DOGE-1

Orbital Debris Assessment Report (ODAR)

September 26, 2022

Revision 2-0

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This document was built using the outline found in the NASA JSC ODAR Software Template and contains relevant abstracted content.

Applicable Mission: DOGE-1

Revision History

Revision	Date	Comment
1-0	June 1, 2022	Initial Release (Draft Template)
1-1	June 15, 2022	Internal review draft (TBD Identification)
1-2	June 30, 2022	Internal review draft (First completed draft)
1-3	June 30, 2022	Internal review draft (Redline resolution)
1-4	July 21, 2022	Release for NASA & FCC review
2-0	September 26, 2022	FCC Submittal Document

Document Approvals

Samuel Reid, President Geometric Energy Corporation — September 26, 2022 (Date)

Gary P. Barnhard, President XISP-Inc — September 26, 2022 (Date)

Contents

SELF-ASSESSMENT (APPENDIX A.2 NASA-STD-8719.14)

A self-assessment is provided below in accordance with the assessment format provided in Appendix A.2 of NASA-STD-8719.14B.

Requirement	Description	Compliance	Comments
4.3-1	Mission-related debris passing through LEO	Compliant	
4.3-2	Mission-related debris passing through GEO	Compliant	
4.4-1	Limiting the risk to other space systems from accidental explosions during deployment and mission operations	Compliant	
4.4-2	Design for passivation after completion of mission operations while in orbit	Compliant	
4.4-3	Limiting the long-term risk to other space systems from planned breakups	Compliant	
4.4-4	Limiting the short-term risk to other space systems from planned breakups	Compliant	
4.5-1	Limiting debris generated by collisions with large objects	Compliant	
4.5-2	Limiting debris generated by collisions with small objects	Compliant	
4.6-1	Disposal for space structures in or passing through LEO	N/A	Not Deployed
4.6-2	Disposal for space structures near GEO	N/A	Not Deployed
4.6-3	Disposal for space structures between LEO and GEO	N/A	Not Deployed
4.6-4	Reliability of post-mission disposal maneuver operations	Compliant	
4.7-1	Limit the risk of human casualty	Compliant	
4.8-1	Mitigate the collision hazards of space tethers in protected regions of space	Compliant	

ASSESSMENT REPORT FORMAT

This ODAR follows the format prescribed in NASA-STD-8719.14B, Appendix A.1 and includes the content indicated as a minimum requirement in each of Sections 1 through 8. Sections 9 through 14 apply to the launch vehicle ODAR and are not covered here.

1. PROGRAM MANAGEMENT AND MISSION OVERVIEW

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Mission Overview: DOGE-1 is a Distributed Ledger Technology and Imaging mission, consisting of one 13.8 kg 12U class satellite intended reach a stable lunar orbit and operate for up to two years.

- DOGE-1 is a Geometric Mission on SpaceX's Falcon 9 2023 Launch paid for entirely in Dogecoin
- First mission to demonstrate Blockchain Technology beyond LEO.
- Unique Marketing Opportunity to display media inside the satellite to be down-linked back to Earth

The DOGE-1 mission entails the design, integration, launch, deployment to a stable lunar orbit, and operation of a 12U CubeSat spacecraft bus and accompanying payloads. DOGE-1 is manifested for launch on a Falcon 9 Rideshare mission offering deployment on a Trans Lunar Injection (TLI) trajectory. Once DOGE-1 is deployed it will transition via a minimum energy ballistic trajectory using its electric propulsion system to the most stable elliptical lunar orbit achievable.

The DOGE-1 payloads consist of:
(1) Distributed Public Ledger Technology Development & related imaging, authorization and authentication services (i.e., communications, control, on board transaction processing, public ledger management, monetizable display imaging overlay experiment).
(2) Interoperable Network Communication Architecture applications development including correlateable range, rate, and attitude data for performance analysis (i.e., GNSS above constellation navigation data acquisition, cooperative laser retroreflector target, cooperative relay target).

The DOGE-1 spacecraft is intended to demonstrate technologies that enable ancillary services (Comm, Data, Time, Nav) relay nodes between Earth satellites, constellations, ground stations, as well as other lunar orbiting and landed devices.

DOGE-1 is intended to serve as an infrastructure testbed for precursors to enable our envisioned commercial IoT network based on Interoperable Network Communication Architectures.

A space plaque will also be included, integrated with BETA, RHO, GAMMA, KAPPA, XI utility tokens for space advertising for a limited period of time.

Schedule of Upcoming Mission Milestones: The launch of DOGE-1 spacecraft is manifested as a lunar Rideshare payload on the SpaceX Falcon 9 launch vehicle IM-1 flight. The launch is scheduled for No Earlier Than (NET) January 1, 2023.

Launch Vehicle and Launch Site: The DOGE-1 spacecraft will be launched as a Surfboard payload using a SpaceX Falcon 9 from Cape Canaveral, FL.

Mission Duration: Nominal operations for the DOGE-1 spacecraft is 2 years, assuming stable lunar orbit and make-up propellant requirement minimization objectives are achieved. A post-operations orbital lifetime of less than 3 months, during which the spacecraft will use its remaining propulsion capabilities to execute a controlled impact on the Moon's surface due to gravitational variation driven orbital decay.

