Application for Experimental License

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I. Mission Summary

By this application, Blue Origin, LLC ("Blue Origin") seeks Federal Communications Commission ("FCC") authorization to conduct a demonstration satellite mission, DarkSky-1 ("DS-1"). The DS-1 mission is partially funded by the United States Government, Washington Headquarters Services, under Agreement No. HQ00342190001, a 10 U.S.C. § 4022 (formerly 2371b) prototype Other Transaction award for the "Multi-Orbital Logistics" Area of Interest. Through the Defense Innovation Unit ("DIU"), the sponsoring Government entity, the Department of Defense ("DoD") is seeking commercial space logistics services to enable low cost, responsive access to orbits beyond low Earth orbit ("LEO"). Blue Origin, DIU, and the U.S. Space Force's Space Systems Command's Launch Enterprise Mission Manifest Office have selected the DS-1 mission as a pathfinder logistics mission opportunity that will demonstrate the integration of Blue Origin's first logistics flight system, with the primary objective as performing in-flight validation of the DS-1 Telemetry, Tracking, and Command ("TT&C") hardware and ground-based radiometric tracking.

The DS-1 mission will also serve as a risk reduction activity for future Blue Origin missions. The lessons learned from the DS-1 mission will be used to ultimately provide greater access to near-earth and cis-lunar space, furthering Blue Origin's vision of millions of people living and working in space for the benefit of Earth. For these reasons, Blue Origin submits that the public interest would be served by grant of the application.

The DS-1 flight system, comprised of Blue Origin avionics equipment, is expected to be launched as a non-separable, secondary payload on the upper stage of a National Security Space Launch-class launch vehicle ("LV") with an expected launch date in Q4 2024. The mission will be an elliptical medium Earth orbit ("MEO") of approximately 21000 km apogee, 2500 km perigee, at an inclination of 55 degrees. The DS-1 flight system will be independent from the LV upper stage, with separate power, communications, and avionics systems. After separation of the unrelated primary payload, the LV upper stage will send an activation signal to the DS-1 flight system but will not have any control over the operation of the DS-1 experiment. Likewise, DS-1 will not be able to control the LV upper stage. Following primary payload separation, DS-1's onboard omnidirectional antennas will be autonomously initiated to downlink via radio frequency real-time equipment health status to the ATLAS ground stations. The DS-1 mission duration will be no greater than 12 hours, concluding when the DS-1 flight system's battery is depleted. At the conclusion of the LV upper stage's mission, the LV upper stage with the DS-1 flight system will be decommissioned according to the LV managed disposal plan.

The Blue Origin DS-1 flight operators will handle operational ground control of the DS-1 flight system at Blue Origin's Orbital Launch Site in Merritt Island, Florida. For the duration of the DS-1 mission, there will be communication with the DS-1 flight system, with the DS-1 flight operators demonstrating the capabilities of the flight system. Regular communication sessions will be scheduled based on DS-1's orbital passes over the ground stations at intervals that meet mission requirements. The DS-1 flight operators will monitor the health and status of the DS-1 flight system during these passes. Additionally, the ground stations will establish an uplink carrier to support ranging as well as commanding to the DS-1 flight system, as needed. As stated above, the DS-1 flight system does not control the LV upper stage and will not be "flying" any

space object. The mission is intended to demonstrate the space-to-ground interfaces between the flight system and ground, via Blue Origin avionics equipment.

Because the DS-1 system will not separate from the LV upper stage, the launch provider's Federal Aviation Administration's launch license is expected to address any orbital debris mitigation matters required by 47 C.F.R. § 5.64(b).

II. Communications Systems

The DS-1 system spacecraft will operate in the S-band (2025-2110 MHz) for space operations (Earth-to-space) and in the X-band (8025-8300 MHz) for space operations (space-to-Earth). *See* Table 1 below. Blue Origin is aware that there are federal and other operations in the S-band and X-band frequencies and intends to share information regarding its proposed operations with affected federal operators prior to operations to mitigate potential interference. Attached to this application in Exhibit B are the antenna gain contours for all the transmit and receive antenna beams.[1]

Blue Origin will operate the DS-1 mission on an unprotected and non-harmful interference basis. The Blue Origin flight operators will monitor the DS-1's transmission and adjust operations as necessary to avoid interference. Additionally, as discussed below, harmful interference is unlikely due to the (i) brief duration of the mission (i.e., less than 12 hours), and (ii) coordination of federal frequency use.

The relevant ground stations are provided as Exhibit A.

