DOGE-1

Lunar Rideshare Mission

Orbital Debris Analysis Report Addendum

Special Trajectory Case A

Non-zero probability that due to some combination of mission events the DOGE-1 spacecraft ends up on a Free Return Trajectory from the Moon back to the Earth

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Under contract to Geometric Energy Corporation

NS 8719.14 – Process for Limiting Orbital Debris

- DAS Start Year 2023.9
- DAS analysis can not accept an apogee greater than 100,000 km
- DAS OREM analysis can not accept an apogee greater than 40,000 km
- Deployment altitude of DOGE-1 is approximately 35,500 km
- DOGE-1 trajectory follows IM-1 Trans Lunar Injection post SpaceX lunar insertion maneuver designed to impart additional delta-V
- Effective trajectory approximation perigee = 400.4 km, apogee = 420,000 km, inclination 28.5 degrees, symmetrical ellipse
- The location of DOGE-1 deployment is assumed to exist on the trajectory symmetrical ellipse.
- Accordingly, if a free return trajectory from the Moon to Earth is achieved then to a first approximation it will be on the trajectory symmetrical ellipse.

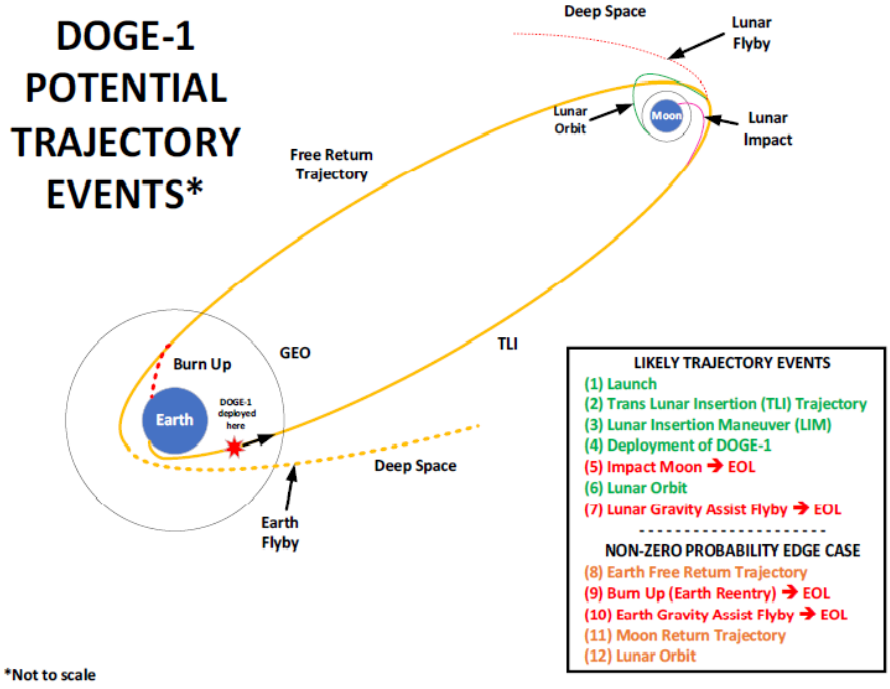


Figure 2-7 – DOGE-1 Potential Trajectory Events.

(Requirement 4.3-1) – Mission-Related Debris Passing Through LEO

- Limit number and orbital lifetime of debris passing through LEO
  - DAS Results: Compliant

(Requirement 4.3-2) – Mission-Related Debris Passing Near GEO

- Limit lifetime of objects passing near GEO
  - DAS Results: Compliant

(Requirements 4.4-1, 4.4-2, 4.4-3, and 4-4-4) Accidental Explosions and Intentional Breakups

This requirement is not unique to this Special Case Trajectory A. See general write up in ODAR.

(Requirement 4.5.1) – Probability of Collision with Large Objects

> *Requirement 4.5-1. Limiting debris generated by collisions with large objects when in Earth orbit: For each spacecraft and launch vehicle orbital stage, the program or project shall demonstrate that, during the orbital lifetime of each spacecraft and orbital stage, the probability of accidental collision with space objects larger than 10 cm in diameter is less than 0.001. For the purpose of this assessment, 100 years is used as the maximum orbital lifetime for the storage disposal option.*

- DAS Results: Compliant

(Requirement 4.5-2) – Probability of Damage from Small Objects

> *Requirement 4.5-2. Limiting debris generated by collisions with small objects when operating in Earth orbit: For each spacecraft, the program or project shall demonstrate that, during the mission of the spacecraft, the probability of accidental collision with orbital debris and meteoroids sufficient to prevent compliance with the applicable postmission disposal maneuver requirements is less than 0.01.*

- DAS Results: Compliant

(Requirement 4.6-1) – Post Mission Disposal

- Natural reentry
  - DAS 3.2.3 software cannot model orbital trajectories with an apogee over 100,000 km,
  - nominal DOGE-1 trajectory is based on a Trans Lunar Injection (TLI) deployment after a lunar insertion maneuver additional delta-V
  - Perigee Altitude = 400.4 km, Apogee = 420,000 km
  - Altitude at deployment approximately 35,500 km
  - Simplifying assumptions used:

        - initial trajectory is an ellipse which is symmetrical regardless of apogee
        - accordingly given sufficient time a Cislunar free return trajectory with no other intervening factors will return the spacecraft to it's point of deployment which has a perigee Altitude = 400.4 km
    - Detailed STK Astrogator trajectory model will be used to verify the viability of this solution.
- Direct reentry <remaining fuel may be sufficient to ensure the modelled perigee altitude for direct reentry of 268.89 km can be achieved allowing for reentry in less than 25 years>
- Direct retrieval <Not planned>

