AEGIS

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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,

Please see the below responses from Atomos Nuclear and Space Corporation ("Atomos") as discussed with representatives of the Federal Communications Commission ("Commission"), copied below, on December 28, 2023.

The questions below are meant to generally reflect the matters raised during the conversation and are *italicized*.

1. *Is there a reservoir of ASCENT present in each thruster head and if so, what is the probability of a critical strike piercing all the way through to the reservoir and how much propellant is stored therein?*

There is no reservoir, all propellant is stored in the capillary network. Per Busek, there is no physical way for the porous network to reach 100% saturation, by design. This prevents the system from losing capillary pressure, and ensures that all of the propellant remains trapped in the network. Since there is no pool of propellant attached to the network, there is not a way for it to get overfilled. The capillaries are intentionally underfilled to account for both thermal expansion of the propellant and to account for any potential additional water adsorption due to humidity exposure, again, to avoid scenarios where the porous material reaches 100% saturation. Each thruster can hold 14 grams of propellant when using the non-ASCENT propellant. For this mission, the thrusters are only filled with approximately 6 grams of ASCENT to account for all contingencies.

2. *Is the fueled thruster head testing complete now and what is the status of that testing?*

All testing has been successfully completed by Busek on the thruster heads and they are being packaged for shipment to the launch site now. No electrical leakage currents were observed in any of the thrusters, which demonstrates conclusively that all propellant was successfully contained. For the other system flying, they are working through the process of commissioning that system and they are not tracking any anomalies with that system currently.

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.

3. *If there were to be a critical strike or inadvertent release of ASCENT propellant into space, what is the lifetime of such a release, given the properties of liquid ASCENT?*

The propulsion unit is an electrospray (also known as a colloid) thruster, consisting of four thruster heads. Each thruster head contains a capillary network of carbon nanotubes which act to wick the propellant out to the surface and to store it in an unpressurized, unsaturated form (6 grams per head). The exterior surfaces are not wetted until exposure to vacuum, which primes the electrospray thruster. Surface tension in the carbon nanotube capillary network prevents leakage of the propellant; The likelihood of leakage is further reduced by the naturally high viscosity of the propellant (approximately 30x as viscous as Hydrazine or water).

Once the propellant reaches the tip of each carbon nanotube, the applied electric field ionizes the propellant and accelerates it out at a high efficiency and very low flow rate (approximately 2 nanograms per second, split across many thousands of carbon nanotube emitters).

Scenarios leading to the formation of significant droplets (on the order of a gram) are nearly impossible to imagine, as the fundamental structure of the electrospray thrusters is unpressurized and propellant is only emitted after ionization and acceleration by electric fields at the tips of each carbon nanotube. The high fluid viscosity and exceptionally fine mesh structure of the capillaries likewise prevents fluid emission outside of powered electrospray operation.

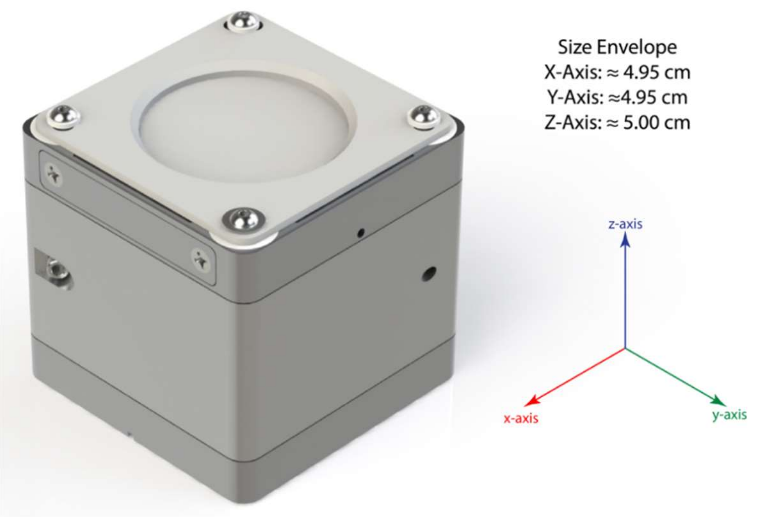

Figure 1: thruster head

Failure cases involving MMOD impacts would disperse or combust the propellant and therefore are not a credible path for the release of a 6 gram droplet. The overall exposed surface area of the propellant is likewise miniscule due to the carbon nanotube lattice structure, which also mitigates evaporation of the propellant when not in operation.