Table 1. Radio frequency plan

	Ranging Downlink	**Ranging Uplink**
Band	X-band	S-band
Frequency Range	8025-8300 MHz	2025-2110 MHz
Center Frequency[2]	8123.077 MHz	2040 MHz
Bandwidth	1.4 MHz	2.0 MHz
Modulation	PCM/PSK/PM + subcarrier TLM	PCM/PSK/PM + subcarrier CMD
Data Rate	2 kbps on 1.024 MHz subcarrier	2 kbps on 16 kHz subcarrier
Transmit RF Power	5 W per antenna (10W total)	100 W
Transmit Antenna Gain	6.98 dBi	41 dBi
Transmit Antenna EIRP	46.98 dBm	91 dBm

[1] *See* Attachment B. For some gain contour plots, the contours at the lower gains are beyond the horizon (or do not exist) and are not shown in the plots.

[2] The identified center frequencies are representative frequency channels. As a result of spectrum discussions with federal spectrum managers, Blue Origin may select another channel within the identified frequency bands for its operations.

Receive Antenna Gain	53 dBi	7.98 dBi
Receive Antenna G/T	31 dB/K	-25 dB/K
Max Transmission Duration per Pass	5 hours	5 hours
Duty Cycle	Continuous downlink	Continuous Uplink

Blue Origin respectfully requests a waiver for Section 5.115 of the Commission's Rules, which requires that experimental stations transmit the call sign at the end of each transmission in either clear voice or Morse code. The equipment does not have the ability to do so. Also, the equipment maximizes the full duration of the downlink communication time. Blue Origin understands the intent of the rule requiring station identification is a means to allow others to trace unwanted interference and assumes that Blue Origin's planned federal frequency coordination process will reduce the likelihood of unwanted interference. As such, Blue Origin submits a waiver is warranted here.

i. 2025-2110 MHz (Earth-to-space)

The 2025-2110 MHz (Earth-to-space) band is allocated internationally and in the U.S. for Earth exploration-satellite service ("EESS") and space research for non-Federal use, subject to conditions as may be applied on a case-by-case basis and the limitation that any use may not cause harmful interference to authorized Federal and non-Federal operations.[3] The 2025-2110 MHz (Earth-to-space) band is also allocated to space operations internationally and for federal operators in the U.S.[4] The DS-1 mission spectrum use is generally consistent with the domestic and international Table of Frequency Allocations. DS-1 will operate in the 2025-2110 MHz band for space operations mostly outside the U.S. (and at two U.S. ground stations). Additionally, because the DS-1 mission is a pathfinder logistics mission aimed to help develop access to orbits beyond LEO under a U.S. Government prototype Other Transaction award, the DS-1 mission spectrum use should qualify as space research.

Moreover, use of this band can and will be coordinated with federal operators ensuring that operations will not cause harmful interference to federal operators. Additionally, sharing of spectrum will be possible because the DS-1 will operate only for a short period of time, and other satellites using these frequencies transmit and receive only in short periods of time while visible to a receiving/transmitting earth station main beam. For harmful interference to occur, satellites belonging to different systems would have to be visible to the earth station and transmitting or receiving using the same frequencies at the exact same time. In such an unlikely event, the resulting inline interference could be avoided by coordinating with federal satellite transmissions so that they do not occur simultaneously. Accordingly, mutual exclusivity between DS-1 and other systems using the same frequency band is unlikely.

[3] *See* 47 C.F.R. § 2.106 n.US347.

[4] *See* 47 C.F.R. § 2.106.

ii. 8025-8300 MHz Downlink (space-to-Earth)

The 8025-8300 MHz (space-to-Earth) band is allocated internationally and in the U.S. for EESS on a primary basis for non-Federal use, subject to conditions as may be applied on a case-by-case basis.[5] Blue Origin would use these frequencies on an unprotected and non-harmful interference basis. Through the operational measures identified in this section, and due to the limited use of these frequencies, Blue Origin expects that its use of these frequencies will not cause harmful interference to authorized users.

