace Corporation which provides access the network. SOCRATES will be using the Aerospace Corporation's ADV radios for uplink and downlink.

After its primary is complete, SOCRATES will point CITIES at the sun to collect solar x-ray emissions associated with solar flare activity for the secondary mission.

Materials

The structure of SOCRATES is made of Aluminum 6061, with stainless steel 361 and 18-8 fasteners. The in-house design boards are made of FR4 substrate. The COTS boards are from GOMSpace, which are the BP4(battery board), and P31us (power management board) which both have flight history.

SOCRATES will be using magnetorquers from CubeSpace, which include the CubeCoil and the CubeTorquer which are primarily made from Aluminum 6065 and 7075, as well as Carapace EMP 110.
Other COTS materials used include the VN-100 from VectorNav, OEM719 from NovAtel, ADV from Aerospace Corporation, BeagleBone Black from BegaleBone and solar cells which are Azurspace 3805-01-00. All these COTS components have flight history. The antennas used are for the GPS and radio, both are ceramic patch, couple layers in composite.

The last major component of SOCRATES are the Cesium Iodide crystals from Alpha Spectra Inc. More detail for the crystals can be found under 'Hazards'. The crystals are held in a 3D printed tray, made of Platinum Series ABS filament from AirWolf.

Hazards

The detector used on SOCRATES contains Thallium-doped, Cesium Iodide crystals. This crystal is hazardous for human contact such as ingestion, inhalation and direct skin contact. However, the crystal is non-flammable and will be fully encased a detector module before delivery, therefore the CubeSat will be safe for handling. This kind of detector system has space heritage and was used as the IBIS imager on the INTEGRAL satellite (https://www.cosmos.esa.int/web/integral/instruments-ibis). The crystal material is stable.

Batteries

The batteries used for SOCRATES is a GOM space BP4 battery pack, a standard common power unit used throughout the CubeSat industry, and has significant flight history.

Section 3: Assessment of Spacecraft Debris Released during Normal Operations

The assessment of spacecraft debris requires the identification of any object (>1 mm) expected to be released from the spacecraft any time after launch, including object dimensions, mass, and material.

The section 3 requires rationale/necessity for release of each object, time of release of each object, relative to launch time, release velocity of each object with respect to spacecraft, expected orbital parameters (apogee, perigee, and inclination) of each object after release, calculated orbital lifetime of each object, including time spent in Low Earth Orbit (LEO), and an assessment of spacecraft compliance with Requirements 4.3-1 and 4.3-2.

No releases are planned for SOCRATES, therefore this section is not applicable.

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 SOCRATES mission.

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 (ref (h)).

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." (ref. (h))

Limitations in space and mass prevent the inclusion of the necessary resources to disconnect the battery or the solar arrays at EOM. However, the low charges and small battery cells on the CubeSat's power system prevents a catastrophic failure, so that passivation at EOM is not necessary to prevent an explosion or deflagration large enough to release orbital debris.

Assessment of spacecraft compliance with Requirements 4.4-1 through 4.4-4 shows that with a maximum CubeSat lifetime of approximately 2.1 years maximum, SOCRATES is compliant.

Section 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 takes into account both the mean cross sectional area and orbital lifetime.

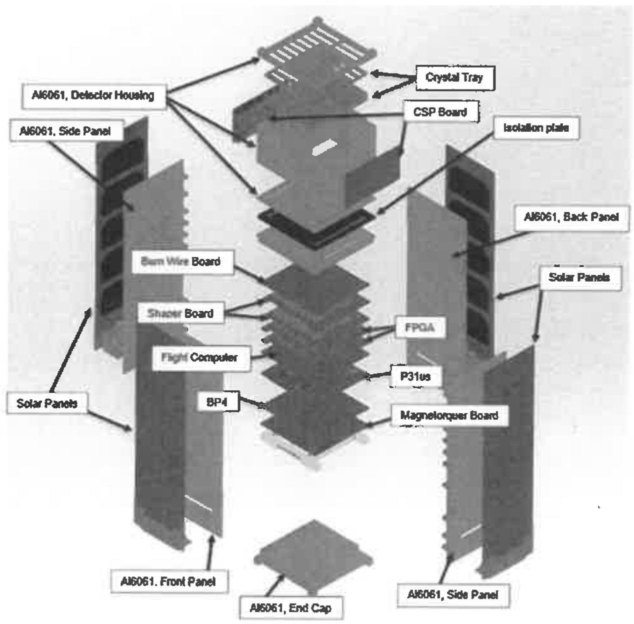

Figure 5: SOCRATES Expanded View

$$\boldsymbol{Mean\ CSA} = \frac{\sum \boldsymbol{Surface\ Area}}{\mathbf{4}} = \frac{[\mathbf{2} * (\boldsymbol{w} * \boldsymbol{l}) + \mathbf{4} * (\boldsymbol{w} * \boldsymbol{h})]}{\mathbf{4}}$$

