Space Sciences and Engineering (dba PlanetiQ)

15000 West 6th Avenue
Suite 202
Golden, Colorado 80401

September 29th, 2020

Mr. Douglas Young
Spectrum Coordination Branch
Office of Engineering and Technology
Federal Communications Commission

Re: Response for Request for Information – Email dated September 1, 2020.

Dear Mr. Young,

These appendices provide responses to the request for information for file # 0504-EX-CN-2020, NG 242014 in your email dated September 1, 2020. Please reference:

Item 1: Correct the 3 fatal errors in the Spacecap file.

PlanetiQ Response:
The initial Spacecap filed was run under ITU software version 8. The errors noted seem to be a result of the release of ITU software version 9 verification code, not the SpaceCap file. The Spacecap was re-run using ITU version 9 and has been uploaded to the FCC license portal. Note from ITU 9/25/20: "There is a bug in Validation if the hour is less than 10. I did the correction and the release will be available probably in one week. If you need to submit the filing before then you can send it with the fatal error mentioning that it is a bug in validation."

Item 2: Provide an EMC analysis.

PlanetiQ Response:
An updated analysis was coordinated with John Kennedy via phone discussions and email exchange. The official response was sent directly to Mr. Kennedy via email dated September 17, 2020 (letter attachment shown in Appendix A) and forwarded to the USAF.

Item 3: Complete the attached additional data form for ITU submission

PlanetiQ Response:
The initial Spacecap filed was run under ITU software version 8. The errors noted seem to be a result of the release of ITU software version 9 verification code, not the Spacecap file. The Spacecap was re-run using ITU version 9 and has been uploaded to the FCC license portal. Note from ITU 9/25/20: "There is a bug in Validation if the hour is less than 10. I did the correction and the release will be available probably in one week. If you need to submit the filing before then you can send it with the fatal error mentioning that it is a bug in validation."

ODAR-related questions:

Item 1: The launch mass is stated to be 40kg with a dry mass of 39.58kg. The reentry mass used for all DAS-related calculations is 36kg. Please provide additional information for these mass numbers.

PlanetiQ Response:

Launch Mass:	40 kg (includes 8" motorized light band deploy mechanism 3.58 kg)
Post-Sep Mass:	36.42 kg
Indium (Thrusters):	.42 kg (.21 kg ea. x 2) Station-keeping
Dry Mass:	36 kg (40 - 3.58 - .42)
Re-Entry:	36 kg

This information is also updated in the ODAR (V2), page 7, section 2; uploaded to the FCC license portal.

Item 2: Provide the station-keeping tolerances for the spacecraft.

PlanetiQ Response:

Clarification on orbit and station-keeping tolerances was coordinated with John Kennedy via phone discussions and email exchange. The official response was sent directly to Mr. Kennedy via email dated September 16, 2020 and forwarded to NASA. Please reference:

LTAN / LTDN 9:00 am / 9:00 pm (+/-15 mins)
Parking/transfer orbit range: Apogee: 525 km; Perigee: 525 km (+/- 20km)
Inclination: Sun-synchronous inclination: 97.5 degrees at launch, 98.0 degrees operational;
Nominal operational case: Apogee: 650 km; Perigee: 650 km (+/- 20km)
All GNOMES have an on-board propulsion system for station-keeping:
Note on 750 km orbit reference – not for this license submission or the GNOMES-2 satellite
This information is also updated in the ODAR (V2), page 6, section 1; FCC license portal.

Item 3: There are no collision risk calculations provided for post operational decay of the satellite. Please provide collision risk calculations for the timeframes consisting of the planned orbit-lowering (EOL maneuvers) and the worst-case EOL scenario (no EOL maneuvers.)

PlanetiQ Response:

The collision risk probability for GNOMES-2:
Injection orbit: 525 km SSO for 18 months (station keeping maneuvers): 1.75E-06
*Operational orbit:*650 km SSO for 7 years and de-orbit (planned EOL maneuvers): 1.59E-05
Worst-case EOL scenario: 650 km SSO de-orbit, natural decay, 25 yrs. (no EOL maneuvers.): 4.64E-05
This information is also updated in the ODAR (V2), page 13, section 5; uploaded to the FCC license portal.

Item 4: The DAS logs indicate all calculations were performed using 2021 as the start date, including the timeframe after the initial 18-month checkout period when the spacecraft raises its orbit to 650km. Please redo any calculations that used an incorrect start date, including the period after the 18-month checkout period and once the spacecraft is no longer performing station-keeping.