- DAS Results: Compliant

(Requirement 4.6-2) – Post Mission Disposal

- Storage <Not planned>
- Earth Escape <Alternative to baselined requirement 4.6-1 solution, viability subject to confirmation by detailed STK Astrogator trajectory analysis>

- DAS Results: Compliant

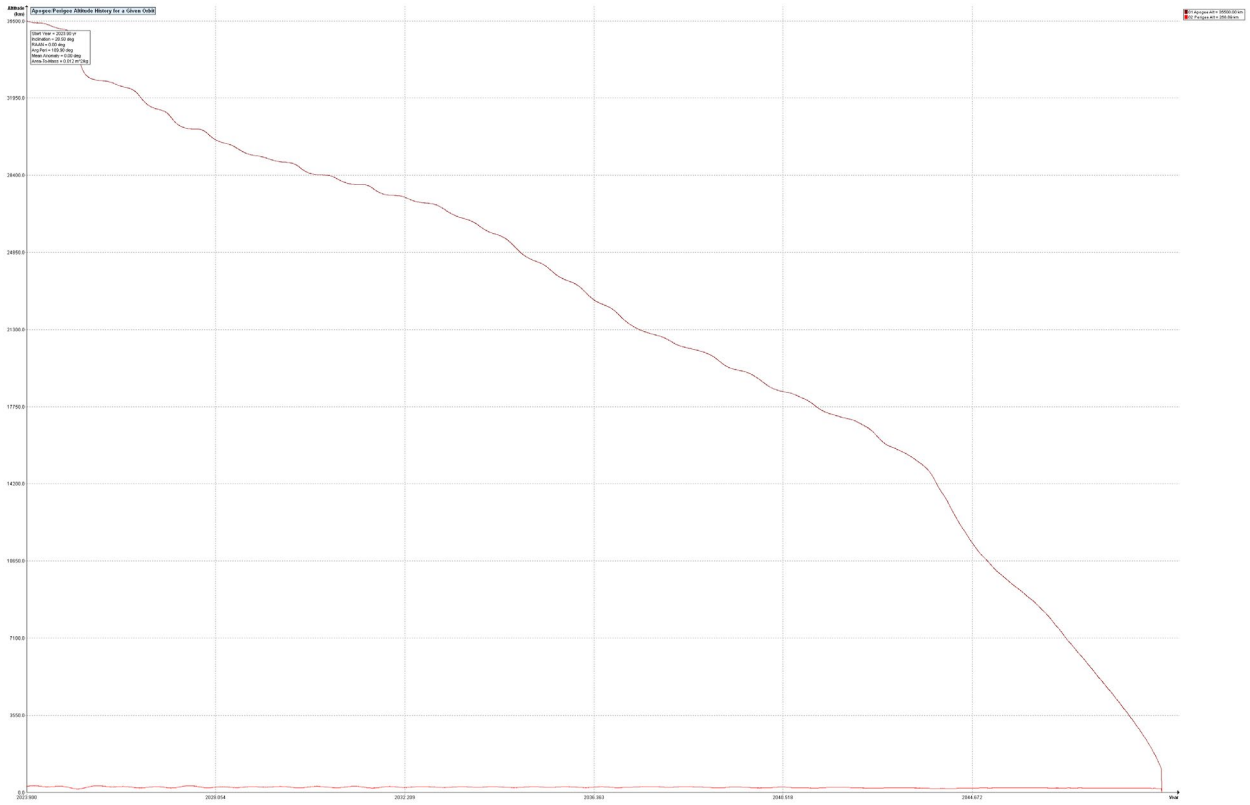
(Requirement 4.6-3) – Post Mission Disposal

- Long-term reentry for structures in MEO, Tundra orbits, highly inclined GEO, and other orbits.
- DAS Results: Compliant

(Requirement 4.6-4) – Reliability of Post Mission Disposal Systems

- The DOGE-1 detailed STK Astrogator trajectory analysis will use an optimization goal of achieving a compliant post mission disposal (1st fully demising reentry, 2nd Earth escape trajectory, 3rd relocation to a storage orbit) regardless of the availability of the two
- Enpulsion propulsion systems that are integrated into the spacecraft.

- DAS Results: DAS does not assess this requirement



(Requirement 4.7-1) – Casualty Risk from Reentry Debris

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 be less than 0.0001 (1:10,000).

- DAS Results: Compliant, 1:53800

b. For controlled reentry, the selected trajectory shall ensure that no surviving debris impact with a kinetic energy greater than 15 joules is closer than 370 km from foreign landmasses, or is within 50 km from the continental U.S., territories of the U.S., and the permanent ice pack of Antarctica.

- DAS Results: Compliant, All mass elements demise

c. For controlled reentry, the product of the probability of failure to execute the reentry burn and the risk of human casualty assuming uncontrolled reentry shall be less than 0.0001 (1:10,000).

