#### 6a. Description of Research Project:

**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 on the Falcon 9 Intuitive Machines IM-1 Launch as a 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 planned for up to 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 is anticipated, 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.

**Communications Overview:** All mission data is transmitted/received over links established between one of two identical S-Band command, telemetry, tracking, and payload radio transceivers accommodated on the DOGE-1 spacecraft and the baseline Goonhilly Earth Station a fixed ground station with a 32 m diameter dish (GHY-6, Merlin) located in Goonhilly Downs, United Kingdom.

A Global Navigation Satellite System (GNSS) receiver intended to experiment with how to correlate and make effective use of above constellation use of the Global Positioning System (GPS) orbital ephemeris data has been included as part of the Interoperable Network Communications Architecture (INCA) payload. The satellite bus uses reaction wheels, multiple star trackers, and sun sensors to enable precision 3-axis pointing. Telemetry & Tracking (TLM), Command (CMD), and Payload (PLD) data transmission from/to the spacecraft are proposed at S-band frequencies. The CMD and TLM links utilize a dual transceiver system, each of which operates in half-duplex mode (but, not on a common transmit/receive frequency). Accommodations have also been provided for an Endurosat X-Band radio transmitter for PLD and TLM downlink serving as a tertiary backup and additional testing resource.

The TLM & PLD S-Band downlink license authority requested utilizes allocated (space-to-Earth) spectrum in accordance with ITU Table of Frequency Allocations – within the frequency band 2200 to 2290 MHz. The applicable allocation is abstracted as the worksheet tab [FCC Regulations Abstract] in the DOGE-1 Radio License Reclama XISP-Inc Workbook. The TLM downlink data rate will vary for experimental purposes from 2.4 kbps (radio minimum bitrate) to 90 kbps (radio maximum bitrate). The requested Center Point Frequency is 2289.5 MHz, and the minimum operational bandwidth is 0.065 MHz. Accordingly, the Necessary Bandwidth of the radio system will vary for experimental purposes from 2.472 to 92.7 kHz, and will in all instances be enveloped by and well within the requested Necessary Bandwidth allocation of 1 MHz requested. See FCC Appendix J based calculations on the worksheet tab [Necessary Bandwidth] in the DOGE-1 Link Budgets, XISP-Inc Workbook. GMSK modulation is employed on the TLM downlink.

The CMD S-Band uplink license authority requested utilizes allocated (Earth-to-space) spectrum in accordance with ITU Table of Frequency Allocations – within the frequency band of 2025 to 2110 MHz. The applicable allocation is abstracted as the worksheet tab [FCC Regulations Abstract] in the DOGE-1 Radio License Reclama XISP-Inc Workbook. The CMD uplink data rate will vary for experimental purposes from 2.4 kbps (radio minimum bitrate) to 90 kbps (radio maximum bitrate). The requested Center Point Frequency is 2025.5 MHz, and the minimum operational bandwidth is 0.065 MHz. Accordingly, the Necessary Bandwidth of the radio system will vary for experimental purposes from 2.472 to 92.7 kHz, and will in all instances be enveloped by and well within the requested Necessary Bandwidth allocation of 1 MHz requested. See FCC Appendix J based calculations on the worksheet tab [Necessary Bandwidth] in the DOGE-1 Link Budgets, XISP-Inc Workbook. GMSK modulation is employed on the CMD uplink.

The PLD & TLM X-Band downlink license authority requested utilizes allocated (space-to-Earth) spectrum in accordance with ITU Table of Frequency Allocations – within the frequency band 2200 to 2290 MHz. The applicable allocation is abstracted as the worksheet tab [FCC Regulations Abstract] in the DOGE-1

<u>Radio License Reclama XISP-Inc Workbook</u>. The TLM downlink data rate will vary for experimental purposes from 2000 kbps (radio minimum bitrate) to 125000 kbps (radio maximum bitrate). The requested Center Point Frequency is 8262.5 MHz, and the minimum operational bandwidth is 60 MHz. Accordingly, the Necessary Bandwidth of the radio system will vary for experimental purposes from 0.65 to 97.5 MHz, and will in all instances be enveloped by and well within the requested Necessary Bandwidth allocation of 375 MHz requested. See FCC Appendix J based calculations on the worksheet tab [Necessary Bandwidth] in the DOGE-1 Link Budgets, XISP-Inc Workbook. QPSK 1/4 modulation is employed on the X-band PLD and TLM downlink.

