Response to FCC Questions Received January 11, 2023 Version 3.0

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To:	Doug Young Douglas.Young@fcc.gov

Applicant:	Geometric Energy Corporation (GEC)
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Dear Mr. Young:

The inline answers to the questions posed on your correspondence of 1/11//2023 are as follows:

The FCC's International Bureau/Satellite Division has the following questions/comments that you will need to address: Standard questions: In accordance with Article 22 of the RR, Space stations shall be fitted with devices to ensure immediate cessation of their radio emissions by telecommand, whenever such cessation is required under the provisions of these Regulations.

(1) Can the spacecraft be commanded by ground station to cease all transmissions?
- ⇨ Yes.

(2) Additionally, please provide the contact information for the person/group/watch floor that can send this command to the spacecraft.
- ⇨ Gary Pearce Barnhard, Xtraordinary Innovative Space Partnerships, Inc. (XISP-Inc), 8012 MacArthur Boulevard, Cabin John, MD 20818. +1 301-229-8012 (Office) +1 301-509-0848 (Mobile). gary@geometricenergy.com, gary.barnhard@xisp-inc.com, barnhard@barnhard.com, gpb8012@gmail.com

(3) The spacecap and mission description indicates the earth station associated with the X-Band downlink is the Goonhilly Downs earth station while the NTIA form states this should be an earth station in Dublin, Ohio. Please correct this inconsistency and reupload the affect file(s) or provide additional information.
- ⇨ The X-Band downlink is an option that may have to be deferred based on the most recent input received from Goonhilly Downs. Specifically, "Goonhilly Downs Earth Station GHY-6 "Merlin" 32 Meter dish antenna is not currently configured to support X-Band" and the availability of a suitable alternate antenna at the facility that can support X-Band at the facility is not assured.
- ⇨ AWS Ground Station has indicated that their AWS Dublin, Ohio ground station does support X-Band communications. Their facility could be used to attempt best effort connections (i.e., significantly less than a 3 dB link margin).

- ⇨ GEC is currently researching any other alternative commercial, university, non-profit, or government facilities.
- ⇨ The DOGE-1 spacecraft S-Band uplink and downlink is intended to use the Goonhilly Downs Earth Station until when and if alternate facilities become available.
- ⇨ Accordingly, the spacecap file accurately reflects the current status and therefore does not need to be replaced.

(4) *The mission description says the S-Band uplink center frequency will be 2025.5 MHz while the spacecap indicates the only requested frequency is 2109.5 MHz. Please correct the appropriate file(s) and reupload them.*
- ⇨ This is errata due to requirements modifications over the course of time.
- ⇨ The Spacecap request is correct.
- ⇨ The necessary mission description corrections will be will be made of any files that have been submitted that need to be changed as documentation errata.
- ⇨ Please note that there is both an S-Band Uplink and Downlink frequency.

(5) *The mission description for the X-Band downlink indicates the frequency range will be 2200-2290 MHz. Additionally, the mission description gives a center frequency of 8262.5 MHz while the spacecap indicates the only requested frequency is 8212.5 MHz. Please correct the appropriate file(s) and reupload them. information.*
- ⇨ This is errata due to requirements modifications over the course of time.
- ⇨ The Spacecap request is correct.
- ⇨ The necessary mission description corrections will be will be made of any files that have been submitted that need to be changed as documentation errata.

(6) *Please provide the actual powers the spacecraft will consume as shown on page 14 of the mission description.*
- ⇨ The mission description will be updated with estimated power the spacecraft will consume.

(7) *Also provide a description of the heating systems on-board the spacecraft.*
- ⇨ The spacecraft uses an integrated power and thermal model for thermal management. Payload and spacecraft bus systems operations will be orchestrated to maintain the equipment within the temperature envelope necessary to protect equipment from freezing or overheating.
- ⇨ The spacecraft bus and payloads do not have separate heaters.
- ⇨ The propulsion systems, electrical system (solar arrays, batteries, power management and distribution), S-band and X-band radios, computers, and attitude control systems all generate excess heat during operations.
- ⇨ Heat flow balance will be maintained by adjusting operational modes.

ODAR questions:

(8) *Please indicate the propellant and associated mass.*
- ⇨ From the Enpulsion ICD for each thruster:

- “Dry” mass: 0.68 kg ±3%
- Propellant mass (Indium): 0.22 kg ±10%
- “Wet” mass: 0.9 kg ±5%

⇨ The spacecraft contains two thrusters for a total of Propellant mass (Indium): 0.44 kg ±10%

(9) Please elaborate further on the collision avoidance section provided, especially in regards to statement "given sufficient time can perform necessary collision avoidance maneuvers." What is sufficient time? What are necessary collision avoidance maneuvers?

⇨ The spacecraft bus includes two Enpulsion NANO Electric Propulsion modules which can be operated in tandem or individually. While their thrust is limited, it is adjustable for each module. Therefore, over time using differential thrusting the propulsion modules can significantly alter the trajectory of the spacecraft.

⇨ No collision avoidance maneuvers are anticipated based on the intended Trans Lunar Injection (TLI) trajectory deployment.

⇨ In the unlikely event ongoing analysis shows the need for a collision avoidance maneuver the necessary modifications to the operating schedule for the propulsion system will be uploaded.

(10) What is the intended elliptical lunar orbit?

⇨ The most stable semi-circularized orbit achievable within the limits of the on-board propulsion system and the calculation of alternate minimum energy trajectories.

⇨ The target apolune is less than 10,000 km. The target perilune is more than 100 km.