- DAS Results: Not Applicable, the reentry is not controlled. The reentry will either be natural or due to successfully executing course corrections. Alternatively, the course corrections may be used to attempt a gravity assist flyby.

d. *For long-term reentry of space structures in MEO, Tundra orbits, highly inclined GEO, and other orbits: Surviving debris shall have less than 7 m2 total debris casualty area or 0.0001 (1 in 10,000) risk of human casualty.*

- DAS Results: Not Applicable

DAS 3.2.3 ANALYSIS LOG FOR SPECIAL TRAJECTORY CASE A

```
04 22 2023; 21:49:51PM Opened Project
C:\Users\GaryBarnhard\AppData\Local\NASA\DAS3.2.3\DOGE-1A\
04 22 2023; 21:52:09PM Processing Requirement 4.3-1:     Return Status :
Not Run

=====================
No Project Data Available
=====================

=============== End of Requirement 4.3-1 ===============
04 22 2023; 21:52:14PM Processing Requirement 4.3-2: Return Status :
Passed

=====================
No Project Data Available
=====================

=============== End of Requirement 4.3-2 ===============
04 23 2023; 00:18:31AM Processing Requirement 4.5-1:     Return Status :
Passed

==============
Run Data
==============

**INPUT**

      Space Structure Name = DOGE-1 Spacecraft
      Space Structure Type = Payload
      Perigee Altitude = 400.400 (km)
      Apogee Altitude = 35500.000 (km)
      Inclination = 28.500 (deg)
      RAAN = 0.000 (deg)
      Argument of Perigee = 189.900 (deg)
      Mean Anomaly = 0.000 (deg)
      Final Area-To-Mass Ratio = 0.0123 (m^2/kg)
      Start Year = 2023.900 (yr)
      Initial Mass = 13.800 (kg)
      Final Mass = 13.800 (kg)
      Duration = 2.000 (yr)
      Station-Kept = False
      PMD Perigee Altitude = 268.890 (km)
      PMD Apogee Altitude = 35500.000 (km)
      PMD Inclination = 28.500 (deg)
      PMD RAAN = 0.000 (deg)
      PMD Argument of Perigee = 0.000 (deg)
      PMD Mean Anomaly = 0.000 (deg)
      Long-Term Reentry = False

**OUTPUT**
```

```
      Collision Probability = 2.2695E-07
      Returned Message: Normal Processing
      Date Range Message: Normal Date Range
      Status = Pass

==============

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

04 23 2023; 00:18:35AM Project Data Saved To File
04 23 2023; 00:18:39AM Requirement 4.5-2:  Compliant

=============== End of Requirement 4.5-2 ===============

04 23 2023; 00:18:42AM Processing Requirement 4.6   Return Status :
Passed

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

**INPUT**

      Space Structure Name = DOGE-1 Spacecraft
      Space Structure Type = Payload

      Perigee Altitude = 400.400000 (km)
      Apogee Altitude = 35500.000000 (km)
      Inclination = 28.500000 (deg)
      RAAN = 0.000000 (deg)
      Argument of Perigee = 189.900000 (deg)
      Mean Anomaly = 0.000000 (deg)
      Area-To-Mass Ratio = 0.012300 (m^2/kg)
      Start Year = 2023.900000 (yr)
      Initial Mass = 13.800000 (kg)
      Final Mass = 13.800000 (kg)
      Duration = 2.000000 (yr)
      Station Kept = False
      Abandoned = False
      Long-Term Reentry = False

**OUTPUT**

      Suggested Perigee Altitude = 268.890000 (km)
      Suggested Apogee Altitude = 35500.000000 (km)
      Returned Error Message = Passes LEO reentry orbit criteria.

      Released Year = 2038 (yr)
      Requirement = 61
      Compliance Status = Pass

==============
```

```
=============== End of Requirement 4.6 ===============
04 23 2023; 00:58:09AM *********Processing Requirement 4.7-1
      Return Status :  Passed

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

name = DOGE-1 Spacecraft
quantity = 1
parent = 0
materialID = 9
type = Box
Aero Mass = 13.800000
Thermal Mass = 13.800000
Diameter/Width = 0.238000
Length = 0.365000
Height = 0.223400

name = Structure / Chassis
quantity = 1
parent = 1
materialID = 9
type = Box
Aero Mass = 10.420400
Thermal Mass = 4.132900
Diameter/Width = 0.238000
Length = 0.365000
Height = 0.223400

name = Battery (Fixture)
quantity = 3
parent = 2
materialID = 5
type = Flat Plate
Aero Mass = 0.156000
Thermal Mass = 0.156000
Diameter/Width = 0.075000
Length = 0.090000

name = StarTracker Housing
quantity = 2
parent = 2
materialID = 9
type = Box
Aero Mass = 0.176000
Thermal Mass = 0.176000
Diameter/Width = 0.055000
Length = 0.065000
Height = 0.035000

name = Magnetorquers
quantity = 1
```

```
parent = 2
materialID = 19
type = Box
Aero Mass = 0.156000
Thermal Mass = 0.156000
Diameter/Width = 0.090500
Length = 0.096900
Height = 0.017200

name = Enpulsion Thruster Housings
quantity = 2
parent = 2
materialID = 5
type = Box
Aero Mass = 0.580000
Thermal Mass = 0.580000
Diameter/Width = 0.100000
Length = 0.100000
Height = 0.100000

name = EnpulsionTank/Emitters
quantity = 2
parent = 2
materialID = 67
type = Cylinder
Aero Mass = 0.580000
Thermal Mass = 0.580000