Launch and Deployment Profile: The DOGE-1 spacecraft will be integrated and launched on a SpaceX Falcon 9 vehicle, using the Surfboard adapter. The DOGE-1 spacecraft will be deployed after Trans Lunar Injection, the accomplishment of the Lunar Injection Maneuver (LIM), and the deployment of the primary payload. The deployment time and coordinates will be at the discretion of the launch service provider. The LIM is being designed to minimize the delta-V required for the primary payload to reach a circularized 100 km Low Lunar Orbit (LLO). By delaying deployment of the DOGE-1 spacecraft until after the primary payload deployment, the delta-V required for DOGE-1 to reach a semi-circularized (elliptical) stable Lunar Orbit will likewise be minimized.

2. SPACECRAFT DESCRIPTION

Physical Description of the Spacecraft: The exterior dimensions of the satellite are shown in Table 2-1 Spacecraft Physical Description. The available rideshare payload envelope and the Mercury 12T dispenser are show in Figure 2-1 Mercury-12T Dispenser within SpaceX Surfboard Volume Envelope. Figure 2-2 Mercury-12T Dispenser shows the dispenser alone. Figure 2-3 Surfboard illustrates the SpaceX Surfboard. Figure 2-4 Rideshare Payload Volume and Surfboard and Figure 2-5 DOGE-1 SpaceX Surfboard Location provides other views.

Deploy Order		1
Payload Constituent		DOGE-1 CubeSat
SpaceX Internal Name		payload_DOGE-1_2
Separation System		Mercury-12T
Quantity of Deployables in this deploy		1.00
Deployable Type(s)		12U CubeSat
Separation Plane Origin (mm)	X_{PL}	578.87
	Y_{PL}	0.00
	Z_{PL}	177.90
Deploy Vector (unit vector)	X_{PL}	1.00
	Y_{PL}	0.00
	Z_{PL}	0.00
Deployable Dimensions (mm) Width x Height is parallel to separation plane	Width	240.40
	Height (in Zpl)	224.90
	Length (along deploy axis)	366.00
Total Deploy Mass	Nominal (kg)	13.80
	+ Tolerance (kg)	1.50
	- Tolerance (kg)	1.50
Total Separation Energy	Nominal (J)	11.07
	+ Tolerance (%)	20
	- Tolerance (%)	20
Time delay from initiation of electrical signal until first movement of Payload Constituent	Nominal Delay (s)	0.02
	+ Tolerance (s)	0.03
	- Tolerance (s)	0.015
Nominal Deploy Velocity [m/sec]		1.267

