**ATTACHMENT A**
**Technical Description**

## A.1 SCOPE AND PURPOSE

This Technical Description provides the Federal Communications Commission ("Commission") with the technical characteristics of Arcturus, a small geostationary orbit ("GSO") fixed-satellite service ("FSS") satellite, as required by 47 C.F.R. §25.114 and other Part 25 rules.[1]

## A.2 GENERAL DESCRIPTION

The Arcturus satellite was manufactured by Astranis Space Technologies Corp. ("Astranis") and will be operated by Astranis Projects USA LLC ("Astranis USA"), a wholly owned subsidiary of Astranis.[2] The Arcturus satellite will be operated at the 163° W.L. orbital location and will provide high-speed, satellite-based connectivity to fixed and mobility (earth stations in motion or "ESIMs") terminals located in Alaska and the surrounding Pacific region, including western Canada and adjacent air and maritime routes.

The gateway earth station supporting the provision of services will be located in Utah.[3] On-station TT&C communications will also be supported by this earth station. TT&C operations will be conducted remotely by Astranis through the gateway earth station. Transfer orbit and emergency/back-up TT&C will be conducted through Intelsat earth stations pursuant to appropriate FCC authority.

## A.3 SPACE STATION TRANSMIT AND RECEIVE CAPABILITY

The Arcturus satellite will support Ka-band user terminal operations using the 18.2-19.3 GHz and 19.7-20.2 GHz (space-to-Earth) bands and 28.0-29.1 and 29.3-30.0 GHz bands (Earth-to-space) in Alaska, western Canada, and the adjacent Pacific Ocean region. Astranis will conduct gateway operations with a single Utah teleport facility using the 18.2-19.3 GHz. 19.3-19.4 GHz, and 19.6-20.2 GHz (space-to-Earth) bands and 28.0-29.1 and 29.25-30.0 GHz (Earth-to-space) bands.

Use of the 18.2-18.3 GHz downlink band will be on a secondary basis with respect to terrestrial services and U.S. government services in the United States. Use of the 18.3-18.6 GHz band will be on a primary basis and Arcturus' gateway and user downlink operations will be consistent with applicable operational requirements and power limits. Operations of the Arcturus satellite in all spectrum used between 18.2 GHz and 19.7 GHz will comply with the

[1] This information is essentially identical to that submitted by Astranis Bermuda Ltd. ("Astranis Bermuda") in support of its petition, as amended, to serve the U.S. market using the Arcturus satellite. *See* Astranis Bermuda Ltd., Petition for Declaratory Ruling, File Nos. SAT-PPL-20210607-00075 and SAT-APL-20210921-00125, Call Sign S3092 (granted February 3, 2022) ("Arcturus Market Access Grant").

[2] For ease of reference, Astranis and Astranis USA will be collectively referred to as "Astranis."

[3] *See* Pacific Dataport Inc., File No. SES-LIC-20200925-01038, Call Sign E202162 (granted Nov. 16, 2020); *see also* File No. SES-MFS-20211013-01714, Call Sign E202162 (pending).

PFD limits set forth in 47 C.F.R. §25.208(c).[4]

Use of the 18.8-19.3 GHz band will be on a secondary basis with respect to non-geostationary ("NGSO") FSS systems authorized to provide services to the United States.

Use of the frequency band 28.0-28.35 GHz will be on a secondary basis with respect to terrestrial services in the United States. Use of the frequency band 28.6-29.1 GHz will be on a secondary basis with respect to NGSO FSS systems authorized to provide services to the United States.

The operations of the Arcturus space station to and from the United States and associated earth stations in the 18.3-18.8 GHz, 19.7-20.2 GHz, 28.35-28.6 GHz, and 29.25-30.0 GHz frequency bands must comply with the applicable power flux density (PFD) limits in 47 C.F.R. §25.140(a)(3)(iii) of the Commission's rules, and associated uplink operations must not exceed the applicable equivalent isotropically radiated power density envelopes in 47 C.F.R. §25.218(i) unless the non-routine uplink and downlink operation is coordinated with operators of authorized co-frequency space stations at assigned locations within 6 degrees of the 163º W.L. orbital location involving approved communications with U.S.-licensed earth stations. If a co-frequency satellite is assigned an orbital location that is less than two degrees from the assigned Arcturus location, pursuant to 47 C.F.R. §25.140(a)(2), Astranis will either coordinate or submit an interference analysis demonstrating compatibility of the systems.[5]

As required by 47 C.F.R. §25.114(c)(4)(vii), the predicted antenna gain contours for typical transmit and receive beams are provided in GXT format in the corresponding Schedule S.