Diameter/Width = 0.053800
Length = 0.072000

name = Thruster PPU Board
quantity = 3
parent = 2
materialID = 5
type = Flat Plate
Aero Mass = 0.114000
Thermal Mass = 0.114000
Diameter/Width = 0.041400
Length = 0.133800

name = Cubestar Star Tracker Housing
quantity = 1
parent = 2
materialID = 5
type = Cylinder
Aero Mass = 0.005500
Thermal Mass = 0.005500
Diameter/Width = 0.021000
Length = 0.037800

name = Startracker Enclosure
quantity = 1
parent = 2
```

```
materialID = 5
type = Box
Aero Mass = 0.119000
Thermal Mass = 0.119000
Diameter/Width = 0.059000
Length = 0.059000
Height = 0.047000

name = X-Band Radio
quantity = 1
parent = 2
materialID = 5
type = Box
Aero Mass = 0.275000
Thermal Mass = 0.275000
Diameter/Width = 0.090100
Length = 0.095900
Height = 0.022500

name = ADCS OBC
quantity = 1
parent = 2
materialID = 19
type = Box
Aero Mass = 0.075000
Thermal Mass = 0.075000
Diameter/Width = 0.040000
Length = 0.065000
Height = 0.007100

name = S-Band Radio
quantity = 1
parent = 2
materialID = 19
type = Box
Aero Mass = 0.088000
Thermal Mass = 0.088000
Diameter/Width = 0.040000
Length = 0.065000
Height = 0.007100

name = Deployment Switch
quantity = 1
parent = 2
materialID = 54
type = Box
Aero Mass = 0.012000
Thermal Mass = 0.012000
Diameter/Width = 0.014800
Length = 0.020000
Height = 0.006400

name = On Board Computer (OBC)
```

```
quantity = 1
parent = 2
materialID = 19
type = Box
Aero Mass = 0.075000
Thermal Mass = 0.075000
Diameter/Width = 0.040000
Length = 0.065000
Height = 0.007100

name = Demised Elements
quantity = 1
parent = 2
materialID = 50
type = Flat Plate
Aero Mass = 2.000000
Thermal Mass = 2.000000
Diameter/Width = 0.500000
Length = 0.500000

name = Sun Sensors
quantity = 6
parent = 1
materialID = 5
type = Box
Aero Mass = 0.001000
Thermal Mass = 0.001000
Diameter/Width = 0.005500
Length = 0.022000
Height = 0.003000

name = S-Band Antenna
quantity = 2
parent = 1
materialID = 5
type = Box
Aero Mass = 0.186000
Thermal Mass = 0.186000
Diameter/Width = 0.100000
Length = 0.100000
Height = 0.012000

name = GPS Antenna
quantity = 1
parent = 1
materialID = 5
type = Cylinder
Aero Mass = 0.010000
Thermal Mass = 0.010000
Diameter/Width = 0.072500
Length = 0.035000

name = Solar Cells
```

```
quantity = 48
parent = 1
materialID = 25
type = Flat Plate
Aero Mass = 0.048000
Thermal Mass = 0.048000
Diameter/Width = 0.040000
Length = 0.069000

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

name = DOGE-1 Spacecraft
Demise Altitude = 77.996157
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Structure / Chassis
Demise Altitude = 73.922316
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Battery (Fixture)
Demise Altitude = 70.963722
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = StarTracker Housing
Demise Altitude = 71.280451
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Magnetorquers
Demise Altitude = 72.461052
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Enpulsion Thruster Housings
Demise Altitude = 70.429531
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = EnpulsionTank/Emitters
Demise Altitude = 0.000000
Debris Casualty Area = 0.735772
Impact Kinetic Energy = 836.731802
```

```
************************************
name = Thruster PPU Board
Demise Altitude = 71.605042
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Cubestar Star Tracker Housing
Demise Altitude = 73.518696
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Startracker Enclosure
Demise Altitude = 72.076536
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = X-Band Radio
Demise Altitude = 70.626993
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = ADCS OBC
Demise Altitude = 72.298833
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = S-Band Radio
Demise Altitude = 72.027782
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Deployment Switch
Demise Altitude = 71.482928
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = On Board Computer (OBC)
Demise Altitude = 72.298833
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Demised Elements
Demise Altitude = 72.437158
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000
```

```
************************************
name = Sun Sensors
Demise Altitude = 77.607732
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = S-Band Antenna
Demise Altitude = 75.568924
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = GPS Antenna
Demise Altitude = 77.733204
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

************************************
name = Solar Cells
Demise Altitude = 76.399289
Debris Casualty Area = 0.000000
Impact Kinetic Energy = 0.000000

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

=============== End of Requirement 4.7-1 ===============
04 23 2023; 00:58:09AM Project Data Saved To File
04 23 2023; 01:42:45AM Project Data Saved To File
```