Table 2-1 Spacecraft Physical Description

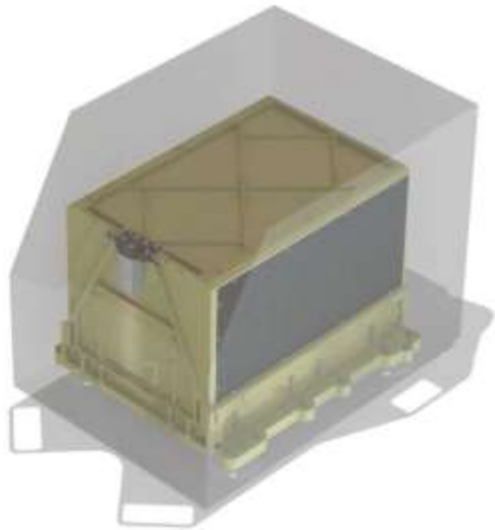

Figure 2-1 Mercury-12T Dispenser within SpaceX Surfboard Volume Envelope

Figure 2-2 Mercury-12T Dispenser

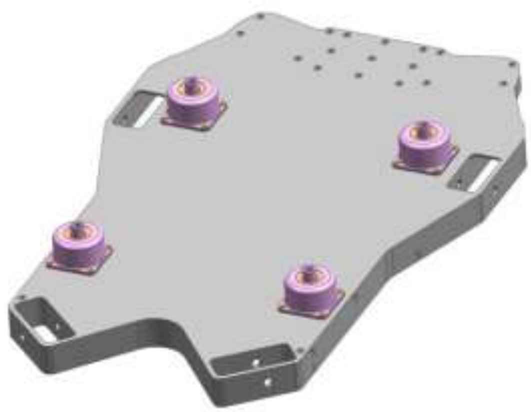

Figure 2-3 SpaceX Surfboard

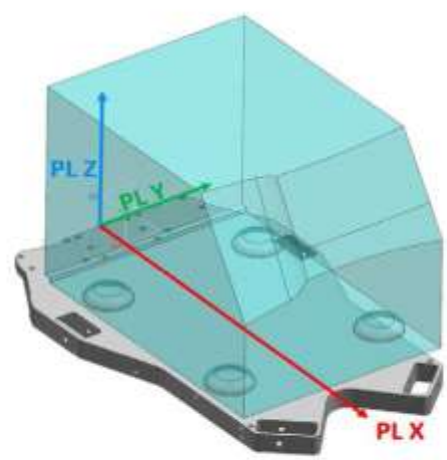

Figure 2-4 Rideshare Payload Volume and Surfboard

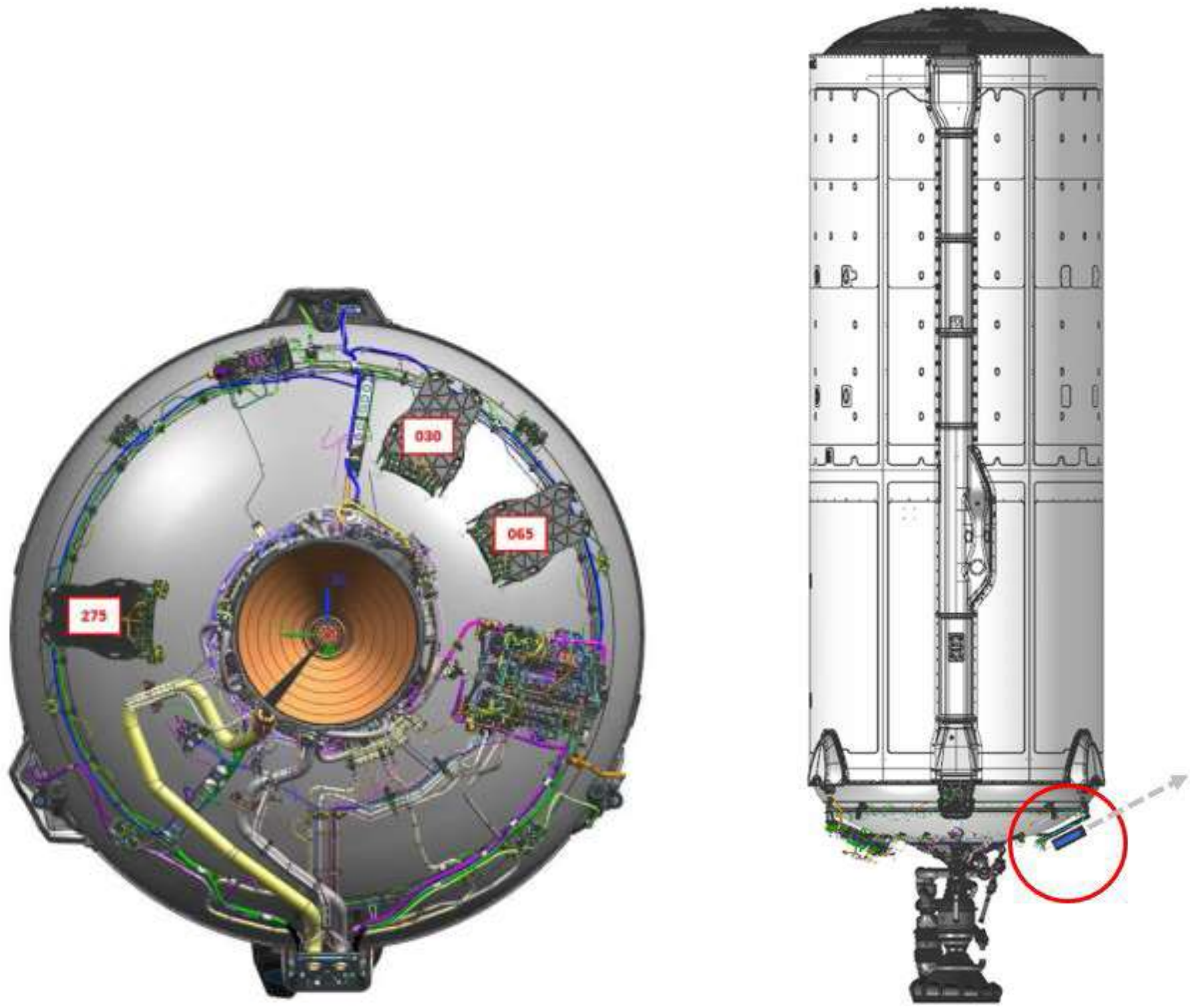

Figure 2-5 DOGE-1 SpaceX Surfboard Location

DOGE-1 Spacecraft Bus & Payloads consist of the following elements:

- 12U tabulated CubeSat structure – Exobotics Ltd
- A3200 On Board Computer – GOMSpace A/S (flight heritage)
- Attitude Determination & Control System (ADCS)
    - Reaction wheels + sun sensors – GOMSpace A/S (flight heritage)
    - Star trackers – CubeSpace SA (flight heritage)
- P31U Electrical Power System (EPS) – GOMSpace A/S (flight heritage)
    - BPX batteries (3x 75 Wh packs) – GOMSpace A/S (flight heritage)
    - Solar panels (8x 8W XY panels + 1x 2.3W Z panel) – Exobotics Ltd
- NanoCom AX2150 S-band radio system – GOMSpace A/S (flight heritage)
- NanoCom AM2150-P S-band antenna – GOMSpace A/S (flight heritage)
- X-Band Transmitter – Endurosat (flight heritage) [Radio Experiment QoS for location]
- X-Band Patch Antenna – Endurosat (flight heritage) [Radio Experiment QoS for location]
- Enpulsion NANO Electric Propulsion (2x) – Enpulsion GmbH (flight heritage)
- Payload 1, Distributed Ledger Technology (DLT) (imaging system + display) – Exobotics Ltd
- Payload 2, Geospatial Navigation Satellite System (GNSS) Multi-channel Receiver & Antenna – Novatel (flight heritage).[Radio Experiment QoS for location]
- Payload 3 (aspirational), Passive Retroreflectors (up to four) – Exobotics Ltd.