PlanetiQ Response:

The calculations were re-run using 2020 as the start date. The DAS logs are included in Appendix B.

This information is also updated in the ODAR (V2), pages 18-23, section 9; uploaded to the FCC license portal.

Best Regards,

Daniel P. Smith
VP - Operations

Appendix A – Letter to John W. Kennedy

15000 West 6th Avenue Suite 202
Golden, Colorado 80401

September 17th, 2020

John W. Kennedy
Chief, Spectrum Coordination Branch
Office of Engineering and Technology
Federal Communications Commission

Re: Request for Information – Emails dated September 15, 2020.

Dear Mr. Kennedy,

This appendix provides responses to the request for information for file # 0504-EX-CN-2020, NG 242014.

Please reference:

USAF Request: Power Flux Density as a function of elevation angle from 0 to 90 degrees and satellite to Geo: (see table 2.4-3 below)

PlanetiQ Response:
GNOMES-2 will carry a single X-band transmitter to downlink data and conduct telemetry, tracking, and command (space-to-Earth). This transmitter is the SDR-X model supplied by Blue Canyon Technologies (BCT), with transmission characteristics described by Table 2.4-1 and in Form 442.

Table 2.4-1. BCT SDR-X X-band transmitter description

	Non-geostationary
Action frequency	8.260 GHz
Maximum output power	2.0 W
ERP	3.85 W
Mean/Peak	Peak
Frequency Tolerance	4 ppm
Emission Designator	20M0G1D
Modulating signal	10000000 baud OQPSK

The X-band and S-band antennas are designed and supplied by Haigh-Farr Inc. Both are nearly hemispherical in their gain patterns and are nadir-pointed. For both antennas, the gain is generally constant and varies between 0 and 5 dBi over Earth coverage angles.

A link budget can be formed from the transmitter characteristics shown in Table 2.4-1 and the expected X-band antenna coverage. The power flux density (PFD) at the maximum gain (5 dB) is calculated to be -119.2 dB(W/m^2) over the total bandwidth of the transmitter at the injection altitude of 525 km and -120.5 dB(W/m^2) at the nominal operational altitude of 650 km. Therefore, the largest PFD resulting from the X-band transmitter on GNOMES-2 will be -132.3

dB(W/m^2·MHz) or at the reference 4kHz bandwidth, it will be -158.4 dBW/m^2 at the sub-satellite point from 650 km, a value that is well below the recommendation given by the ITU[1].

The ITU also recommends the following limits of PFD from space stations as received at the Earth's surface[2]. These limits relate to the PFD obtained only under free-space path loss conditions and a 4 kHz bandwidth.

Table 2.4-2. ITU PFD limits at the Earth's surface

Frequency band	**Service**	**Limit in dB(W/m^2) for angles of arrival (δ) above the horizontal plane**			**Reference bandwidth**
		0°-5°	5°-25°	25°-90°	
8025-8500 MHz	Earth exploration satellite (space-to-Earth) Space research (space-to-Earth)	-150	-150 + 0.5(δ-5)	-140	4 kHz

Table 2.4-3. GNOMES-2 Peak Power Flux Density from 650km to Earth, and from 650km to GSO (if pointing up, vs. pointing to the Earth).

	650km to Earth	**650km to GSO**
Peak Power Density/Hz	1.925E-07W/Hz	1.925E-07W/Hz
Peak Power Density/4kHz	0.00077W/4kHz	0.00077W/4kHz
Peak Power Flux Density (4kHz)	-158.4 dBW/m**2	-193.05 dBW/m**2
Peak Power Flux Density (20MHz bandwidth)	-121.6 dBW/m**2	-156.06dBW/m**2

Note: Reference Appendix 1 for equations and data used

The PFD produced by GNOMES-2 satisfies the ITU PFD limits at all angles of arrival and possible altitudes, with over 10 dB of margin. In addition, the BCT X-band radio is adjustable on orbit, allowing PlanetiQ to control the PFD levels during all phases of the mission.

Finally, the ITU specifies a maximum allowable interference power spectral flux-density at Earth's surface of -255.1 dB(W/m^2·Hz) to protect earth-station receivers in the deep-space research band of 8.40-8.45 GHz[3]. The chosen data rate and center frequency for the X-band transmission on GNOMES-2 should guarantee that no close-in side lobes are within the deep space band. Additionally, the chosen ground stations, described in Section 2.4.2, are sufficiently far from Deep Space Network (DSN) stations that GNOMES-2 can avoid downlink operations while within sight of a DSN station (see Figure 2.4-2).