## A.4 FREQUENCY AND POLARIZATION PLAN

The Arcturus satellite frequency plan is provided in Figure 1, below.

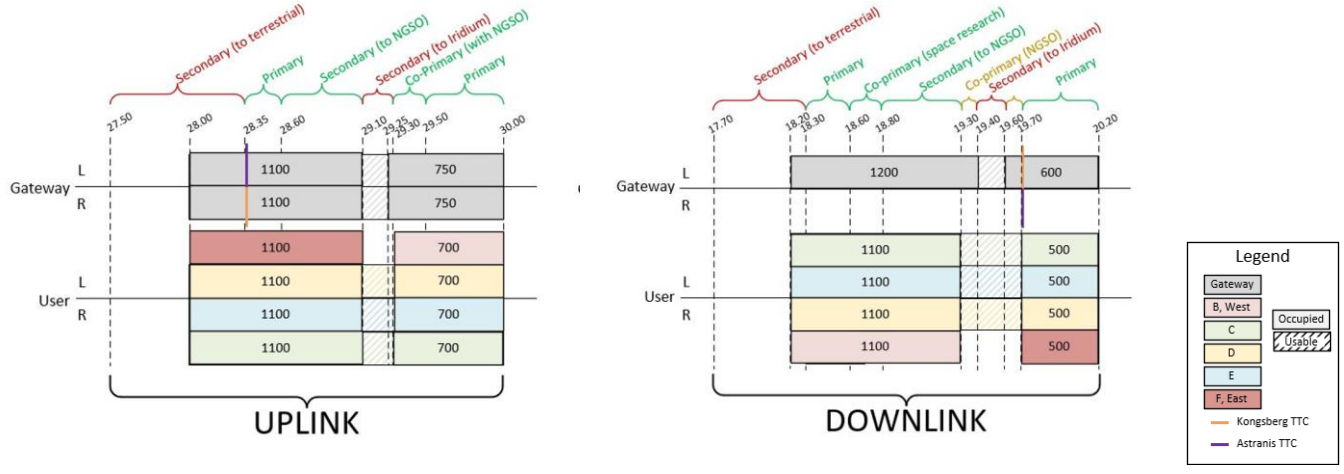


**Figure 1. Arcturus Frequency Plan**

[4] *See* Arcturus Market Access Grant at 2 (Condition 8.)

[5] *See* Arcturus Market Access Grant at 1-2 (Condition 6.)

## A.5 DESCRIPTION OF SYSTEM FACILITIES, OPERATIONS AND SERVICES

A single teleport facility located in Utah will conduct gateway and TT&C communications. A single antenna in 9.4 m diameter range will be used for both types of communications. Transfer orbit and emergency/back-up TT&C will be conducted through Intelsat earth stations pursuant to appropriate FCC authority on the same frequency and using the same antenna as on-station TT&C.

A spot beam covering Utah will be used for gateway links and five spot beams covering Alaska and coastal cruise routes between Alaska and Seattle will be used for service links. Each spot beam will be capable of operating variable bandwidth transponders of at least 100 MHz within the two pairs of band segments described above, in one or two senses of circular polarization as detailed in the accompanying Schedule S.

Uplink transmissions will be digitally processed and can be routed to any downlink beam at any downlink frequency. The actual transponder bandwidth and beam interconnectivity will be configured by telecommand according to customer requirements. The satellite will employ a two-fold frequency re-use pattern such that any channel will be re-used multiple times by a combination of polarization and spatial isolation.

## A.6 CESSATION OF EMISSIONS

All downlink transmissions can be turned on and off by ground telecommand, thereby causing cessation of emissions from the satellite as required by 47 C.F.R. §25.207.