The nominal mass of the deployed satellite is 13.8 kg.

The DOGE-1 spacecraft has no deployables and is shown in Figure 2-6 DOGE-1 Spacecraft Isometric Renderings.

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Figure 2-6 DOGE-1 Spacecraft Isometric Renderings

Total Mass of Satellite at Launch, Including All Propellants and Fluids: 13.8 kg.

Dry Mass of the Satellite: 13.8 kg.

payload__1			
Name	Deployable Identifier	Coordinate System	Separation Plane Distance [mm]
payload__1	1	Payload	0.00
Mass			
	Nominal [kg]	Plus Tolerance [+]	Minus Tolerance [-]
Mass	13.8000	1.5000	1.5000
Center of Gravity			
	Nominal [mm]	Plus Tolerance [+]	Minus Tolerance [-]
X_{PL}	372.4000	25.0000	25.0000
Y_{PL}	-1.5000	25.0000	25.0000
Z_{PL}	200.1000	25.0000	25.0000
Moment of Inertia			
	Nominal [millimeters ** 2 * kg]	Plus Tolerance [+]	Minus Tolerance [-]
Ixx	160000.0000	24000.00	24000.00
Iyy	234000.0000	35100.00	35100.00
Izz	236000.0000	35400.00	35400.00
Product of Inertia			
	Nominal [millimeters ** 2 * kg]	Plus Tolerance [+]	Minus Tolerance [-]
Ixy	2420.0000	9440.00	9440.00
Iyz	4470.0000	9440.00	9440.00
Izx	2000.0000	9440.00	9440.00

Table 2-2 DOGE-1 Mass Properties

Identification of All Fluids On-Board: No fluids are on-board.

Description of Propulsion System: The DOGE-1 spacecraft will be equipped with dual Enpulsion FEEP Nano electric propulsion system as previously noted.

Description of Attitude Determination and Control System: Following separation from the launch vehicle, the DOGE-1 spacecraft will autonomously de-tumble and be oriented into sun-pointing mode. The following chart describes the attitude determination and control system ("ADCS") modes that will be employed, using a combination of sun sensors, reaction wheels, star trackers, and if necessary, the electric propulsion system to orient the DOGE-1 spacecraft.

The spacecraft is three axis stabilized using its ADCS. The anticipated spacecraft bus and payload pointing objectives (ADCS modes) are outlined in Table 2-2 DOGE-1 Anticipated ADCS modes.

ADCS Mode	Description
Safe Mode	Coarse pointing of Z+ face NADIR with low-rate Z axis roll for detumbling with minimum power requirements.
Sun Pointing	Optimized sun pointing for power generation.
Low-rate Comms Pointing (TT&C)	Optimized Earth station pointing for S-Band Tracking, Telemetry & Command (TTC) communications uplink and downlink.
Image Pointing	Optimized pointing for Distributed Ledger Technology (DLT) image acquisition and display.
Navigation Pointing	Optimized GNSS pointing for above constellation multi-satellite fixes.
High-rate Comms Pointing (Payload)	Optimized Earth station pointing for X-Band payload high-rate data downlink (aspirational).
Relay Comms Pointing	Optimized pointing for space-to-space data relay communication (aspirational).
Retroreflector Pointing	Optimized pointing for Earth-to-space, and space-to-space passive laser retroreflector acquisition (aspirational).
Sun Clocking	To generate additional power, this mode permits the satellite to rotate around its fixed inertial axis towards the sun, while also operating in the Pointing modes.

Table 2-2 DOGE-1 Anticipated ADCS modes

Fluids in Pressurized Batteries: None. The DOGE-1 spacecraft employ unpressurized standard lithium-ion battery cells.

Description of Pyrotechnic Devices: None.

Description of Electrical and Power System:

The P31U Electrical Power System (EPS) provided by GOMSpace A/S is flight heritage equipment which supplies power to the spacecraft bus and payload. The EPS includes:

- BPX batteries (3x 75 Wh packs = 225 Wh total) – GOMSpace A/S (flight heritage)
- Solar panels (8x 8W XY panels + 1x 2.3W Z panel = 66.3 W total) – Exobotics Ltd

The spacecraft bus and payloads can draw power from both the batteries and the solar arrays individually or simultaneously as needed to support operations.

The battery packs are all equipped with power regulation ICs which regulate the discharge state of the individual battery cells. All of the battery packs are charged by the solar panels.

The satellite bus nominally consumes less than 20 W of power, with certain modes reducing or increasing the load. The payload maximum available power (solar array + batteries) is 100 W. The charge/discharge cycle is managed by a power management system overseen by the On-Board Computer (OBC) and the Electrical Power System (EPS).

Identification of Other Stored Energy: None.

Identification of Any Radioactive Materials: None.