FCC ONLINE TABLE OF FREQUENCY ALLOCATIONS Exceptions/Coordination/Special Requests

## ITU Frequency Allocation: 2025-2110 MHz

- Goonhilly Earth Station S-Band Uplink to DOGE-1 (Earth-to-Space)

FIXED NG118 – Does not conflict and requested allocation is consistent with Region 1 (Goonhilly Earth Station is in Region 1) SPACE OPERATION, EARTH EXPLORATION SATELLITE, SPACE RESEARCH, and FIXED frequency allocations.

- 5.392 Compliant
- US90 Compliant
- US92 Compliant, coordination initiated through NASA
- US222 Not Applicable
- US346 Compliant, coordination initiated through NASA
- US347 Special Request for Allocation is hereby made, coordination initiated through NASA

### ITU Frequency Allocation: 2200-2290 MHz

- DOGE-1 S-Band Downlink to Goonhilly Earth Station (space-to-Earth)

5.392 – Does not conflict and requested allocation is consistent with Region 1 (Goonhilly Earth Station is in Region 1) SPACE OPERATION, EARTH EXPLORATION SATELLITE, SPACE RESEARCH, and FIXED frequency allocations.

US303 – Special Request for Allocation is hereby made for potential transmission to the Tracking and Data Relay Satellite System, coordination initiated through NASA.

### ITU Frequency Allocation: 8025-8400 MHz

– DOGE-1 X-Band Downlink to Goonhilly Earth Station (space-to-Earth)

5.462A – Compliant. However, Special Request for Authorization to make use of the Region 1 EARTH EXPLORATION-SATELLITE (space-to-Earth) Allocation is hereby requested.

US258 – Special Request for Authorization to make use of the EARTH EXPLORATION-SATELLITE (space-to-Earth) Allocation is hereby requested subject to satisfactory resolution of electromagnetic compatibility analysis. Coordination has been initiated through NASA.

			47 C.F.R. § 2.106		
			Revised on February 1,	, 2021	
able of Frequency	Allocations		1626.5-2110 MHz (UHF)		Pag
able of Frequency	International Tabl	e		d States Table	FCC Rule Part(s)
legion 1 Table	Region 2 Table	Region 3 Table	Federal Table	Non-Federal Table	
025-2110	Ŭ	Ū	2025-2110	2025-2110	
PACE OPERATION	l		SPACE OPERATION	FIXED NG118	TV Auxiliary Broadcasting (74F)
(Earth-to-space) (sp	pace-to-space)		(Earth-to-space) (space-to-space)	MOBILE 5.391	Cable TV Relay (78)
ARTH EXPLORATIO	ON-SATELLITE		EARTH EXPLORATION-SATELLITE		Local TVT ransmission (101J)
(Earth-to-space) (sp	pace-to-space)		(Earth-to-space) (space-to-space)		
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(Earth-to-space) (sp	pace-to-space)		(Earth-to-space) (space-to-space)		
IXED			FIXED		
OBILE 5.391			MOBILE 5.391	5 202 11000 11002 110222	
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(space-to-Earth) (space-to-space)			(space-to-Earth) (space-to-space)		
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nis FCC Regulation erations for less that		DOGE-1 12U lunar orbiting	cubesat applying for an Experimental Operators License in conjunction with G	oonhilly Earth Station for S-Ba	nd downlink services, with anticipated
392 Administrations	are urged to take all prac	cticable measures to ensure	e that space-to-space transmissions between two or more non-geostationary sa	atellites, in the space research	, space operations and Earth exploration
		and <u>2200-2290 MHz</u> , shall	not impose any constraints on Earth-to-space, space-to-Earth and other space	-to-space transmissions of the	se services and in those bands between
-	n-geostationary satellites.	and a second second second		a de la contra de la	
			ace research, space operations and Earth exploration-satellite services may be		
			ch transmissions shall not cause harmful interference to authorized Federal st	ations. The power flux-density	at the Earth's surface from such non-
			on angle of arrival, in accordance with ITU Radio Regulation 21.16.		
	<u>ke use of this allocation</u>	n to transmit to the Track	ing and Data Relay Satellite System as an alternate communication path	to Earth subject to such co	nditions as may be applied is hereby
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G117 In the bands 7.25-7.75 GHz, 7.9-8.4 GHz, 17.375-17.475 GHz, 17.6-21.2 GHz, 30-31 GHz, 33-36 GHz, 39.5-41 GHz, 43.5-45.5 GHz and 50.4-51.4 GHz, the Federal fixed-satellite and mobile-satellite services are limited to military systems.