## A.7 POWER FLUX DENSITY AT THE EARTH'S SURFACE

47 C.F.R. §25.208(c) contains PFD limits that apply in the 18.2-19.3, 19.3-19.4 GHz and 19.6-19.7 GHz bands. The PFD limits of 47 C.F.R. §25.208(c) are as follows:

- -115 dB(W/m$^2$) in any 1 MHz band for angles of arrival between 0 and 5 degrees above the horizontal plane;
- -115 + 0.5 ($\delta$-5) dB(W/m$^2$) in any 1 MHz band for angles of arrival $\delta$ (in degrees) between 5 and 25 degrees above the horizontal plane; and
- -105 dB(W/m$^2$) in any 1 MHz band for angles of arrival between 25 and 90 degrees above the horizontal plane.

In addition, 47 C.F.R. §25.208(d) contains PFD limits that apply in the 18.6-18.8 GHz band produced by emissions from a space station under assumed free-space propagation conditions as follows:

- -95 dB(W/m$^2$) for all angles of arrival. This limit may be exceeded by up to 3 dB for no more than 5% of the time.

The maximum downlink EIRP that the Arcturus satellite can transmit in the Ka-band frequencies is 42.6 dBW in 1 MHz. The shortest distance from the satellite to the Earth is 35,786 km, corresponding to a spreading loss of 162.06 dB. Therefore, the maximum

possible PFD at the Earth's surface will not exceed -119.5 dBW/$m^2$/MHz at an elevation angle of 90°. This level is less than the -115 dBW/$m^2$/MHz PFD limit value that applies at elevation angles of 5° and below, and consequently compliance with the PFD limits in Section 25.208(c) is assured.

In addition, 47 C.F.R. §25.208(d) provides an additional aggregate PFD limit in the 200 MHz wide band 18.6-18.8 GHz of -95 dBW/$m^2$. In the worst case, this will correspond to a PFD limit of -118 dBW/$m^2$/MHz (*i.e.*, -95-10 $_{\log}$ (200)). As noted above, downlink transmissions from the Arcturus satellite cannot exceed -119.5 dBW/$m^2$/MHz at any angle of arrival, and therefore compliance with 47 C.F.R. §25.208(d) is also assured.

## A.8 KA-BAND TWO-DEGREE COMPATIBILITY

The Arcturus satellite will meet the Commission's two-degree spacing requirements. Uplink transmissions of the earth stations communicating with the Arcturus satellite will not exceed the off-axis EIRP density envelopes of 47 C.F.R. §25.218(i) and the Arcturus satellite will not generate PFD at the Earth's surface in excess of the limit of 47 C.F.R. §25.140(a)(3)(iii). If any non-routine uplink or downlink operations are contemplated, the Astranis will seek modification of its operating authority, will coordinate with operators of authorized co-frequency satellites at locations within six degrees, and otherwise will ensure compliance with 47 C.F.R. §25.140(d). Likewise, to the extent a co-frequency satellite is assigned an orbital location that is less than two degrees from the assigned Arcturus location, Astranis will either coordinate or submit an interference analysis demonstrating compatibility of the systems.[6]

The Arcturus satellite will operate in spectrum that may be subject to Section 25.140(a)(3)(vi). Since there are no commercial satellites operating within two degrees of Arcturus and providing CONUS coverage, the impact from the operations of hypothetical satellites having the same or worst case two-degree spacing operating characteristics as Arcturus located at 161° W.L. and 165° W.L. was analyzed. The results of this interference configuration are included in the link budget provided in Exhibit 1, below. Furthermore, separate C/I calculations were conducted for the two-degree spacing analysis and are provided in Exhibit 2, below.

## A.9 SHARING WITH NGSO FSS

In the United States, the 18.8-19.3 GHz and 28.6-29.1 GHz bands are designated for NGSO FSS operations on a primary basis and for GSO FSS operations on a secondary basis. Stations operating in a secondary service cannot cause harmful interference to or claim protection from harmful interference from stations of a primary service.

Astranis and its gateway earth station partner have made substantial progress coordinating with Ka-band NGSO FSS systems across a range of bands, including 18.8-19.3 GHz and 28.6-29.1 GHz. In the Arcturus Market Access Grant, the request to operate in the 18.8-19.3 GHz and 28.6-29.1 GHz bands was deferred pending completion of coordination or a demonstration of non-interference vis-à-vis co-frequency NGSO systems.[7] Astranis accepts that it will be subject to a similar deferral and similar conditions regarding potential access to these bands.