3. ASSESSMENT OF SPACECRAFT DEBRIS RELEASE DURING NORMAL OPERATIONS

REQUIREMENT 4.3-1: DEBRIS PASSING THROUGH LEO.

No release of debris will occur during the lifetime of the DOGE-1 satellite. DOGE-1 deployments use a Maverick Space Systems Mercury 12 Dispenser to deploy the spacecraft from the launch vehicle, from which no debris will be generated. Additionally, there is no probable scenario for unintentional debris generation.

Result for Requirement 4.3-1: COMPLIANT

REQUIREMENT 4.3-2: DEBRIS PASSING NEAR GEO.

There will be no intentional release of debris near Geostationary Orbit during the lifetime of the mission. However, the DOGE-1 spacecraft is being deployed on a TLI trajectory that passes Geostationary Orbit. When the launch date firms up the launch service provider launch conjunction assessment (CA), launch support and early orbit determination, onorbit CA and collision avoidance (COLA) screening request time will be adjusted as deemed necessary to address the extant conditions.

Result for Requirement 4.3-2: COMPLIANT

4. ASSESSMENT OF SPACECRAFT INTENTIONAL BREAKUPS AND POTENTIAL FOR EXPLOSIONS

REQUIREMENT 4.4-1: LIMITING THE RISK TO OTHER SPACE SYSTEMS FROM ACCIDENTAL EXPLOSIONS DURING DEPLOYMENT AND MISSION.

The in-orbit failure of a battery cell protection circuit could lead to a short circuit resulting in overheating and a very remote possibility of battery cell explosion. Due to the small mass of the satellite and its short orbital lifetime, the long-term effects of an unlikely explosion on the Low Earth Orbit (LEO), Trans Lunar Injection (TLI) trajectory, or the achieved Lunar orbit environment are negligible. Available Failure Modes and Effects Analysis (FMEA) results for similar batteries describe the combined faults that must occur for any of seven (7) independent, mutually exclusive failure modes to lead to such an explosion.

Result for Requirement 4.4-1: 0.000; COMPLIANT.

Supporting Rationale and FMEA Details:

- **Failure Mode 1:** Internal short circuit.
  - Mitigation: Qualification and acceptance shock, vibration, thermal cycling, and vacuum tests followed by maximum system rate-limited charge and discharge will prove that no internal short circuit sensitivity exists.
  - Combined Faults Required for Realized Failure: Environmental testing and functional charge and discharge tests must both be ineffective in discovery of the failure mode.
- **Failure Mode 2:** Internal thermal rise due to high load discharge rate.
  - Mitigation: Battery cells were tested in the lab for high load discharge rates in a variety of flight-like configurations to determine if the feasibility of an out-of-control thermal rise in the cell. Cells were also tested in a hot, thermal vacuum environment in order to test the upper limits of the cells capability. No failures were observed via satellite telemetry or external monitoring circuitry.
  - Combined Faults Required for Realized Failure: Spacecraft thermal design must be incorrect *and* external over-current detection and disconnect function must fail to enable this failure mode.
- **Failure Mode 3:** Excessive discharge rate or short circuit due to external device failure or terminal contact with conductors not at battery voltage levels (due to abrasion or inadequate proximity separation).
  - Mitigation: This failure mode will be negated by:
    a) Qualification-tested short circuit protections on each external circuit;
    b) Design of battery packs and insulators such that no contact with nearby board traces is possible without being cause by some other mechanical failure; and
    c) Obviation of such other mechanical failures by proto-qualification and acceptance environmental tests (shock, vibration, thermal cycling, and thermal-vacuum tests).
  - Combined Faults Required for Realized Failure: An external load must fail or short- circuit *and* external over-current detection and disconnect function must all occur to enable this failure mode.
- **Failure Mode 4:** Inoperable vents.
  - Mitigation: Battery venting is not inhibited by the battery holder design or the spacecraft design. The battery is capable of venting gases to the external

environment.

- Combined Faults Required for Realized Failure: The cell manufacturer or the satellite integrator fails to install proper venting.

- **Failure Mode 5:** Crushing.
  - Mitigation: This mode is negated by spacecraft design. There are no moving parts in the proximity of the batteries.
  - Combined Faults Required for Realized Failure: A catastrophic failure must occur in an external system *and* the failure must cause a collision sufficient to crush the batteries leading to an internal short circuit *and* the satellite must be in a naturally sustained orbit at the time the crushing occurs.

- **Failure Mode 6:** Low level current leakage or short-circuit through battery pack case or due to moisture-based degradation of insulators.
  - Mitigation: This failure mode is mitigated by:
    - a) Battery holder and case design made of non-conductive plastic; and
    - b) Operation in vacuum such that no moisture can affect insulators.
  - Combined Faults Required for Realized Failure: Abrasion or piercing failure of circuit board coating or wire insulators and dislocation of battery packs *and* failure of battery terminal insulators *and* failure to detect such failures in environmental tests must occur to result in this failure mode.

- **Failure Mode 7:** Excess temperatures due to orbital environment and high discharge combined.
  - Mitigation: The spacecraft thermal design will negate this possibility. Thermal rise has been analyzed in combination with space environment temperatures showing that batteries do not exceed normal allowable operating temperatures under a variety of modeled cases, including worst-case orbital scenarios. Analysis shows these temperatures to be well below temperatures of concern for explosions.
  - Combined Faults Required for Realized Failure: Thermal analysis *and* thermal design *and* mission simulations in thermal-vacuum chamber testing *and* over-current monitoring and control must all fail for this failure mode to occur.