Equation 1: Mean Cross Sectional Area for Convex Objects

$$\boldsymbol{Mean\ CSA} = \frac{(\boldsymbol{A_{max}} + \boldsymbol{A_1} + \boldsymbol{A_1})}{\mathbf{2}}$$

Equation 2: Mean Cross Sectional Area for Complex Objects

The CubeSat evaluated for this ODAR are stowed in a convex configuration, indicating there are no elements of the CubeSat obscuring another element of the same CubeSat from view. Thus, the mean CSA for the stowed CubeSat was calculated using Equation 1. This configuration renders the longest orbital life times for all CubeSat.

Once a CubeSat has been ejected from the CubeSat dispenser, Equation 2 is utilized to determine the mean CSA. A_{max} is identified as the view that yields the maximum cross-sectional area, if the CubeSat has deployables, such as solar panels or antennae. A_1 and A_2 are the two cross-sectional areas orthogonal to A_{max}. Refer to Appendix A for component dimensions used in these calculations

The SOCRATES (3.6 kg) orbit at deployment will be 424 x 410 km at a 51.6° inclination. With an area to mass ratio of ~0.046m^2/kg, DAS yields approximately 2.1 years for orbit lifetime for its deployed state, which in turn is used to obtain the collision probability. SOCRATES is calculated to have a probability of collision of 0.0. Table 3 below provides complete results.

There will be no post-mission disposal operation. As such the identification of all systems and components required to accomplish post-mission disposal operation, including passivation and maneuvering, is not applicable.

	CubeSat	SOCRATES
	Mass (kg)	3.6
Stowed	Mean C/S Area (m^2)	0.018
Stowed	Area-to Mass (m^2/kg)	0.004
Stowed	Orbital Lifetime (yrs)	**2.1**
Stowed	Probability of collision (10^X)	**0.0000**
Deployed	Mean C/S Area (m^2)	0.1699
Deployed	Area-to Mass (m^2/kg)	0.046
Deployed	Orbital Lifetime (yrs)	**0.59**
Deployed	Probability of collision (10^X)	**0.0000**

Solar Flux Table Dated
12/18/2018

Table 3: CubeSat Orbital Lifetime & Collision Probability

The probability of SOCRATES colliding with debris and meteoroids greater than 10 cm in diameter and capable of preventing post-mission disposal is less than 0.00000, for any configuration. This satisfies the 0.001 maximum probability requirement 4.5-1.

SOCRATES has no capability nor have plans for end-of-mission disposal, therefore requirement 4.5-2 is not applicable.

Assessment of spacecraft compliance with Requirements 4.5-1 shows SOCRATES to be compliant. Requirement 4.5-2 is not applicable to this mission.

Section 6: Assessment of Spacecraft Postmission Disposal Plans and Procedures

SOCRATES 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.

Calculating the area-to-mass ratio for the SOCRATES, the area-to-mass is calculated for is as follows:

$$\frac{\boldsymbol{Mean}\ {}^{\boldsymbol{C}}/_{\boldsymbol{S}}\,\boldsymbol{Area}\ (\boldsymbol{m^2})}{\boldsymbol{Mass}\ (\boldsymbol{kg})} = \boldsymbol{Area - to - Mass}\ (\frac{\boldsymbol{m^2}}{\boldsymbol{kg}})$$

Equation 3: Area to Mass

$$\frac{0.018\,m^2}{3.66\,kg} = 0.004\frac{m^2}{kg}$$

The assessment of the spacecraft illustrates they are compliant with Requirements 4.6-1 through 4.6-5.

DAS 2.1.1 Orbital Lifetime Calculations:
DAS inputs are: 424 km maximum apogee 410 km maximum perigee altitudes with an inclination of 51.6° at deployment no earlier than April 2020. An area to mass ratio of ~0.004 m^2/kg for the SOCRATES CubeSat was used. DAS 2.1.1 yields a 2.1 years orbit lifetime for SOCRATES in its stowed state.

This meets requirement 4.6-1. For the complete list of CubeSat orbital lifetimes reference **Table 3: CubeSat Orbital Lifetime & Collision Probability**.

Assessment results show compliance.

Section 7: Assessment of Spacecraft Reentry Hazards

A detailed assessment of the components of SOCRATES was performed. 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.