[6] *See* 47 C.F.R. § 25.140(a)(2).

[7] Arcturus Market Access Grant at 2-3 (Condition 11).

## A.10 SHARING WITH UMFUS

The 27.5-28.35 GHz (Earth-to-space) band, FSS is allocated on a co-primary basis with fixed and mobile services in band in the U.S. Table of Frequency Allocations. Pursuant to 47 C.F.R. §25.136(a), however, FSS is secondary to UMFUS in the band. An earth station operating in this band may operate consistent with the terms of its authorization and will not be required to take additional actions to provide interference protection to UMFUS licensees if it meets the requirements of 47 C.F.R. §25.136(a). Arcturus's gateway earth station operations in the 28.0-28.35 GHz (Earth-to-space) band will meet these requirements.

With respect to user terminal operations, appropriate earth station blanket license applications will address compliance with the requirements of 47 C.F.R. §25.136(a) and other FCC rules. Thus, the Commission can authorize Arcturus receive operations in this band subject to consideration and potential grant of relevant earth station blanket licenses.

## A.11 CARRIER FREQUENCY OF SPACE STATION TRANSMITTERS

Arcturus will comply with 47 C.F.R. §25.202(e).

## A.12 EMISSION LIMITATIONS

Arcturus will comply with 47 C.F.R. §25.202(f)(1), (2) and (3).

## A.13 TELEMETRY, TRACKING, AND COMMAND

Arcturus will comply with 47 C.F.R. §25.202(g)(1). Telemetry, tracking, and command ("TT&C") operations are planned to avoid interference and will be coordinated with potentially affected satellite networks. Specifically, Arcturus's transmissions will cause no greater interference and require no greater protection from harmful interference than the communications traffic on the satellite network. Astranis will also seek to coordinate with operators of authorized co-frequency space stations at orbital locations within six degrees of the assigned orbital location consistent with Section 25.202(g)(1).

TT&C communications will be supported by the Utah earth station described above.[8] TT&C operations will be conducted by Astranis. As required by Section 25.172 of the Commission's rules, this section provides contact details for the teleport facility:

LBISat LLC
1082 East 2400 North
Eagle Mountain, Utah 84005
Phone: (801) 501 9090
rusty@lbisat.com

Satellite control center addresses and telephone numbers:

[8] *See* File No. SES-LIC-20200925-01038, Call Sign E202162 (grant Nov. 16, 2020).

Astranis Control Center
575 20th Street
San Francisco, CA 94107

Short-term interference and emergency response contact:
Roshena MacPherson, Mission Operations and Ground Software Lead
Phone: 925-257-3617
Email: roshena@astranis.com

Long-term engineering and technical design contact:
Andrew Ramsey, Payload Engineer
Phone: 925-257-3615
Email: andrew@astranis.com

## A.14 STATE-OF-THE-ART FULL FREQUENCY REUSE

Arcturus will comply with 47 C.F.R. §25.210(f), as discussed in Section A.5 above. In particular, Arcturus will employ full-frequency reuse through both orthogonal polarization and spatial reuse of frequencies. As demonstrated in the Frequency Plan above, every unique pair of frequency and polarization is used by two beams (stacking), which allows for reuse of every set of frequencies. User beams will employ spatial isolation with one polarization to each beam, while the gateway will utilize dual polarization on the same beam.

***CERTIFICATION OF PERSON RESPONSIBLE FOR PREPARING ENGINEERING INFORMATION***

I hereby certify that I am the technically qualified person responsible for preparation of the engineering information contained in this application, that I am familiar with Part 25 of the Commission's rules, that I have either prepared or reviewed the engineering information submitted in this application and that it is complete and accurate to the best of my knowledge and belief.