REQUIREMENT 4.4-2: DESIGN FOR PASSIVATION AFTER COMPLETION OF MISSION OPERATIONS.

The DOGE-1 satellite has the capability to fully disconnect the lithium ion cells from the charging current of its respective solar arrays. At end of life, this feature will be used to disconnect all energy generation sources and deplete all remaining stores. In the unlikely event that a battery cell explosively ruptures, the small size, mass, and potential energy of these batteries is such that while the spacecraft could be expected to vent gases, the debris from the battery rupture will be contained within the spacecraft due to the lack of penetration energy to the multiple enclosures surrounding the batteries.

Result for Requirement 4.4-2: COMPLIANT.

List of components which shall be passivated at End of Mission:

- Three lithium-ion battery packs – spacecraft will be configured to keep solar array from charging and let batteries deplete completely;
- Solar array charging circuit – will be disabled, discharging all cells fully within a few days;
- Reaction wheels – will have the power removed and spacecraft will be configured to keep from reenergizing.

Rationale for all items which are required to be passivated, but cannot be due to their design: None.

REQUIREMENT 4.4-3: LIMITING THE LONG-TERM RISK TO OTHER SPACE SYSTEMS FROM PLANNED BREAKUPS.

There is no planned breakup during the mission.

Result for Requirement 4.4-3: COMPLIANT.

REQUIREMENT 4.4-4: LIMITING THE SHORT-TERM RISK TO OTHER SPACE SYSTEMS FROM PLANNED BREAKUPS.

There is no planned breakup during the mission.

Result for Requirement 4.4-4: COMPLIANT.

5. ASSESSMENT OF POTENTIAL FOR ON-ORBIT COLLISIONS

REQUIREMENT 4.5-1: LIMITING DEBRIS GENERATED BY COLLISIONS WITH LARGE OBJECTS.

The DOGE-1 Mission Team (DMT) will use all design and operational strategies available to minimize the potential for in-orbit collision with crewed spacecraft and all other objects. DMT will be proactive in ensuring that any risks to inhabitable orbiting objects posed by a DOGE-1 satellite are mitigated. This will include coordinating with NASA to ensure protection of the International Space Station on an ongoing basis, and coordinating with the China National Space Agency with respect to Tiangong-2 and successor vehicles should circumstances evolve where such coordination is required. DMT will provide all relevant agencies with any information they need to assess risks and ensure safe flight profiles, as well as contact information for DMT personnel on a 24 hours per-day/7 days per-week basis. Through these measures, it is anticipated that the DMT will be able to avoid any collisions which could possibly result from unanticipated events (e.g., non-nominal deployment, extended life, off nominal propulsion performance resulting in unintended trajectory modifications).

Assuming a nominal launch and deployment, and the total failure/malfunction of the propulsion system there is a non-zero probability that the DOGE-1 spacecraft will not achieve a stable elliptical lunar orbit as intended. Indeed, even with a fully functional propulsion system the ability to achieve a stable elliptical lunar orbit as intended is not assured. The worst-case scenario is that a total failure of the propulsion system occurs. In the event that this occurs DOGE-1 in order of probability will either impact the Moon, achieve a hyperbolic flyby of the Moon, or enter into a free return trajectory to the Earth resulting in a highly elliptical Earth Orbit that resolves to a either an atmospheric reentry, a hyperbolic flyby of the Earth, or achieving a free return trajectory to the Moon. It is anticipated and will be proved out by analysis that the likelihood of the necessary sequence of events occurring that would result in a stable cycler orbit based on free return trajectories is vanishingly small. In the event that the propulsion system does not totally fail it will just be a matter of time for the spacecraft to impact either the Moon, reenter the Earth's atmosphere (burning up on reentry), or using the gravity assist obtaining achieving sufficient delta-V to proceed outbound into deep space. No proximity operations are planned. The trajectory possibilities are illustrated in Figure 2-7 – DOGE-1 Potential Trajectory Events.