Table 4: SOCRATES High Melting Temperature Material Analysis

Name	Material	Total Mass (kg)	Demise Alt (km)	Kinetic Energy (J)
Tape Spring Hinge	Steel (generic)	.010	0	0
Hex Nylon-Insert Locknut, 4-40	Stainless Steel 18-8	.102	76.7	0
Hex Button Head Screw, 4-40, 3/8"	Stainless Steel 316	.019	77.4	0
Hex Button Head Screw, 4-40, 5/8"	Stainless Steel 316	.011	77.4	0
Phillips T.L. Flat Head Screw, 4-40, 3/8"	Stainless Steel 18-8	.019	77.2	0
Phillips Flat Head Screw, 4-40, 1/2"	Stainless Steel 316	.017	77.5	0
Phillips Flat Head Screw, 0-80, 1"	Stainless Steel 18-8	.0008	77.2	0
Hexnut 0-80	Stainless Steel 18-8	.0003	77.4	0

The majority of stainless steel components demise upon reentry and SOCRATES complies with the 1:10,000 probability of Human Casualty Requirement 4.7-1. A breakdown of the determined probabilities follows:

Table 5: Requirement 4.7-1 Compliance for SOCRATES

Name	Status	Risk of Human Casualty
SOCRATES	Compliant	1:0

*Requirement 4.7-1 Probability of Human Casualty > 1:10,000

If a component survives to the ground but has less than 15 Joules of kinetic energy, it is not included in the Debris Casualty Area that inputs into the Probability of Human Casualty calculation. This is why SOCRATES has a 1:0 probability as none of its components have more than 15J of energy.

SOCRATES is shown to be in compliance with Requirement 4.7-1 of NASA-STD-8719.14A.

Section 8: Assessment for Tether Missions

SOCRATES will not be deploying any tethers.

SOCRATES satisfies Section 8's requirement 4.8-1.

Section 9-14

ODAR sections 9 through 14 pertain to the launch vehicle, and are not covered here. Launch vehicle sections of the ODAR are the responsibility of the CRS provider.

If you have any questions, please contact the undersigned at 321-867-2098.

/original signed by/

Yusef A. Johnson
Flight Design Analyst
a.i. solutions/KSC/AIS2

cc: VA-H/Mr. Carney
VA-H1/Mr. Beaver
VA-H1/Mr. Haddox
VA-C/Mr. Higginbotham
VA-C/Mrs. Nufer
VA-G2/Mr. Treptow
SA-D2/Mr. Frattin
SA-D2/Mr. Hale
SA-D2/Mr. Henry
Analex-3/Mr. Davis
Analex-22/Ms. Ramos

Appendix Index:

Appendix A. SOCRATES Component List

Item Number	Name	Qty	Material	Body Type	Mass (g) (total)	Diameter / Width (mm)	Length (mm)	Height (mm)	High Temp	Melting Temp (F°)	Survivability
1	Detector Housing	1	AL 6061	Cube Alum.	273	100	100	53	No	-	Demise
2	Bottom Cap	1	AL 6061	Rectangular Plate	78	100	100	6.5	No	-	Demise
3	Front Panel	1	AL 6061	Rectangular Plate	130	95.83	253.07	3	No	-	Demise
4	Back Panel	1	AL 6061	Rectangular Plate	130	95.83	253.07	3	No	-	Demise
5	Left Panel	1	AL 6061	Rectangular Plate	148	94	262.07	2	No	-	Demise
6	Right Panel	1	AL 6061	Rectangular Plate	151	94	262.07	2	No	-	Demise
7	Solar Panel	4	FR4, Copper, InGaAs (solar cell makeup)	Rectangular PCB	368	82.6	278	1.6	No	-	Demise
8	AC1007 Antenna	1	Ceramic	Rectangular Prism	11.9	38.1	40.132	3.302	No	-	Demise
9	Detector top/window	1	AL 6061	Square Alum.	35	100	100	8	No	-	Demise
10	Seperation Switch	2	AL 6061		0	x	x	x	No	-	Demise
11	Hinge Adapter	4	AL 6061	Rectangular Prism	44	82.8	53.25	6.5	No	-	Demise
12	Tape Spring Hinge	12	Steel	Rectangular cuved plane	10.668	19.05	50.8	1	Yes	2500°	0 km
13	Hex Nylon-Insert Locknut, 4-40	74	Stainless Steel 18-8	Cylinder	38.924	6.223	3.55	x	Yes	2500°	Demise
14	Hex Button Head Screw, 4-40, 3/8"	36	Stainless Steel 316	Cylinder	16.704	5.21	9.25	x	Yes	2500°	Demise
15	Hex Button Head Screw, 4-40, 5/8"	4	Stainless Steel 316	Cylinder	2.8	5.21	15.87	x	Yes	2500°	Demise
16	Phillips T.L. Flat Head Screw, 4-40, 3/8"	40	Stainless Steel 18-8	Cylinder	16.32	5.23	9.25	x	Yes	2500°	Demise
17	Phillips Flat Head Screw, 4-40, 1/2"	30	Stainless Steel 316	Cylinder	15.78	5.23	12.7	x	Yes	2500°	Demise
18	Phillips Flat Head Screw, 4-40, 1"	4	Aluminum 2024	Cylinder	1.2	5.23	25.4	x	No	-	Demise
19	Hex Nylon-Insert Locknut, 4-40	108	Stainless Steel 18-8	Cylinder	56.808	6.223	3.55	x	Yes	2500°	Demise