/s/
Steve Joseph
Director of Networks

**Exhibit 1: Satellite Link Budget – Nominal Interference Conditions**

| Parameter | Units | | | | | |
|---|---|---|---|---|---|---|
| Case | | Beam B | Beam C | Beam D | Beam E | Beam F |
| Bandwidths | | | | | | |
| Bandwidth per Beam | Hz | 250.0E+06 | 750.0E+06 | 750.0E+06 | 750.0E+06 | 500.0E+06 |
| Allocated Bandwidth | Hz | 250.0E+06 | 750.0E+06 | 750.0E+06 | 750.0E+06 | 500.0E+06 |
| Rolloff | % | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| Symbol Rate | sps | 238.1E+06 | 714.3E+06 | 714.3E+06 | 714.3E+06 | 476.2E+06 |
| in dBHz | dBHz | 83.77 | 88.54 | 88.54 | 88.54 | 86.78 |
| Gateway | | | | | | |
| Fractional power | % | 16.74% | 50.23% | 50.23% | 50.23% | 33.49% |
| Fractional power | dB | -7.76 | -2.99 | -2.99 | -2.99 | -4.75 |
| Uplink Terminal Description | | 9.4m GW | 9.4m GW | 9.4m GW | 9.4m GW | 9.4m GW |
| EIRP | | 84.38 | 84.38 | 84.38 | 84.38 | 84.38 |
| EIRP for Shared Carrier | dBW | 76.62 | 81.39 | 81.39 | 81.39 | 79.63 |
| EIRP Density | dBW/GHz | 82.85 | 82.85 | 82.85 | 82.85 | 82.85 |
| Uplink Path | | | | | | |
| Uplink elevation angle | degrees | 21.1 | 21.1 | 21.1 | 21.1 | 21.1 |
| Uplink Slant Range | km | 39451.0 | 39451.0 | 39451.0 | 39451.0 | 39451.0 |
| Uplink Frequency | MHz | 29200 | 29200 | 29200 | 29200 | 29200 |
| Path Loss: | dB | 213.68 | 213.68 | 213.68 | 213.68 | 213.68 |
| Atmospheric Link Degradation (dB) | dB | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Total path loss | dB | 214.68 | 214.68 | 214.68 | 214.68 | 214.68 |
| Spacecraft Rx | | | | | | |
| Equiv. Isotropic Signal Level at Spacecraft | dBW | -138.06 | -133.29 | -133.29 | -133.29 | -135.05 |
| Signal Flux density at Spacecraft | dBW/m^2 | -87.29 | -82.52 | -82.52 | -82.52 | -84.28 |
| G/T | dB/K | 14.10 | 14.10 | 14.10 | 14.10 | 14.10 |
| Directivity | | 45.70 | 45.70 | 45.70 | 45.70 | 45.70 |
| S/No | dBHz | 104.64 | 109.41 | 109.41 | 109.41 | 107.65 |
| Receive C/N | dBc | 20.87 | 20.87 | 20.87 | 20.87 | 20.87 |
| Cross-Pol Interference | dBc | 25.00 | 25.00 | 25.00 | 25.00 | 25.00 |
| Adjacent Beam | dBc | 30.89 | 30.89 | 30.89 | 30.89 | 30.89 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Interference (ABI) | | | | | | |
| Receiver Parasitics | dBc | 40.00 | 40.00 | 40.00 | 40.00 | 40.00 |
| Receive C/I | dB | 23.90 | 23.90 | 23.90 | 23.90 | 23.90 |
| Receive C/(N+I) | dBc | 19.12 | 19.12 | 19.12 | 19.12 | 19.12 |
| Uplink C/I | dB | 23.90 | 23.90 | 23.90 | 23.90 | 23.90 |
| Uplink C/(N+I) | dBc | 19.12 | 19.12 | 19.12 | 19.12 | 19.12 |
| Spacecraft Tx | | | | | | |
| Fraction of BW per HPA | % | 100.00% | 100.00% | 100.00% | 100.00% | 100.00% |
| Fraction of Power per Beam | % | 100.00% | 100.00% | 100.00% | 100.00% | 100.00% |
| EIRP | dBW | 51.43 | 57.21 | 57.22 | 56.81 | 54.51 |
| Noise Power Stealing | dB | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| EIRP per Shared Carrier | dBW | 51.38 | 57.16 | 57.17 | 56.76 | 54.46 |
| EIRP Density | dBW/GHz | 57.61 | 58.62 | 58.63 | 58.22 | 57.68 |
| HPA Intermodulation | dBc | 17.00 | 17.00 | 17.00 | 17.00 | 17.00 |
| Transmitter Parasitics | dBc | 99.00 | 99.00 | 99.00 | 99.00 | 99.00 |
| Transmit C/(N+I) | dBc | 14.92 | 14.92 | 14.92 | 14.92 | 14.92 |
| Downlink Path | | | | | | |
| User Elevation Angle | deg | 29.1 | 23.0 | 20.6 | 20.9 | 23.4 |
| User Slant Range | km | 38691 | 39263 | 39497 | 39463 | 39222 |
| User Downlink Frequency | MHz | 18500 | 19000 | 19000 | 19000 | 20000 |
| Path Loss: | dB | 209.56 | 209.92 | 209.97 | 209.96 | 210.35 |
| Atmospheric Link Degradation (dB) | dB | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 |
| Total Path Loss | dB | 210.26 | 210.62 | 210.67 | 210.66 | 211.05 |
| Ground User | | | | | | |
| Downlink Ground Terminal | | 1.2m, 6W | 1.2m, 6W | 1.2m, 6W | 1.2m, 6W | 1.2m, 6W |
| Equiv. Isotropic Signal Level at User Terminal | dBW | -158.88 | -153.46 | -153.50 | -153.91 | -156.60 |
| Signal Flux density at Ground Station | dBW/m^2 | -112.1 | -106.4 | -106.5 | -106.9 | -109.1 |
| Size (m) | | 1.20 | 1.20 | 1.20 | 1.20 | 1.20 |
| G/T | dB/K | 22.20 | 22.20 | 22.20 | 22.20 | 22.20 |
| Link | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Receive S/No | dBHz | 91.92 | 97.34 | 97.30 | 96.89 | 94.20 |
| Receive C/N | dBc | 8.15 | 8.80 | 8.76 | 8.36 | 7.42 |
| Cross-Pol Interference | dBc | 29.00 | 29.00 | 29.00 | 29.00 | 29.00 |
| Adjacent Beam Interference (ABI) | dBc | 21.65 | 22.87 | 22.92 | 22.33 | 25.50 |
| Receive C/I | dBc | 20.92 | 21.92 | 21.96 | 21.48 | 23.90 |
| Receive C/(N+I) | dBc | 7.93 | 8.59 | 8.56 | 8.15 | 7.33 |
| Clear Sky Forward Link C/(N+I) | dBc | 7.14 | 7.68 | 7.65 | 7.32 | 6.63 |
| MODCOD | | 8PSK 25/36 | 8PSK 13/18 | 8PSK 13/18 | 8PSK 25/36 | 8PSK 2/3 |
| Required C/(N+I) | dBc | 7.09 | 7.59 | 7.59 | 7.09 | 6.59 |
| Link Margin | dB | 0.05 | 0.09 | 0.06 | 0.23 | 0.04 |