DOGE-1 ODAR NAS Workbook March 2023 V1-1
DOGE-1 Exobotics Raw List

DOGE-1 Estimated Mass (g) **11441.5**

Vehicle	Item Number	Name	Quantity	Material	Shape	Total Mass (g)	Diameter / Width (mm)	Length (mm)	Height (mm)	High Temperature?	Melting Temperature (C)	Survivability
DOGE-1	1	Structure / Chassis	1	AL 7075-T651	Box	4132.9	238	365	223.4	No	-	
	2	Solar Panel Substrate 1U	8	High TG FR4 + Kapton Polyimide Coverlay	Flat Plate	224	83	98	1.2	No	-	
	3	Solar Panel Substrate 2U	8	High TG FR4 + Kapton Polyimide Coverlay	Flat Plate	448	83	211	1.2	No	-	
	4	Solar Cells	48	Germanium Wafer	Flat Plate	48	69	40	0.2	No	-	
	5	Battery (Cells)	24	Lithium Ion	Cylinder	1344	18	-	63	No	-	
	6	Battery (Fixture)	3	Aluminium Alloy	Plate	156	40	90	15	No	-	
	7	EPS	1	PCB	Sheet	100	89.3	92.9	15.3	No	-	
	8	OBC	1	PCB/Aluminium	Box	75	40	65	7.1	No	-	
	9	ADCS OBC	1	PCB/Aluminium	Box	88	40	65	7.1	No	-	
	10	S-Band Radio	1	PCB/Aluminium	Box	32	43	75	9	No	-	
	11	Payload Interface Board	1	PCB	Sheet	51	88.77	91.7	8.6	No	-	
	12	Sun Sensors	6	PCB/Aluminium	Box	11	22	5.5	3	No	-	
	13	Startracker Housing	2	AL 7075-T651	Box	176	55	65	35	No	-	
	14	Startracker PCB	2	High TG FR4 + Kapton Polyimide Coverlay	Flat Plate	174	50	131	1.6	No	-	
	15	Startracker Optics	2	N-F2 and N-BK7	Cylinder	2	8	-	6	No	-	
	16	Magnetorquers	1	Polymer / Copper / Rods	Box	156	90.5	96.9	17.2	No	-	
	17	Reaction Wheel Assembly	4	PCB/Aluminium/Stainless Steel	Box	940	95	95	62	No	-	
	18	S-Band Antenna	2	PCB/Aluminium	Box	186	100	100	12	No	-	
	19	Deployment Switch	2	300 Series Stainless Steel	Box	12	6.4	20	14.8	No	-	
	20	Harnessing	1	Copper and PTFE	Wire	150	-	-	-	No	-	
	21	Internal Camera Housing	2	AL 7075-T651	Box	176	93	89	55	No	-	
	22	Internal Camera PCB	2	High TG FR4 + Kapton Polyimide Coverlay	Flat Plate	174	50	131	1.6	No	-	
	23	Internal Camera Optics	2	N-F2 and N-BK7	Cylinder	2	8	-	6	No	-	
	24	Internal Display	1	AMOLED Display	Flat Plate	5	62	52	0.2	No	-	
	25	Internal Display PCB	1	High TG FR4 + Kapton Polyimide Coverlay	Flat Plate	71.5	100	100	1.6	No	-	
	26	Standoffs	133	AL 7075-T651	Cylindrical	159.6	5.5	-	13.5	No	-	
	27	PCB Conformal Coatings	2	CV-1152P Controlled Voltaility RTV	Flat Plate	20	100	100	1	No	-	
	28	Enpulsion Thruster Housings	2	Aluminium Alloy	Box	580.0	100	100	100	No	-	
	29	Enpulsion Fuel	2	Indium	Cylindrical	465.6	100	100	66.8	No	-	
	30	Enpulsion Tank/Emitters	2	Tungsten, Tantalum, Indium, Stainless Steel	Cylindrical	580.0	72	-	53.8	Yes	-	
	31	Enpulsion PCB	2	FR-4	Flat Plate	50	94	90	1.6	No		
	32	Thruster PPU Boards	3	Aluminium PCB	Flat Plate	114	133.8	41.4	3.2	No	-	
	33	CubeStar Startracker PCBs	3	FR-4	Flat Plate	30.3	50	35	1.6	No	-	
	34	CubeStar Startracker Optics	1	TBD	Cylinder	19.6	16	-	13	No	-	
	35	CubeStar Startracker Housir	1	Aluminium Alloy	Tube	5.5	21	-	37.8	No	-	
	36	Startracker Enclosure	1	Aluminium Alloy	Box	119	59	59	47	No	-	
	37	Fasteners	352	316 Stainless Steel	Cylindrical	263.5	M1.6 - M3	-	4 - 16	No	-	
						11341.5						

DOGE-1 Estimated Mass (g)	11441.5
DOGE-1 Scheduled Mass (g)	11341.5
DOGE-1 Unscheduled Mass (g)	100
Mass Delta	0