If a droplet of propellant as a complete compound were to be released (i.e., worst case scenario where front emitter face suddenly does not exist), the full fuel load of 6 grams would result in a sphere approximately 1 cm in radius. Simulation of evaporation of this sphere was undertaken to understand its lifetime, using conservative assumptions where possible (in addition to the conservative assumption of complete containment failure of the ASCENT propellant and a single sphere forming from the resultant free-flying liquid).

The governing equation is based on the Maxwell droplet evaporation model, assuming quasi-steady evaporation/diffusion from the surface of a liquid droplet into an ambient environment. Assume that the droplet exists in a thermodynamic equilibrium state at 20C (balance solar irradiation with evaporation energy loss). Evaporation is not in equilibrium, as it would be in a sealed container, due to the assumed zero ambient pressure environment, but the thermal effects should rapidly equilibrate when not in eclipse. This can be written as:

$$\frac{\mathrm{d}m_{\mathrm{p}}}{dt} = -\frac{2\pi d_{\mathrm{p}} D_{\mathrm{v}} M_{\mathrm{v}}}{RT}(p_{\mathrm{v,\,s}} - p_{\mathrm{v,\,a}})$$

Without accounting for eclipses where reduced temperature would significantly curtail evaporation, a few hours of sunlight are expected to result in evaporation of this droplet. In practice this is equivalent to sun exposure time, but is also likely to be accelerated by the LEO plasma environment and vacuum UV light causing accelerated ionization and decomposition of the droplet into non-hazardous vapor, which will decompose to water, and oxides of nitrogen and carbon.

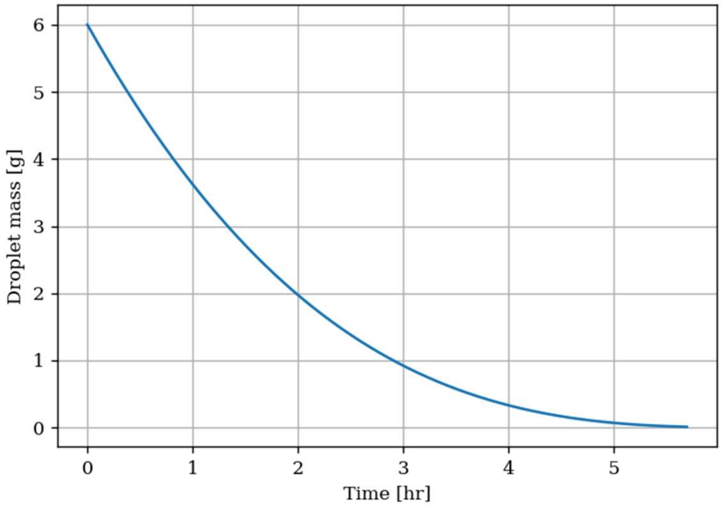

Figure 2: Total thruster head volume evaporation time

4. *Please expand on the use of automatic aborts and impacts to trajectory screening provided by the 18th Space Defense Squadron ("SDS").*

Regarding screening maneuvers and SDS, Atomos will screen the desired trajectory Meson will take to rendezvous and dock with Gluon. Additionally, planned abort rendezvous maneuvers, to support potential aborts, will be screened for conjunction analysis with the SDS. With these nominal and off-nominal planned maneuvers screened and cleared Atomos will then submit our nominal trajectory as operational per the "Spaceflight Safety Handbook for Satellite Operators" by the SDS. If an abort is performed, then the appropriate screened trajectory will be immediately submitted as operational.

There is a small amount of variability in when an automatic abort could occur that results in a manifold of trajectories that can be taken from the approach trajectory to the safe staging trajectory forward of Gluon in the line of flight. It is important to remember that all of these trajectories remain within 5 km of Gluon's nominal/stable trajectory, so the level of variability is less than 5 km total. This variability is further managed by providing a covariance matrix to SDS that is built up from the sampling of possible abort paths taken from the approach to the staging trajectories. This ensures that all possible paths are represented in a statistical sense and the abort design is effectively screened by the SDS prior to engaging in the docking attempt.

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

Respectfully submitted,

/S/ Will Lewis

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CC:

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