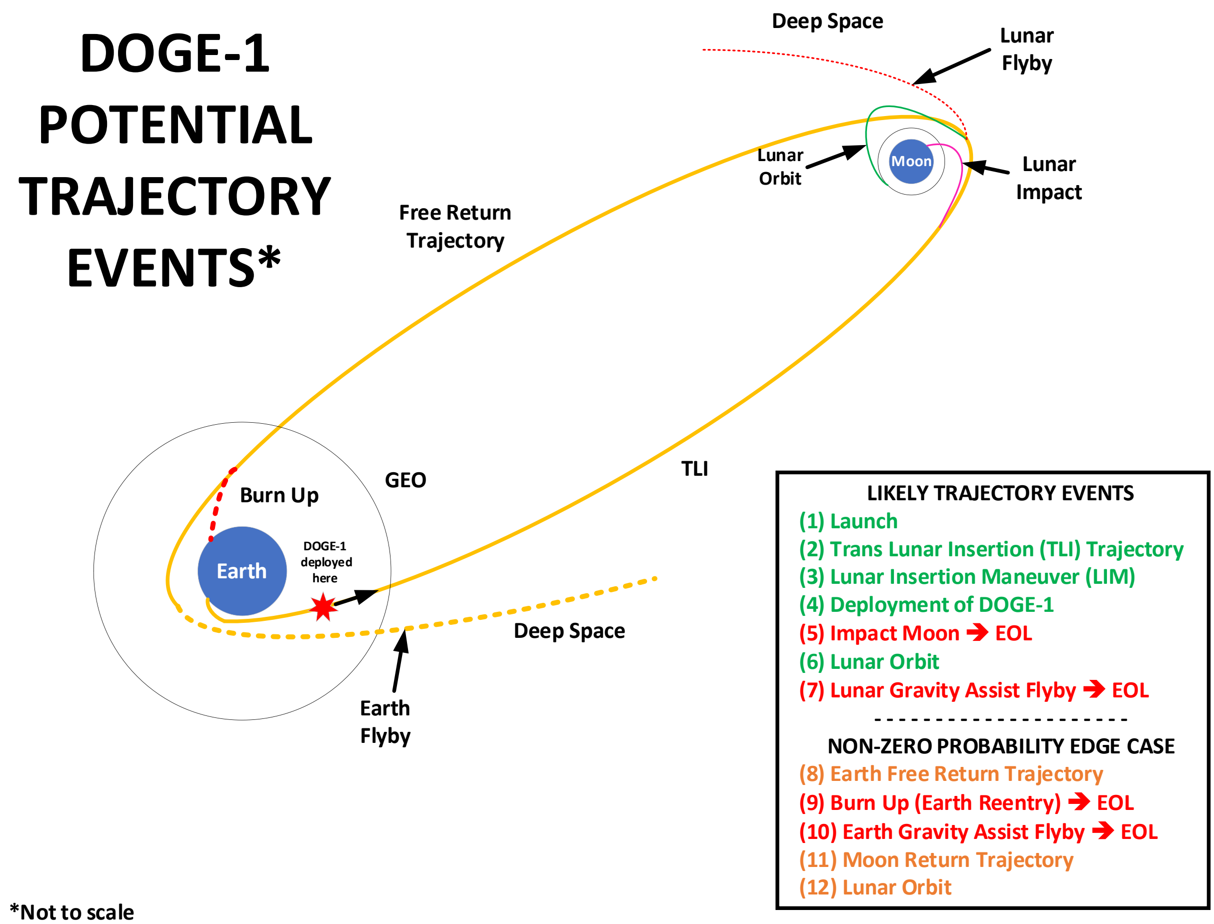

Figure 2-7 – DOGE-1 Potential Trajectory Events.

DMT does not anticipate having to conduct any collision avoidance procedures. However, analysis will be performed including conjunction assessment, execution of avoidance maneuvers, and trajectory planning for any significant planned alterations of satellite trajectory, and notification to other potentially affected operators of any planned alteration of a satellite's trajectory for all phases of operations. DMT certifies that upon receipt of a space situational awareness conjunction warning, it will review and take all possible steps to assess the collision risk and will mitigate the collision risk if necessary. As appropriate, steps to assess and mitigate the collision risk may include, but are not limited to: contacting the operator of any active spacecraft involved in such a warning; sharing ephemeris data and other appropriate operational information with any such operator; and modifying space station attitude and/or operations.

The DOGE-1 satellite has propulsive capabilities (two electrical propulsion systems), and given sufficient time can perform necessary collision avoidance maneuvers. In addition, it can accomplish a limited course change by either altering the orientation, and thus the drag profile, of the DOGE-1 satellite (when proximate to the Earth) or the make-up propulsion requirements by ground tracking over mass concentrations (when proximate to the Moon) to modify the orbit.

Prior to deployment, the DOGE-1 satellite will be registered with the 18th Space Control Squadron (or a successor entity). Following deployment, DOGE-1 will be identified and actively tracked using its authorized ground station network. DOGE-1will have a unique telemetry marker allowing it to be distinguished from other satellites or space objects.[3] DOGE-1 will routinely perform precise orbit determination and orbit prediction and will share that information to the 18th Space Control Squadron (or a successor entity) and other satellite operators to aid collision avoidance response, including conjunction assessment and maneuver planning. DMT plans to share information regarding initial deployment, ephemeris, and significant planned maneuvers with the 18th Space Control Squadron (or a successor entity) and other entities that engage in space situational awareness or space traffic management functions.

DMT will participate as needed in a sharing agreement with the Combined Space Operations Center ("CSpOC") to better coordinate collision avoidance measures and receive conjunction threat reports. DMT receives updated two-line element sets from CSpOC, which facilitate the identification and tracking of the DMT satellite. CSpOC will be able to contact the DMT satellite operations team, accessible 24 hours per day/seven days per week, to ensure that DMT can take immediate action to coordinate collision avoidance measures.

Result for Requirement 4.5-1: 0.0000093; COMPLIANT.

REQUIREMENT 4.5-2. LIMITING DEBRIS GENERATED BY COLLISIONS WITH SMALL OBJECTS.