DOGE-1 ODAR NAS Workbook March 2023 V1-1
DOGE-1 Cull for demise < 1000 C

DOGE-1 Estimated Mass (g) 11441.5

Vehicle	Item Number	Name	Quantity	Material	Material (Adjusted)	Shape	Total Mass (g)	Diameter / Width (mm)	Length (mm)	Height (mm)	High Temperature?	Melting Temperature (C)	Survivability
DOGE-1	1	Structure / Chassis	1	AL 7075-T651	AL 7075-T651	Box	4132.9	238	365	223.4	No	-	Analyze
DOGE-1	2	Solar Panel Substrate 1U	8	High TG FR4 + Kapton Polyimide Coverlay	High TG FR4 + Kapton Polyimide Coverlay	Flat Plate	224	83	98	1.2	No	Demise @ < 1000 °C	No
DOGE-1	3	Solar Panel Substrate 2U	8	High TG FR4 + Kapton Polyimide Coverlay	High TG FR4 + Kapton Polyimide Coverlay	Flat Plate	448	83	211	1.2	No	Demise @ < 1000 °C	No
DOGE-1	4	Solar Cells	48	Germanium Wafer	Germanium Wafer	Flat Plate	48	69	40	0.2	No	-	Analyze
DOGE-1	5	Battery (Cells)	24	Lithium Ion	Lithium Ion	Cylinder	1344	18	63	-	No	Demise @ < 1000 °C	No
DOGE-1	6	Battery (Fixture)	3	Aluminium Alloy	Aluminium Alloy	Plate	156	40	90	15	No	-	Analyze
DOGE-1	7	EPS	1	PCB	PCB	Sheet	100	89.3	92.9	15.3	No	Demise @ < 1000 °C	No
DOGE-1	8	OBC	1	PCB/Aluminium	PCB/Aluminium	Box	75	40	65	7.1	No	-	Analyze
DOGE-1	9	ADCS OBC	1	PCB/Aluminium	PCB/Aluminium	Box	88	40	65	7.1	No	-	Analyze
DOGE-1	10	S-Band Radio	1	PCB/Aluminium	PCB/Aluminium	Box	32	43	75	9	No	-	Analyze
DOGE-1	11	Payload Interface Board	1	PCB	PCB	Sheet	51	88.77	91.7	8.6	No	Demise @ < 1000 °C	No
DOGE-1	12	Sun Sensors	6	PCB/Aluminium	PCB/Aluminium	Box	11	22	5.5	3	No	-	Analyze
DOGE-1	13	Startracker Housing	2	AL 7075-T651	AL 7075-T651	Box	176	55	65	35	No	-	Analyze
DOGE-1	14	Startracker PCB	2	High TG FR4 + Kapton Polyimide Coverlay	High TG FR4 + Kapton Polyimide Coverlay	Flat Plate	174	50	131	1.6	No	Demise @ < 1000 °C	No
DOGE-1	15	Startracker Optics	2	N-F2 and N-BK7	N-F2 and N-BK7	Cylinder	2	8	6	-	No	Demise @ < 1000 °C	No
DOGE-1	16	Magnetorquers	1	Polymer / Copper / Rods	Polymer / Copper / Rods	Box	156	90.5	96.9	17.2	No	-	Analyze
DOGE-1	17	Reaction Wheel Assembly	4	PCB/Aluminium/Stainless Steel	PCB/Aluminium/Stainless Steel	Box	940	95	95	62	No	-	Analyze
DOGE-1	18	S-Band Antenna	2	PCB/Aluminium	PCB/Aluminium	Box	186	100	100	12	No		
DOGE-1	19	Deployment Switch	2	300 Series Stainless Steel	300 Series Stainless Steel	Box	12	6.4	20	14.8	No		
DOGE-1	20	Harnessing	1	Copper and PTFE	Copper and PTFE	Wire	150	-	-	-	No	Demise @ < 1000 °C	No
DOGE-1	21	Internal Camera Housing	2	AL 7075-T651	AL 7075-T651	Box	176	93	89	55	No	-	Analyze
DOGE-1	22	Internal Camera PCB	2	High TG FR4 + Kapton Polyimide Coverlay	High TG FR4 + Kapton Polyimide Coverlay	Flat Plate	174	50	131	1.6	No	Demise @ < 1000 °C	No
DOGE-1	23	Internal Camera Optics	2	N-F2 and N-BK7	N-F2 and N-BK7	Cylinder	2	8	6	-	No	Demise @ < 1000 °C	No
DOGE-1	24	Internal Display	1	AMOLED Display	AMOLED Display	Flat Plate	5	62	52	0.2	No	Demise @ < 1000 °C	No
DOGE-1	25	Internal Display PCB	1	High TG FR4 + Kapton Polyimide Coverlay	High TG FR4 + Kapton Polyimide Coverlay	Flat Plate	71.5	100	100	1.6	No	Demise @ < 1000 °C	No
DOGE-1	26	Standoffs	133	AL 7075-T651	AL 7075-T651	Cylindrical	159.6	5.5	13.5	-	No	Demise @ < 1000 °C	No
DOGE-1	27	PCB Conformal Coatings	2	CV-1152P Controlled Voltaility RTV	CV-1152P Controlled Voltaility RTV	Flat Plate	20	100	100	1	No	Demise @ < 1000 °C	No
DOGE-1	28	Enpulsion Thruster Housings	2	Aluminium Alloy	Aluminium Alloy	Box	580.0	100	100	100	No	-	Analyze
DOGE-1	29	Enpulsion Fuel	2	Indium	Indium	Cylindrical	465.6	100	100	66.8	No	Demise @ < 1000 °C	No
DOGE-1	30	Enpulsion Tank/Emitters	2	Tungsten, Tantalum, Indium, Stainless Steel	Tungsten, Tantalum, Indium, Stainless Steel	Cylindrical	580.0	72	53.8	-	Yes	Demise @ < 1000 °C	No
DOGE-1	31	Enpulsion PCB	2	FR-4	FR-4	Flat Plate	50	94	90	1.6	No	Demise @ < 1000 °C	No
DOGE-1	32	Thruster PPU Boards	3	Aluminium PCB	Aluminium PCB	Flat Plate	114	133.8	41.4	3.2	No		Analyze
DOGE-1	33	CubeStar Startracker PCBs	3	FR-4	FR-4	Flat Plate	30.3	50	35	1.6	No	Demise @ < 1000 °C	No
DOGE-1	34	CubeStar Startracker Optics	1	TBD	N-F2 and N-BK7	Cylinder	19.6	16	13	-	No	Demise @ < 1000 °C	No
DOGE-1	35	CubeStar Startracker Housir	1	Aluminium Alloy	Aluminium Alloy	Tube	5.5	21	37.8	-	No	-	Analyze
DOGE-1	36	Startracker Enclosure	1	Aluminium Alloy	Aluminium Alloy	Box	119	59	59	47	No	-	Analyze
DOGE-1	37	Fasteners	352	316 Stainless Steel	316 Stainless Steel	Cylindrical	263.5	M1.6 - M3	4 - 16	-	No	Demise @ < 1000 °C	No
					Currently Scheduled Mass Elements		11341.5						
DOGE-1	38	GPS Antenna	1	PCB/Aluminium	PCB/Aluminium	Cylinder	50	35	7.25		No	-	Analyze
DOGE-1	39	GPS Module	1	PCB	PCB	Flat Plate	31	72	46	11	No	Demise @ < 1000 °C	No
DOGE-1	40	X-Band Radio	1	PCB/Aluminium	PCB/Aluminium	Box	275	90.1	95.9	22.5	No	-	Analyze
DOGE-1	41	X-Band Patch Antenna	1	Ceramic PCB	Ceramic PCB	Sheet	2.2	24	24	1.52	No	Demise @ < 1000 °C	No
					Recommended Additional Mass Elements		358.2						