[1] Rec. ITU-R SA.1810
[2] ITU Radio Regulations Table 21-4
[3] ITU-R SA-1157

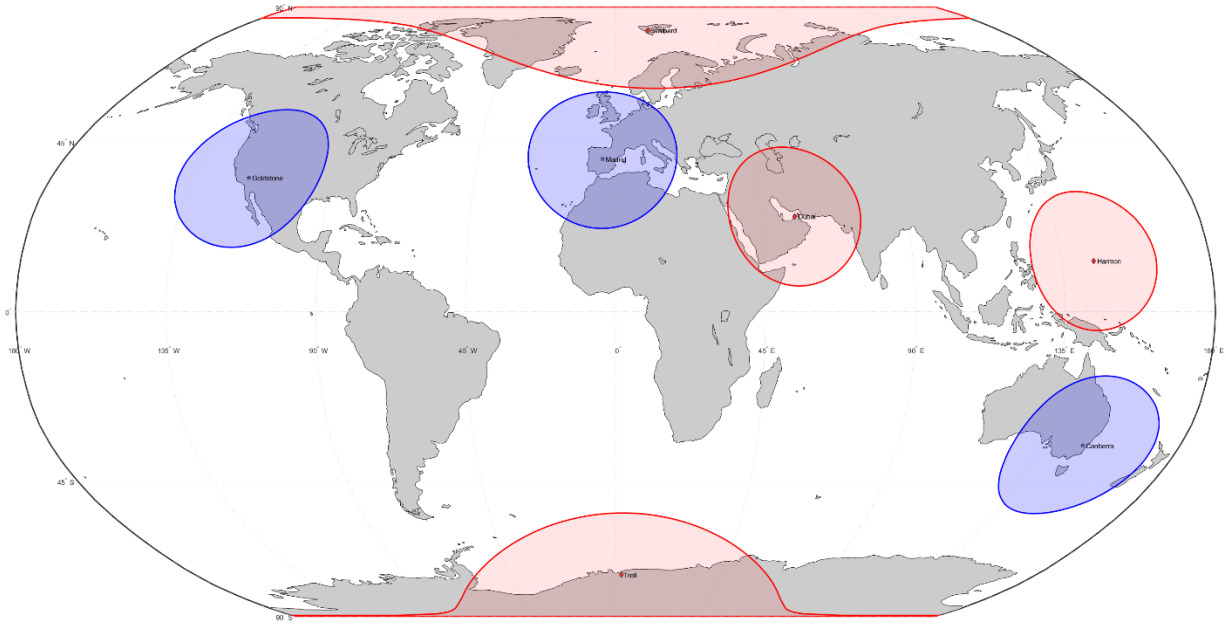

Figure 2.4-1. Transmission footprints for the possible ground stations for GNOMES-2 (in red) showing no overlap with DSN station (in blue).

Under contingency operations, the downlink data rate for GNOMES-2 will drop to 200 kbps, causing the power spectral flux density to approach the interference protection level of -255.1 dB(W/m^2·Hz) at the closest possible slant ranges to the DSN stations. Under these uncommon conditions, PlanetiQ plans to lower the X-band radio transmit power to abide by ITU recommendations.

Thank you for facilitating this effort.

Best Regards,

Daniel P. Smith
VP - Operations

Appendix 1 – Equations and Data used

Power Densities at transmit antenna

At the Source: PD = Power/Occupied Bandwidth (per Hz)

PD(Hz) = 3.85 watts /20,000,000 Hz = 1.925E-07 watts/Hz

PD(4kHz) = 1.925E-07 * 4000 = 0.00077W/(4kHz)

Power Flux Densities

Power Flux Density (PFD) (650km) =

PFD = Power at Transmit antenna /(4*pi*distance**2) in watts/m**2

PFD = 3.85W/(4*pi*650km*650km) = 6.969 E-13 W/m**2 or -121.6 dBW/m**2

(note, convert km to meters)

Power Flux Density 4 kHz (650km) = -158.4 dBW/m**2

Worst Cast PFD at GSO, is if we pitch up and point our downlink antenna up to point at GSO's

Power Flux Density GSO (35135.9 km above 650km)

PFD(20MHz@GSO)=3.85W/(4*pi*35135.9km*35135.9km)

Power Flux Density 20MHz = -156.06 dBW/m**2

Power Flux Density 4kHz = -193.05 dBW/m**2

Appendix B – DAS Logs (Start date 2020)

