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Via Electronic Filing
Federal Communications Commission
45 L Street, NE
Washington, D.C. 20554

RE: Atomos Nuclear and Space Corporation
File Nos.: 0911-EX-ST-2023 and 0943-EX-ST-2023; Call Sign: WV9XQX

Hello,

Thank you for your questions, please see the below responses from Atomos Nuclear and Space Corporation ("Atomos"). Atomos has also posted an overview of the Busek thruster qualification test, described below, in the above referenced application files.

As a reminder, Atomos's launch provider requires a grant of the above referenced application before or by **January 18, 2024**, in order to ship the Atomos spacecraft and have them integrated onto the launch vehicle. Atomos will not be able to execute its mission if it has not received a grant by **January 18**.

The Commission's questions below are *italicized*.

1. *What is the expected likelihood of an MMOD strike on a critical surface that may puncture the propulsion system carrying the ASCENT propellant?*

In order to define the level of risk and criticality resulting from the ASCENT stored onboard, it should first be noted that the total quantity of ASCENT in the system is a small fraction of the spacecraft's mass. This propellant is held inside the thruster via capillary action inside a capillary network behind the emitter heads so it is not a typical propellant tank that holds the propellant in place. For MMOD strikes, it is a much safer configuration than a typical pressure vessel.

Per DAS the probability of penetration due to MMOD strike on a critical surface of the ASCENT experimental thruster is 1.6502E-4. The low probability is primarily derived due to the minimal surface area of the ASCENT thrusters on the Gluon bus, .005 m^2. This probability of penetration is significantly lower than the required probability of .01 specified in requirement 4.5-2. Additionally, it should be noted that the ASCENT thruster is not required for disposal of the Gluon spacecraft as Gluon will passively re-enter Earth's atmosphere within 2.5 years from end of mission via uncontrolled reentry.

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This analysis assumes that the internal propellant would be liberated if a MMOD strike pierced the critical surface of the thruster head, but this is not a given. Most of the propellant held inside of the thruster head would remain held in place by the capillary network behind the emitter, and the fraction that was hit by the MMOD would likely be vaporized during the event leading to no actual ASCENT dumped into the space environment. Again, this would be a small fraction of a single head's propellant.

2. *Please provide detailed information on the methods used during qualification testing for the propulsion systems and spacecraft, especially as they relate to the containment of the ASCENT propellant under launch and space environmental conditions.*

The thruster design configuration of the thrust system was qualified via NASA GEVS standards. Atomos has submitted a white paper in parallel to this letter on the qualification campaign for the thruster, which included a non-ASCENT propellant.

The summary of the testing performed is that the baseline design was:

1. Fueled thruster function testing (under vacuum)
2. Thermal vacuum testing
3. Protoflight vibration testing at NASA GEVS levels +6dB
4. Post-vibration functional testing (under vacuum)

The qualification campaign was executed without any observed case of propellant being released from the system.

Although the qualification test did not use ASCENT fuel, a thruster unit using ASCENT has recently flown in an extremely similar launch configuration and is now operating successfully on-orbit without any noted issues during launch or operations.

At the spacecraft level, a spacecraft mass simulator underwent qualification level vibration testing. Then the flight article of the spacecraft underwent protoflight vibration qualification. The spacecraft then went through 1 full cycle (5 days) of thermal vacuum testing with temperature extremes bounding for flight. And then the spacecraft was subjected to a final round of vibration testing at acceptance test levels.

3. *Please provide details on the testing performed on the spacecraft, with ionic liquid loaded, and the results, for tests like vibration testing, shake testing, etc.*

Atomos elected to use the previous test campaign along with the successful flight testing of the ASCENT thruster in order to determine that the design had been successfully qualified for those environments and then use that bounding environment to determine that it was qualified for its location on Gluon during launch. Because of the expedited launch campaign, the TVAC test campaign planned subsequent to vibration testing, and the difficulty of getting vibration test

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houses to accept vibration testing an unproven spacecraft with actual propellant onboard, it was not feasible to test with the thruster heads fueled with ASCENT.

The ASCENT is proportioned equally among each head and is not a material amount of mass compared to the driving dynamics of the system. The thruster heads were subsequently removed, fueled at Busek's facility, and will be installed at the launch site by trained personnel qualified for the operation. The thruster heads showed no visible impact from the vibration test campaign, and no issues with propellant integrity have been observed since their fueling.

Subsequent to fueling, each fueled thruster undergoes the following: settling vibe, sine sweep, random vibe, sine sweep, then repeat for all three axes. Any loss of propellant containment would have been quickly detected as part of subsequent functional testing and would have been evident by leakage current when voltage was applied to the thruster. No loss occurred during this testing. Therefore, the fueled thruster heads have undergone a very rigorous test campaign and have demonstrated that they are qualified to launch at their location on the Gluon spacecraft.