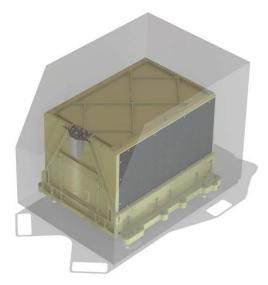
0475 0045	0175 0015		
8175-8215	8175-8215		
EARTH EXPLORATION-SATELLITE (space-to-Earth)	EARTH EXPLORATION-SATELLITE (space-to-Earth)		
FIXED	FIXED		
FIXED-SATELLITE (Earth-to-space)	FIXED-SATELLITE (Earth-to-space)		
METEOROLOGICAL-SATELLITE (Earth-to-space)	METEOROLOGICAL-SATELLITE (Earth-to-space)		
	Mobile-satellite (Earth-to-space)(no airborne transmissions)		
MOBILE 5.463	US258 G104 G117		
NOTES:			•
This FCC Regulations Abstract applies to the DOGE-1 12U lunar of	rbiting cubesat applying for an Experimental Operators License in conjunction	with Goonhilly Earth Station for X-Ban	d downlink services, with anticipated
	pated at this time but the capability to support the same at some level is anticipated	•	•
5.463 Aircraft stations are not permitted to transmit in the band 802	5-8400 MHz.		
US258 In the bands 8025-8400 MHz and 25.5-27 GHz the Earth e	xploration-satellite service (space-to-Earth) is allocated on a primary basis for n	on-Federal use. Authorizations are sul	pject to a case-by-case electromagnetic
compatibility analysis. Authorization to make use of this alloca	tion is hereby requested subject to satisfactory resolution of electromag	netic compatibility analysis.	, , , ,
G104 In the bands 7450-7550 and 8175-8215 MHz, it is agreed that	at although the military space radio communication systems, which include ear	th stations near the proposed meteoro	logical-satellite installations will precede
	to either the military or the meteorological-satellite systems or both will be made		
concerned.			. ,
G117 In the bands 7.25-7.75 GHz, <b>7.9-8.4 GHz</b> , 17.375-17.475 GH	z, 17.6-21.2 GHz, 30-31 GHz, 33-36 GHz, 39.5-41 GHz, 43.5-45.5 GHz and 50.4	-51.4 GHz, the Federal fixed-satellite	and mobile-satellite services are limited to
military systems.			
8215-8400	8215-8400		
EARTH EXPLORATION-SATELLITE (space-to-Earth)	EARTH EXPLORATION-SATELLITE (space-to-Earth)		
FIXED	FIXED		
FIXED-SAT ELLIT E (Earth-to-space)	FIXED-SAT ELLIT E (Earth-to-space)		
MOBILE 5.463	Mobile-satellite (Earth-to-space)(no airborne transmissions)		
5.462A	US258 G117	US258	
NOTES:			
This FCC Regulations Abstract applies to the DOGE-1 12U lunar of	rbiting cubesat applying for an Experimental Operators License in conjunction	with Goonhilly Earth Station for X-Ban	d downlink services, with anticipated
operations for less than two years. Use of this capability is not antici	pated at this time but the capability to support the same at some level is anticipated	ated to be extant.	
5.462A In Regions 1 and 3 (except for Japan), in the band 8025-84	00 MHz, the Earth exploration-satellite service using geostationary satellites sha	all not produce a power flux-density in	excess of the following values for angles of
arrival ( $\theta$ ), without the consent of the affected administration:	<u></u> ,		
-135 dB(W/m <sup>2</sup> ) in a 1 MHz band for $0 \le \theta \le 5^{\circ}$			
$-135 + 0.5 (\theta - 5) dB(W/m^2)$ in a 1 MHz band for $5 \le \theta \le 25^{\circ}$			
-125 dB(W/m <sup>2</sup> ) in a 1 MHz band for $25 \le \theta \le 90^{\circ}$ (WRC-12)			
	ploration-satellite service (space-to-Earth) is allocated on a primary basis for n	on-Federal use. Authorizations are sul	piect to a case-by-case electromagnetic
	tion is hereby requested subject to satisfactory resolution of electromag		,
G117 In the bands 7.25-7.75 GHz, <b>7.9-8.4 GHz</b> , 17.375-17.475 GH			and mahile actallite consists are limited to
military systems.	2, 17.0=21.2 GHz, 30=31 GHz, 33=30 GHz, 33.3=41 GHz, 43.3=43.3 GHz and 30.4		and mobile-salenile services are infilled to