Power Flux Density at the Surface of the Earth in the band 8025-8400 MHz

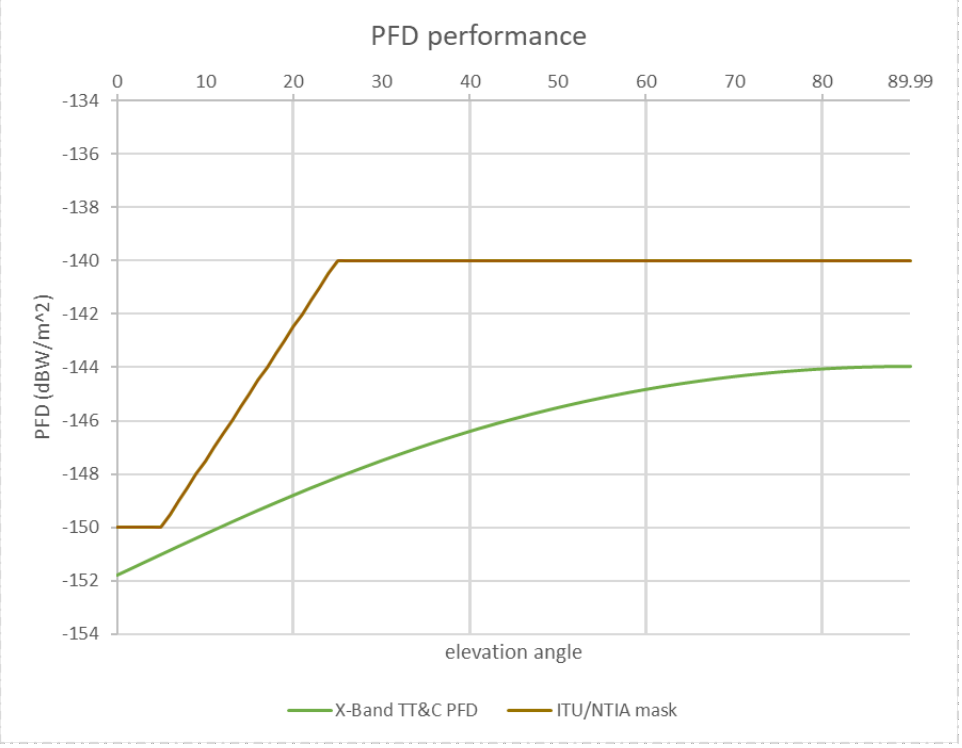
Table 21-4 of the ITU Radio Regulations states that the power flux density ("PFD") at the Earth's surface produced by emissions from an EESS in the 8025-8500 MHz band, for all conditions and methods of modulation, shall not exceed the following values:

Table 2. Maximum PFD in 8025-8400 MHz band, as a function of elevation angle, in a 4 kHz bandwidth

0-5 deg	-150 dB(W/m^2)
5-25 deg	-150 + 0.5*(el – 5) dB(W/m^2)
25-90 deg	-140 dB(W/m^2)

DS-1 has the following PFD values:

Figure 1. DS-1 PFD values as a function of elevation angle



[5] *See* 47 C.F.R. § 2.106 n.US258.

As shown in Figure 1 above, DS-1's PFD values are within the acceptable limits of Table 21-4 of the ITU Radio Regulations.

Power Flux Density at the GSO arc in the band 8025-8400 MHz

No. 22.5 of the ITU Radio Regulations specifies that in the frequency band 8025-8400 MHz, which the EESS (using non-geostationary satellites) shares with the Fixed-Satellite Service (FSS) (Earth-to-space) and the meteorological-satellite service (Earth-to-space), the maximum PFD produced at the geostationary satellite orbit (GSO) by any EESS space station shall not exceed -174 dB(W/m2) in any 4 kHz band. See ITU Radio Regulations, Article 22, Section 4. The calculation below shows that the PFD produced by the transmissions from the TT&C transmitter on DarkSky-1 does not exceed the limit in No. 22.5 under nominal operating conditions.

The PFD at the GSO produced by the DarkSky-1 X-band transmission is:

$$PFD = EIRPD(\phi) - 10log(4 * \pi * d^2)$$

where:

$EIRPD(\phi)$: the DarkSky-1 EIRP density in the direction of the GSO arc at off-axis angle ϕ with units in dBW/4 kHz, and,

d: the distance, in meters, between DarkSky-1 and the GSO arc.

Since the GSO arc will be visible to the DarkSky-1 satellite at many off-axis angles, two representative calculations are performed based on the nominal operating behavior of the DarkSky-1 satellite. Under nominal operations, the X-band antenna beam peak will be pointed toward the Earth such that the off-axis gain in the direction of the GSO arc will be less than the beam peak gain.[6] The limb of the Earth column represents the highest off-axis antenna gain, but maximum distance, toward the GSO arc while the backlobe represents a low off-axis antenna gain, but minimum distance toward the GSO arc. In both cases, the PFD limit is met with margin to spare.

Table 3. Maximum PFD at GSO arc in 8025-8400 MHz band at three representative off-axis angles.

	Limb of Earth	Backlobe
EIRP Density [dBW/4kHz]	-9.9	-25.4
Distance to GSO [km]	68300	14789
Spreading Loss [dB]	167.7	154.4
Max PFD in 4kHz at GSO [dB(W/m^2)/4kHz]	-177.6	-179.8
PFD limit in 4kHz at GSO [dB(W/m^2)/4kHz]	-174	-174
Margin to limit	3.6	5.8

[6] *See* Exhibit B for the X-band antenna pattern data.

Sharing with other non-Federal Systems

As explained above, shared use of these frequencies can be readily accomplished, and harmful interference is unlikely.