4. *Please provide detailed information on any expected sublimation of the ASCENT propellant if released in droplet form and any additional supporting information, to include the expected rate of sublimation and/or erosion by atomic oxygen, residual orbital lifetime of any such droplets, etc..*

For the nominally emitted propellant, within a second or two, the emitted droplets fragment into molecular ions due to the charge imparted into them as part of the emission process. Any neutral fragments will be rapidly charged by the local plasma and then they will fragment as well. Thus, in a very short distance and time, there are no droplets and the emitted ions remaining are negligible in current density as compared to the existing ion density at LEO altitudes. Based on the fact that the charge in the plume and the local plasma will make droplets exist for only seconds, we can assume that the "sublimation" rate will be equal to total propellant flow rate from the thruster. Using the usual equation Isp = T/mdot * g, at nominal thrust (40 microNewtons, 2300s Isp) we will be sublimating 1.78e-9 kg/s per thruster in operation. With all four thrusters at nominal that's 7.1e-9kg/s. At maximum thrust a single thruster is dispensing 4.4e-9kg/s, and all four thrusters at maximum thrust would be 1.8e-8kg/s. So the highest rate possible is 17.7 micrograms/s.

There's no force to cause the propellant to come out of the thruster, there's no pressure vessel applying pressure for the propellant to escape, so there's no mechanism to expel the propellant except when under nominal thrusting conditions. Thus, even with mechanical damage and exposure to vacuum, the capillary pressure that contains the propellant is still in effect and has been demonstrated to conclusively hold on to all of the propellant contained in the spacecraft.

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5. *In the ODAR, you indicate that you will be venting residual propellant in the lines and tanks. Does this include the ASCENT propellant or is it limited to the ammonia? If related to the ASCENT propellant, please describe the venting process.*

Venting residual propellant in the lines and tanks is only applicable to the ammonia. Any ASCENT propellent remaining at the end of mission is held in place via capillary action and re-enters with Gluon, burning up during disintegration. The nominal experimentation on the ASCENT system will result in full depletion of the ASCENT stored in the thruster heads.

6. *Please indicate whether the experimental propulsion system on Gluon will be operated when Gluon is coupled with Meson, uncoupled, or both. If it will be operated when uncoupled, please indicate whether there will be trajectory screening for possible conjunctions with other spacecraft, and measures to avoid collision with Meson.*

Atomos will only use the experimental propulsion system on Gluon when Gluon is coupled with Meson. This is done in order to minimize any potential for collisions with Meson.

7. *Please indicate whether trajectories for planned maneuvers will be screened through the 18th SDS for possible conjunctions.*

All nominal trajectories and stable contingency trajectories will be screened through SDS for conjunction probabilities. Atomos will also provide covariance data to SDS to ensure that all trajectory deviations are covered by the SDS conjunction screening.

8. *The mission plans as indicated in section 2 of the ODAR include several instances of automatic aborts, please describe the method or process for ensuring that third parties are apprised of possible trajectories resulting from anticipated abort modes.*

ATOMOS: During the approach to Gluon, Meson will be staged in a stable orbit relative to Gluon, forward in the line of flight by 5 km. Then in order to rendezvous, Meson will transfer to a relative orbit below and behind of Gluon to begin the approach. If an abort is called at any point in this approach, Meson will establish a safe opening rate relative to Gluon using its abort maneuver and then transfer to the original pre-defined, safe staging orbit which has already been screened by SDS. Conjunction probabilities in the intervening time (<24 hours) will be covered by Gluon's trajectory screening as well as Meson's nominal trajectory screening with associated covariances.

9. *During the phases of operations addressed in Section 2 of the ODAR, how often will trajectory information be updated for third parties, and the amount of time between notification and commencement of any trajectory changes.*

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During mated operations without trajectory perturbations, Atomos will provide weekly updates for third parties on the latest spacecraft state. When in separate operations, Atomos will perform daily screening for trajectory data and communicate with third parties on a daily cadence for nominal operations. Any deviation from nominal operations will be processed as a "Special" update and those updates will be worked as soon as they are available (<12 hours from first observation).

10. *Procedures to be undertaken if the 18th SDS notifies Atomos of a potential conjunction during the mission phases as described in the ODAR section 2.*

In the event that a conjunction probability is detected with Gluon, Atomos will request that the other party perform a collision avoidance maneuver when it is separated from Meson. In the event that the other party can't or won't perform a collision avoidance maneuver, Atomos will attempt to dock to Gluon and move it away if time permits. Otherwise, there is nothing to do except allow Gluon to drift.

In the event that a conjunction probability is detected with Meson's trajectory during separate operations, Atomos will request that the other party perform a collision avoidance maneuver given that it will be in close proximity (<10 km) to Gluon anyway. In the event that the other party can't or won't perform a collision avoidance maneuver, Meson will be maneuvered away from the conjunction location and the rendezvous will be replanned.

11. *Any conditions (e.g., maneuver sequences, predicted conjunctions with third parties) under which more frequent observations of data received typically received through telemetry will be undertaken, and, if so, the details of dissemination of any such information or derived data to third parties.*

Atomos benefits from extremely regular communication with our spacecraft. Atomos will receive positioning information from both spacecraft continuously (>1 fix per hour) through our Eyestar beaconing radio. Then Atomos will perform high bandwidth downlinks through our IDRS radio at least once every other revolution during rendezvous operations. Any deviations from the nominal plan will be sent to SDS as a "Special" screening so that Atomos can assess these deviations rapidly while both vehicles are in relatively close (<10 km) proximity.

Please do not hesitate to contact me if you have any questions regarding the above answers.

Respectfully submitted,

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