Estimated Total Mass Elements 11699.7

Review Points:

[1] Startracker Optics is listed as TBD, assumed to be glass
[2] Missing recommended components (see add list below)
[3] Swap height and length for cylinders
[4] All box elements are analyzed

DOGE-1 Estimated Mass (g) 11441.5

Vehicle	Item Number	Name	Quantity	Material	Material (Adjusted)	Shape	Total Mass (g)	Diameter / Width (mm)	Length (mm)	Height (mm)	Survivability	Notes
DOGE-1	1	Structure / Chassis	1	AL 7075-T651	AL 7075-T651	Box	4132.9	238	365	223.4	Analyze	Material Matched - Shape Matched - Mass Matched - Dims Matched
DOGE-1	4	Solar Cells	48	Germanium Wafer	Germanium	Flat Plate	48	69	40	0.2	Analyze	**Material Tweaked** - Shape Matched - Mass Matched - Dims Matched
DOGE-1	6	Battery (Fixture)	3	Aluminium Alloy	Aluminum (generic)	Plate	156	40	90	15	Analyze	**Material Tweaked** - Shape Matched - Mass Matched - Dims Matched
DOGE-1	8	OBC	1	PCB/Aluminium	Copper	Box	75	40	65	7.1	Analyze	**Material Tweaked** - Shape Matched - Mass Matched - Dims Matched
DOGE-1	9	ADCS OBC	1	PCB/Aluminium	Copper	Box	88	40	65	7.1	Analyze	**Material Tweaked** - Shape Matched - Mass Matched - Dims Matched
DOGE-1	10	S-Band Radio	1	PCB/Aluminium	Aluminum (generic)	Box	32	43	75	9	Analyze	**Material Tweaked** - Shape Matched - Mass Matched - Dims Matched
DOGE-1	12	Sun Sensors	6	PCB/Aluminium	Aluminum (generic)	Box	11	22	5.5	3	Analyze	**Material Tweaked** - Shape Matched - **Mass Tweaked** - Dims Matched
DOGE-1	13	Startracker Housing	2	AL 7075-T651	AL 7075-T651	Box	176	55	65	35	Analyze	Material Matched - Shape Matched - Mass Matched - Dims Matched
DOGE-1	16	Magnetorquers	1	Polymer / Copper / Rods	Copper	Box	156	90.5	96.9	17.2	Analyze	**Material Tweaked** - Shape Matched - Mass Matched - Dims Matched
DOGE-1	17	Reaction Wheel Assembly	4	PCB/Aluminium/Stainless Steel	Copper	Box	940	95	95	62	Analyze	**Material Tweaked** - Shape Matched - Mass Matched - Dims Matched
DOGE-1	18	S-Band Antenna	2	PCB/Aluminium	Aluminum (generic)	Box	186	100	100	12	Analyze	**Material Tweaked** - Shape Matched - Mass Matched - Dims Matched
DOGE-1	19	Deployment Switch	2	300 Series Stainless Steel	Stainless Steel (generic)	Box	12	6.4	20	14.8	Analyze	**Material Tweaked** - Shape Matched - Mass Matched - Dims Matched
DOGE-1	21	Internal Camera Housing	2	AL 7075-T651	AL 7075-T651	Box	176	93	89	55	Analyze	Material Matched - Shape Matched - Mass Matched - Dims Matched
DOGE-1	28	Enpulsion Thruster Housings	2	Aluminium Alloy	Aluminum (generic)	Box	580.0	100	100	100	Analyze	**Material Tweaked** - Shape Matched - Mass Matched - Dims Matched
DOGE-1	30	Enpulsion Tank/Emitters	2	Tungsten, Tantalum, Indium, Stainless Steel	Tungsten	Cylinder	580.0	72	53.8	-	Analyze	**Material Matched - Shape Tweaked** - Mass Matched - Dims Tweaked
DOGE-1	32	Thruster PPU Boards	3	Aluminium PCB	Aluminum (generic)	Flat Plate	114	133.8	41.4	3.2	Analyze	**Material Tweaked** - Shape Matched - Mass Matched - Dims Matched
DOGE-1	35	CubeStar Startracker Housing	1	Aluminium Alloy	Aluminum (generic)	Tube	5.5	21	37.8	-	Analyze	**Material Tweaked** - Shape Matched - Mass Matched - Dims Matched
DOGE-1	36	Startracker Enclosure	1	Aluminium Alloy	Aluminum (generic)	Box	119	59	59	47	Analyze	**Material Tweaked** - Shape Matched - Mass Matched - Dims Matched
DOGE-1	38	GPS Antenna	1	PCB/Aluminium	Aluminum (generic)	Cylinder	50	35	7.25	-	Analyze	**Material Tweaked** - Shape Matched - **Mass Tweaked** - Dims Matched
DOGE-1	40	X-Band Radio	1	PCB/Aluminium	Aluminum (generic)	Box	275	90.1	95.9	22.5	Analyze	**Material Tweaked** - Shape Matched - Mass Matched - Dims Matched
							7912.4					
DOGE-1	2	Solar Panel Substrate 1U	8	High TG FR4 + Kapton Polyimide Coverlay	High TG FR4 + Kapton Polyimid	Flat Plate	224	83	98	1.2	No	
DOGE-1	3	Solar Panel Substrate 2U	8	High TG FR4 + Kapton Polyimide Coverlay	High TG FR4 + Kapton Polyimid	Flat Plate	448	83	211	1.2	No	
DOGE-1	5	Battery (Cells)	24	Lithium Ion	Lithium Ion	Cylinder	1344	18	63	-	No	
DOGE-1	7	EPS	1	PCB	PCB	Sheet	100	89.3	92.9	15.3	No	
DOGE-1	11	Payload Interface Board	1	PCB	PCB	Sheet	51	88.77	91.7	8.6	No	
DOGE-1	14	Startracker PCB	2	High TG FR4 + Kapton Polyimide Coverlay	High TG FR4 + Kapton Polyimid	Flat Plate	174	50	131	1.6	No	
DOGE-1	15	Startracker Optics	2	N-F2 and N-BK7	N-F2 and N-BK7	Cylinder	2	8	6	-	No	
DOGE-1	20	Harnessing	1	Copper and PTFE	Copper and PTFE	Wire	150	-	-	-	No	
DOGE-1	22	Internal Camera PCB	2	High TG FR4 + Kapton Polyimide Coverlay	High TG FR4 + Kapton Polyimid	Flat Plate	174	50	131	1.6	No	
DOGE-1	23	Internal Camera Optics	2	N-F2 and N-BK7	N-F2 and N-BK7	Cylinder	2	8	6	-	No	
DOGE-1	24	Internal Display	1	AMOLED Display	AMOLED Display	Flat Plate	5	62	52	0.2	No	
DOGE-1	25	Internal Display PCB	1	High TG FR4 + Kapton Polyimide Coverlay	High TG FR4 + Kapton Polyimid	Flat Plate	71.5	100	100	1.6	No	
DOGE-1	26	Standoffs	133	AL 7075-T651	AL 7075-T651	Cylindrical	159.6	5.5	13.5	-	No	
DOGE-1	27	PCB Conformal Coatings	2	CV-1152P Controlled Voltaility RTV	CV-1152P Controlled Voltaility R	Flat Plate	20	100	100	1	No	
DOGE-1	29	Enpulsion Fuel	2	Indium	Indium	Cylindrical	465.6	100	100	66.8	No	
DOGE-1	31	Enpulsion PCB	2	FR-4	FR-4	Flat Plate	50	94	90	1.6	No	
DOGE-1	33	CubeStar Startracker PCBs	3	FR-4	FR-4	Flat Plate	30.3	50	35	1.6	No	
DOGE-1	34	CubeStar Startracker Optics	1	TBD	N-F2 and N-BK7	Cylinder	19.6	16	13	-	No	