20	Hex Button Head Screw, 4-40, 5/8"	4	Stainless Steel 316	Cylinder	2.8	5.21	15.87	x	Yes	2500˚	Demise
21	Hex Button Head Screw, 4-40, 3/8"	104	Stainless Steel 316	Cylinder	48.256	5.21	9.25	x	Yes	2500˚	Demise
22	CSP board	2	FR4, copper	Rectangular PCB	70	48	89	25	No	-	Demise
23	Bottom Plate	1	AL 6061	Square Alum.	65	100	100	2	No	-	Demise
24	Crystal Tray	1	ABS	Rectangular ABS	33	82	89	12	No	-	Demise
25	Isolation Plate	1	G10	Square G10	27	100	100	2	No	-	Demise
26	Crystals	16	CsI(Tl)	Rectangular	144	7	7	40	No	-	Demise
27	Shaper board	2	FR4, Copper	Rectangular PCB	168	90	90	30	No	-	Demise
28	Cube Coil	1	Aluminium 6065 and 7075	Rectangular Prism	46	88	95	5.8	No	-	Demise
29	CubeRod	1	Aluminium 6065 and 7075	Cylinder	28	60	18	13.5	No	-	Demise
30	BP4	1	Polyimide, Lithium Ion	Rectangular PCB	373	89	92	25.1	No	-	Demise
31	P31us	1	Polyimide, coppper	Rectangular PCB	200	89	92	15.24	No	-	Demise
32	Computer/IMU/GPS/Radio	1	FR4, copper	Rectangular PCB	185	89	92	50.83	No	-	Demise
33	HVPS*	1	FR4, copper	Rectangular PCB	200	89	92	15.24	No	-	Demise
34	FPGA*	2	FR4, copper	Rectangular PCB	100	89	92	16.2	No	-	Demise
35	Shaper*	2	FR4, copper	Rectangular PCB	120	89	92	22.3	No	-	Demise
36	Burn Wire	1	FR4, copper	Rectangular PCB	30	89	92	10	No	-	Demise
37	ADV Radio	1	FR4	Rectangular PCB	21	55.88	55.88	17.6	No	-	Demise
38	Crystal tray holder	1	AL 6061	Rectangular Alum.	53	90	75	9	No	-	Demise
39	Connector Cap	1	AL 6061	Square Alum.	77	100	100	10	No	-	Demise
40	Crystal Tray Top	1	ABS	Rectangular ABS	10	88	83	4	No	-	Demise
41	Hex Nylon-Insert Locknut, 4-40	12	Stainless Steel 18-8	Cylinder	6.312	3.96		6.17	Yes	2500˚	Demise
42	Hex T.L. Button Head Screw, 4-40, 1/2"	8	Stainless Steel 18-8	Cylinder	4.68	2.884	12.7	x	Yes	2500˚	Demise

43	Phillips Flat Head Screw, 4-40, 1/2"	4	Stainless Steel 316	Cylinder	2.104	5.23	12.7	x	Yes	2500°	Demise
44	Phillips T.L. Flat Head Screw, 4-40, 3/8"	8	Stainless Steel 18-8	Cylinder	3.264	5.23	9.25	x	Yes	2500°	Demise
45	Hex Button Head Screw, 4-40, 5/8"	8	Stainless Steel 316	Cylinder	5.6	5.21	15.87	x	Yes	2500°	Demise
46	Phillips Flat Head Screw, 0-80, 1"	3	Stainless Steel 18-8	Cylinder	0.801	5.23	25.4	x	Yes	2500°	Demise
47	Hexnut, 0-80	3	Stainless Steel 18-8	Cylinder	0.3	3.96		1.27	Yes	2500°	Demise
48	Cabling (MMCX, MCX, Picoblade, etc.)	38	Copper	Cylinder	114	4.45	152.4	x	No	-	Demise