## 1. 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	Payload Constituent			
SpaceX Internal Name	SpaceX Internal Name			
Separation System				
Quantity of Deployables in this de	Quantity of Deployables in this deploy			
Deployable Type(s)		12U CubeSat		
	X <sub>PL</sub>	578.87		
Separation Plane Origin (mm)	Y <sub>PL</sub>	0.00		
	Z <sub>PL</sub>	177.90		
	X <sub>PL</sub>	1.00		
Deploy Vector (unit vector)	Y <sub>PL</sub>	0.00		
	Z <sub>PL</sub>	0.00		
	Width	240.40		
Deployable Dimensions (mm)	Height (in Zpl)	224.90		
Width x Height is parallel to separation plane	Length (along deploy axis)	366.00		
	Nominal (kg)	13.80		
Total Deploy Mass	+ Tolerance (kg)	1.50		
	- Tolerance (kg)	1.50		
	Nominal (J)	11.07		
Total Separation Energy	+ Tolerance (%)	20		
	- Tolerance (%)	20		
Time delay from initiation of electrical cignal until first	itiation of electrical signal until first Nominal Delay (s)			
Time delay from initiation of electrical signal until first movement of Payload Constituent	+ Tolerance (s)	0.03		
	- Tolerance (s)	0.015		
Nominal Deploy Velocity [m/se	1.267			

Table 2-1 Spacecraft Physical Description



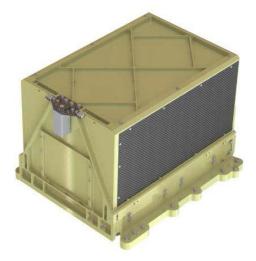
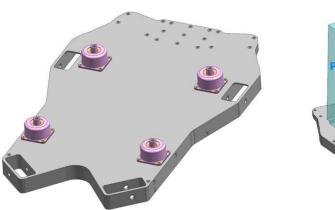


Figure 2-1 Mercury-12T Dispenser within SpaceX Surfboard Volume Envelope

Figure 2-2 Mercury-12T Dispenser



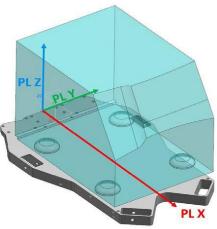


Figure 2-3 SpaceX Surfboard

Figure 2-4 Rideshare Payload Volume and Surfboard

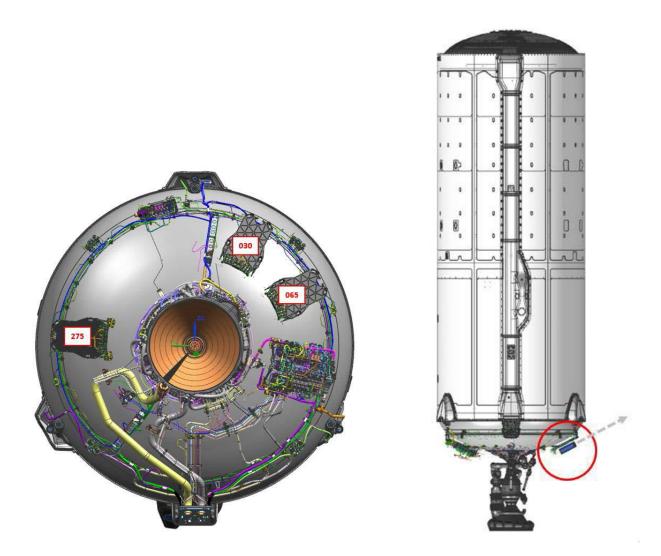


Figure 2-5 DOGE-1 SpaceX Surfboard Location

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 deployable and is shown in Figure 2-6 DOGE-1 Spacecraft Isometric Renderings.





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.

payload1					
Name	Deployable Identifier	Coordinate System	Separation Plane Distance [mm]		
payload1	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 <sub>PL</sub>	372.4000	25.0000	25.0000		
Y <sub>PL</sub>	-1.5000	25.0000	25.0000		
Z <sub>PL</sub>	200.1000	25.0000	25.0000		
	Moment of Inertia				
	Nominal [millimeters ** 2 * kg]	Plus Tolerance [+]	Minus Tolerance [-]		
lxx	160000.0000	24000.00	24000.00		
lyy	234000.0000	35100.00	35100.00		
Izz	236000.0000	35400.00	35400.00		
Product of Inertia					
	Nominal [millimeters ** 2 * kg]	Plus Tolerance [+]	Minus Tolerance [-]		
lxy	2420.0000	9440.00	9440.00		
lyz	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 sunpointing 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.