The spacecraft will be disposed of via controlled lunar impact and does not require a specific orientation and drag state to meet the disposal requirements. The operational orbit will be chosen to allow for safe disposal even in the event of total spacecraft failure. Therefore, no element or component is required to complete post-mission operations.

Result for Requirement 4.5-2: Not applicable.

6. ASSESSMENT OF SPACECRAFT POST-MISSION DISPOSAL PLANS AND PROCEDURES

Description of spacecraft disposal option selected: Assuming that the intended stable elliptical lunar orbit is achieved the satellite and the propulsion system is not used to make up altitude lost the space spacecraft will de-orbit naturally due gravitational variations (lunar mass concentrations) perturbing its orbit. The use of the on-board propulsion system provides an additional measure of control allowing for near deterministic choice of the time and location of end-of-life impact.

Plan for any spacecraft maneuvers required to accomplish post-mission disposal: None.

Calculation of area-to-mass ratio after post-mission disposal[3]:

- Mass: 13.8 kg
- Cross-sectional Area: 0.17 m^2
- Area-to-mass Ratio: 0.0123 m^2/kg

Deployable Dimensions (mm) Width x Height is parallel to separation plane	Width	W	240.40	mm
	Height (in Zpl)	H	224.90	mm
	Length (along deploy axis)	L	366.00	mm
Side 1 Area (W X L)	87986.4	mm^2		
Side 2 Area (H X L)	82313.4	mm^2		
Cross-sectional Area	170299.8	mm^2		
Cross-sectional Area	0.17	m^2		
Nominal Mass	13.8	kg		
Area to Mass Ratio	0.0123	m^2/kg		

Table 2-3 Calculation of Area-to-Mass Ratio

REQUIREMENT 4.6-1: DISPOSAL FOR SPACE STRUCTURES IN OR PASSING THROUGH LEO.

Result for Requirement 4.6-1: Analysis is not applicable.

REQUIREMENT 4.6-2. DISPOSAL FOR SPACE STRUCTURES NEAR GEO.

Result for Requirement 4.6-2: Analysis is not applicable.

REQUIREMENT 4.6-3. DISPOSAL FOR SPACE STRUCTURES BETWEEN LEO AND GEO.

Result for Requirement 4.6-3: Analysis is not applicable.

[3] The DOGE-1 satellite is larger than 10 cm in their smallest dimension, and are therefore presumed trackable pursuant to the Commission's rules.

REQUIREMENT 4.6-4. RELIABILITY OF POST-MISSION DISPOSAL OPERATIONS.

The above analysis has been performed with an average area-to-mass ratio, which means that even in the case of massive power or ADCS failure, a tumbling spacecraft, the spacecraft will deorbit within the allowable timeframe under the Commission's Part 25 Streamlined Rules as well as Part 5 Rules as applicable.

Result for Requirement 4.6-4: COMPLIANT.

7. ASSESSMENT OF RE-ENTRY HAZARDS

REQUIREMENT 4.7-1(A): LIMIT THE RISK OF HUMAN CASUALTY.

The risk of human casualty is zero for the DOGE-1 spacecraft operating properly and achieving some form of stable lunar orbit during the anticipated lifecycle of the spacecraft.

In the event of any combination of failures up to and including a total loss of the spacecraft before or after achieving some form of stable lunar orbit since no humans are anticipated to be living or operating on the Moon or even in the vicinity of the Moon during the lifecycle of the DOGE-1 spacecraft the risk of human casualty is effectively 0.

In the event that some combination of failures results in spacecraft not achieving some form of stable lunar orbit and instead ends up on a hyperbolic trajectory to deep space the risk of human casualty is effectively 0 since no human will be there within the lifecycle of the spacecraft.

In the event that some combination of failures results in spacecraft not achieving some form of stable lunar orbit and it does achieve a free return trajectory to Earth, the trajectory will be well characterized allowing for collision avoidance, and an atmospheric reentry occurs the spacecraft will burn up totally so the risk of human casualty is effectively 0.

In the event that some combination of failures results in spacecraft not achieving some form of stable lunar orbit and it does achieve a free return trajectory to Earth, the trajectory will be well characterized allowing for collision avoidance, and atmospheric reentry does not occur, instead it ends up on a hyperbolic fly-by trajectory to deep space the risk of human casualty is effectively 0 since no human will be there within the lifecycle of the spacecraft.

In the event that some combination of failures results in spacecraft not achieving some form of stable lunar orbit and it does achieve a free return trajectory to Earth, the trajectory will be well characterized allowing for collision avoidance, atmospheric reentry does not occur, a hyperbolic fly-by trajectory does not occur, instead it ends up on a free return trajectory to the Moon the risk of human casualty is effectively 0 since no human will be there within the lifecycle of the spacecraft.

Result for Requirement 4.7-1(a): COMPLIANT.

8. COLLISION RISK POSED BY TETHER SYSTEMS

REQUIREMENT 4.8-1: MITIGATE THE COLLISION HAZARDS OF SPACE TETHERS.

No tethers are to be used in the DOGE-1 mission and no tethers are known to be scheduled for deployment during the lifecycle of the mission.

Result for Requirement 4.8-1: COMPLIANT.