⇨ The achievable orbit will be modeled using Ansys STK Astrogator once the launch service provider has provided final deployment parameters.

⇨ The trajectory analysis will continue as an integral part of the mission

⇨ Circumstances permitting the spacecraft will be equipped with a laser retroreflector as a ranging target

(11) Please provide more information regarding disposal.

⇨ Based on the assumption that a stable semi-circularized orbit is achieved an updated assessment will be made of the projected orbital lifetime of the spacecraft, the anticipated operational lifetime of the spacecraft, and the minimum propellant and time to ensure an ability to modify the anticipated lunar impact site.

⇨ Analysis results will be coordinated with NASA to ensure that any anticipated impact will not be near any lunar site of concern.

(12) How will use of the propulsion system impact disposal as indicated in the ODAR on page 17?

⇨ The propulsion system can over time enable the spacecraft velocity, trajectory, and/or orbital plane to be altered in the event that ongoing trajectory modeling shows a credible possibility of lunar impact near a lunar site of concern.

(13) How will the propulsion system provide an additional measure of control for disposal as indicated on ODAR page 17?

- ⇨ The first measure of control for disposal is making the optimal choice of achievable lunar orbit to avoid any potential impact based on the ongoing trajectory modelling.
- ⇨ The second measure of control for disposal is the use of the propulsion system to enable the spacecraft velocity, trajectory, and/or orbital plane to be altered in conjunction with the ongoing trajectory modeling to minimize or eliminate the possibility of lunar impact near a lunar site of concern.

(14) Have you coordinated with the NASA Planetary Protection Office for this Lunar mission?

- ⇨ The standard requirement that must be adhered to is that any spacecraft that may potentially impact the Moon must minimize or eliminate the possibility of lunar impact near a lunar site of concern. DOGE-1 will meet this requirement.
- ⇨ Detailed, specific coordination is an open action to be completed once we have been able to model the achievable lunar orbit in sufficient fidelity to identify probable disposal impact zones.
- ⇨ If requested, in the interim a letter can been sent notifying the NASA Planetary Protection Office of the particulars of the mission and our desire to coordinate the same with them.

(15) What software was used in the calculations conducted for this ODAR?

- ⇨ Excel models, comparison to other analysis runs with Ansys STK Version 11 Astrogator.
- ⇨ If requested, or otherwise deemed necessary based on ongoing analysis, a NASA DAS 3.2.3 analysis of the presumed deprecated case of free return trajectory leading to Earth atmospheric reentry will be performed based on the most reasonable approximation of the reentry orbital conditions we can construct. There is no certainty that DAS 3.2.3 analysis can even accommodate the eccentric orbit that would correspond to a free return trajectory for DOGE-1.
- ⇨ Free-return trajectory. (2022, December 1). In Wikipedia. https://en.wikipedia.org/wiki/Free-return_trajectory
    - o This problem is an example of a circular restricted three-body problem. While in a true free-return trajectory no propulsion is applied, in practice there may be small mid-course corrections or other maneuvers. A free-return trajectory may be the initial trajectory to allow a safe return in the event of a systems failure; this was applied in the Apollo 8, Apollo 10, and Apollo 11 lunar missions. In such a case a free return to a suitable reentry situation is more useful than returning to near the Earth, but then needing propulsion anyway to prevent moving away from it again. Since all went well, these Apollo missions did not have to take advantage of the free return and inserted into orbit upon arrival at the Moon.
    - o The atmospheric entry interface velocity upon return from the Moon is approximately 36,500 ft/s (11.1 km/s; 40,100 km/h; 24,900 mph)[4] whereas the more common spacecraft return velocity from low Earth orbit (LEO) is approximately 7.8 km/s (28,000 km/h; 17,000 mph).Given the return condition of the Apollo spacecraft and the Artemis-1 spacecraft all of which used the likelihood of

(16) *How did you calculate the large object collision risk?*

- ⇨ The Trans Lunar Injection (TLI) trajectory for the DOGE-1 spacecraft is approximately identical to that of the IM-1 Commercial Lunar Payload Services (CLPS) lander spacecraft until after deployment from the launch vehicle.
- ⇨ DOGE-1 will continue to alter its trajectory to intersect the Moon in one, two, or three lunar cycles depending on the achievable velocity and the efficacy of the alternate minimum energy (ballistic escape) trajectory calculations.
- ⇨ For all intents and purposes the probability of large object collision in the time frame of the DOGE-1 flight is zero.

(17) *How do you determine the spacecraft would burn up completely in the even it reenters earth atmosphere?*

- ⇨ Verification by similarity based on the parts list compared to the demise of cubesats made of similar components and materials, as well as the potential velocity of a free return trajectory reentry (Artemis-1 reentry photographs are a useful anecdotal reference for consideration).
- ⇨ If requested, or otherwise deemed necessary based on ongoing analysis, a NASA DAS 3.2.3 analysis of the presumed deprecated case of Earth atmospheric reentry will be performed.
- ⇨ Pursuant to the answer to question 15 above the reentry velocity on a free-return trajectory from the Moon would be significantly higher than from LEO. DAS 3.2.3 analysis very similar spacecraft (Geometric-2) show full demise of the spacecraft reentering from LEO at a significantly lower velocity. Accordingly, it is reasonable to deduce that in the very unlikely event that DOGE-1 ends up on a free return trajectory which would result in Earth atmospheric reentry it will fully demise.

This response has been provided within 30 days of 01/11/2023 deadline stated in the correspondence. This response has been submitted using The OET Experimental Licensing System, followed by clicking on the "Reply to Correspondence" hyperlink.