**Exhibit 2: C/I Calculations for Two-Degree Spacing Analysis**

The minimum antenna size expected within the Arcturus service area is 1.2 m. The following table describes the delta-to-peak used for calculating adjacent satellite C/I to and from a terminal this size. This analysis assumes two identical satellites operating with identical configurations at +/- 2°. For the purposes of this analysis, the C/I is the power level received from the intended target relative to the power received from the interferer(s). PSDs are presented in dBW/GHz and C/Is are given in dBc.

Table 1: Arcturus PSD for two-degree-spacing Analysis.

| | On-axis PSD | |
|---|---|---|
| | Uplink | Downlink |
| Forward | 82.3 | 58.2 |
| Return | 73.2 | 54.1 |

Table 2: Adjacent Satellite PSD for two-degree-spacing Analysis.

| | Uplink | Downlink |
|---|---|---|
| | PSD towards Arcturus | Peak PSD |
| | | |
| Forward | 36.5 | 58.2 |
| Return | 45.3 | 54.1 |

Table 3: C/I Analysis for two-degree-spacing.

| | Uplink | | Downlink | |
|---|---|---|---|---|
| | 1 Satellite C/I | 2 Satellite C/I | 1 Satellite C/I | 2 Satellite C/I |
| Forward | 45.8 | 42.8 | 42.1 | 39.1 |
| Return | 27.9 | 24.9 | 24.2 | 21.2 |