DOGE-1	37	Fasteners	352	316 Stainless Steel	316 Stainless Steel	Cylindrical	263.5	M1.6 - M3	4 - 16	-	No
DOGE-1	39	GPS Module	1	PCB	PCB	Flat Plate	31	72	46	11	No
DOGE-1	41	X-Band Patch Antenna	1	Ceramic PCB	Ceramic PCB	Sheet	2.2	24	24	1.52	No

Mass of Elements to be analyzed	7912.4
Mass of Culled Elements	3787.3
Estimated Total Mass Elements	11699.7
Substract Additional Mass	-358.2
Corrected Total Mass Elements	11341.5
Original Estimated Mass of Elements	11441.5
	-100

Review Points:

[1] Startracker Optics is listed as TBD, assumed to be glass
[2] Missing recommended components scheduled (see add list below)
[3] Swap height and length for cylinders

DOGE-1 ODAR NAS Workbook March 2023 V1-1
Format and Convert Units

Item Number	Parent	Name	Quantity	Material	Shape	Total Mass (kg)	Diameter / Width (m)	Length (m)	Height (m)
1	1	Structure / Chassis	1	AL 7075-T651	Box	4.1329	0.238	0.365	0.2234
2	1	Solar Cells	48	Germanium	Flat Plate	0.048	0.069	0.04	0.0002
3	1	Battery (Fixture)	3	Aluminum (generic)	Plate	0.156	0.04	0.09	0.015
4	1	OBC	1	Copper	Box	0.075	0.04	0.065	0.0071
5	1	ADCS OBC	1	Copper	Box	0.088	0.04	0.065	0.0071
6	1	S-Band Radio	1	Aluminum (generic)	Box	0.032	0.043	0.075	0.009
7	1	Sun Sensors	6	Aluminum (generic)	Box	0.011	0.022	0.0055	0.003
8	1	Startracker Housing	2	AL 7075-T651	Box	0.176	0.055	0.065	0.035
9	1	Magnetorquers	1	Copper	Box	0.156	0.0905	0.0969	0.0172
10	1	Reaction Wheel Assembly	4	Copper	Box	0.94	0.095	0.095	0.062
11	1	S-Band Antenna	2	Aluminum (generic)	Box	0.186	0.1	0.1	0.012
12	1	Deployment Switch	2	Stainless Steel (generic)	Box	0.012	0.0064	0.02	0.0148
13	1	Internal Camera Housing	2	AL 7075-T651	Box	0.176	0.093	0.089	0.055
14	1	Enpulsion Thruster Housings	2	Aluminum (generic)	Box	0.58	0.1	0.1	0.1
15	1	Enpulsion Tank/Emitters	2	Tungsten	Cylinder	0.58	0.072	0.0538	0
16	1	Thruster PPU Boards	3	Aluminum (generic)	Flat Plate	0.114	0.1338	0.0414	0.0032
17	1	CubeStar Startracker Housing	1	Aluminum (generic)	Tube	0.0055	0.021	0.0378	0
18	1	Startracker Enclosure	1	Aluminum (generic)	Box	0.119	0.059	0.059	0.047
19	1	GPS Antenna	1	Aluminum (generic)	Cylinder	0.05	0.035	0.00725	0
20	1	X-Band Radio	1	Aluminum (generic)	Box	0.275	0.0901	0.0959	0.0225
						7.9124			