09 21 2020; 14:36:59PM Processing Requirement 4.5-1: Return Status: Passed

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

INPUT

Space Structure Name = GNOMES_2
Space Structure Type = Payload
Perigee Altitude = 525.000 (km)
Apogee Altitude = 525.000 (km)
Inclination = 97.500 (deg)
RAAN = 0.000 (deg)
Argument of Perigee = 0.000 (deg)
Mean Anomaly = 0.000 (deg)
Final Area-To-Mass Ratio = 0.0160 (m^2/kg)
Start Year = 2020.800 (yr)
Initial Mass = 40.000 (kg)
Final Mass = 36.420 (kg)
Duration = 1.500 (yr)
Station-Kept = True
PMD Perigee Altitude = 1.000 (km)
PMD Apogee Altitude = 1.000 (km)
PMD Inclination = 0.000 (deg)
PMD RAAN = 0.000 (deg)
PMD Argument of Perigee = 0.000 (deg)
PMD Mean Anomaly = 0.000 (deg)

OUTPUT

Collision Probability = 1.7501E-06
Returned Message: Normal Processing
Date Range Message: Normal Date Range
Status = Pass

==========

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

09 22 2020; 12:43:21PM Processing Requirement 4.5-1: Return Status: Passed

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

INPUT

Space Structure Name = GNOMES_2
Space Structure Type = Payload
Perigee Altitude = 650.000 (km)
Apogee Altitude = 650.000 (km)
Inclination = 98.000 (deg)
RAAN = 0.000 (deg)
Argument of Perigee = 0.000 (deg)
Mean Anomaly = 0.000 (deg)
Final Area-To-Mass Ratio = 0.0160 (m^2/kg)
Start Year = 2020.800 (yr)
Initial Mass = 36.420 (kg)
Final Mass = 36.000 (kg)
Duration = 7.000 (yr)
Station-Kept = True
PMD Perigee Altitude = 90.000 (km)
PMD Apogee Altitude = 650.000 (km)
PMD Inclination = 98.000 (deg)
PMD RAAN = 0.000 (deg)
PMD Argument of Perigee = 0.000 (deg)
PMD Mean Anomaly = 0.000 (deg)

OUTPUT

Collision Probability = 1.5886E-05
Returned Message: Normal Processing
Date Range Message: Normal Date Range
Status = Pass

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

09 21 2020; 16:03:40PM Processing Requirement 4.5-1: Return Status: Passed

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

INPUT

Space Structure Name = GNOMES_2
Space Structure Type = Payload
Perigee Altitude = 650.000 (km)
Apogee Altitude = 650.000 (km)
Inclination = 98.000 (deg)
RAAN = 0.000 (deg)
Argument of Perigee = 0.000 (deg)
Mean Anomaly = 0.000 (deg)
Final Area-To-Mass Ratio = 0.0160 (m^2/kg)
Start Year = 2020.800 (yr)
Initial Mass = 36.420 (kg)
Final Mass = 36.000 (kg)
Duration = 25.000 (yr)
Station-Kept = False
Abandoned = True

OUTPUT

Collision Probability = 4.6411E-05
Returned Message: Normal Processing
Date Range Message: Normal Date Range
Status = Pass

==========

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

09 24 2020; 12:45:36PM Processing Requirement 4.6 Return Status : Passed

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

INPUT

Space Structure Name = GNOMES_2
Space Structure Type = Payload

Perigee Altitude = 650.000000 (km)
Apogee Altitude = 650.000000 (km)
Inclination = 98.000000 (deg)
RAAN = 0.000000 (deg)
Argument of Perigee = 0.000000 (deg)
Mean Anomaly = 0.000000 (deg)
Area-To-Mass Ratio = 0.016000 (m^2/kg)
Start Year = 2020.800000 (yr)
Initial Mass = 36.420000 (kg)
Final Mass = 36.000000 (kg)
Duration = 7.000000 (yr)
Station Kept = True
Abandoned = True
PMD Perigee Altitude = 650.000000 (km)
PMD Apogee Altitude = 650.000000 (km)
PMD Inclination = 98.000000 (deg)
PMD RAAN = 0.000000 (deg)
PMD Argument of Perigee = 0.000000 (deg)
PMD Mean Anomaly = 0.000000 (deg)

OUTPUT

Suggested Perigee Altitude = 650.000000 (km)
Suggested Apogee Altitude = 650.000000 (km)
Returned Error Message = Passes LEO reentry orbit criteria.

Released Year = 2047 (yr)
Requirement = 61
Compliance Status = Pass

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========== End of Requirement 4.6 ==========