ANDURIL

# EXHIBIT C

## TECHNICAL ANNEX

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## I. Scope and Purpose

This exhibit offers additional technical information regarding the ANDURIL-216 non-geostationary orbit ("NGSO") satellite.

## II. Frequency Plan

Table 1 below summarizes ANDURIL-216's radiofrequency characteristics. A summary of the earth station characteristics for this mission appears in Exhibit D.

*Table 1: Frequency Plan (continued overleaf)*

| Beam ID | UDA | UUA | SDA | SUA | XDA |
|---|---|---|---|---|---|
| Description | UHF Downlink (Space-to-Earth) | UHF Uplink (Earth-to-Space) | S-band Downlink (Space-to-Earth) | S-band Uplink (Earth-to-Space) | X-band Downlink (Space-to-Earth) |
| Center Frequency[1] | 400.25[2] | 402.85 | 2250.0 | 2070.0 | 8075 |
| Maximum Bandwidth | 20 kHz | 20 kHz | 3.5 MHz | 4.0 MHz | 38 MHz |
| Transmit Power (dBW) | 3.01 | 3.01* | 3.01 | 10.0-19.03* | 3.01 |
| Transmit Antenna Gain (dBi) | 1.00 | 16.20 | 6.10 | 34.0-39.0 | 16.38 |
| System Losses (dB) | 4.20 | N/A | 4.70 | N/A | 4.00 |

[1] The precise center frequency will be within the identified tunable band but has not been finalized because coordination has not been completed.

[2] In the 400.25 MHz downlink, beacons will transmit intermittently and only upon the spacecraft's receipt of a ground command from an authorized earth station. Each beacon transmission event will not exceed 8 minutes in duration, and beacon transmissions will occur no more than 2 times per orbital period and no more than 12 times per 24-hour period.

| Beam ID | UDA | UUA | SDA | SUA | XDA |
|---|---|---|---|---|---|
| EIRP (dBW) | -0.19 | 19.21 | 4.41 | 44.0-58.03[3] | 15.39 |
| Half-Power Beamwidth (degrees) | 120 | See NTIA Space Record Data Form | 92 | See NTIA Space Record Data Form | 16 |
| Polarization | Linear | Linear | RHCP | RHCP | RHCP |
| Receive Antenna G/T (dB/K) | -10.00 | -30.80 | 12.60 | -28.56 | 26.50 |

* Transmit power is at the antenna input terminal, so it includes all system losses

## III. Telemetry, Tracking and Control

The Telemetry, Tracking, and Control ("TT&C") subsystem provides communications during nominal operations and during spacecraft emergencies. The UHF channels are intended for telecommand and telemetry services, and will be used during initial contact and spacecraft emergencies. The S-band channels are intended for telecommand and telemetry services, as well as a secondary downlink for payload data, and will be used during nominal operations and spacecraft emergencies. The X-band channel is intended for payload data downlink, and will be used during nominal operations.

The UHF telecommand (*i.e.* uplink) and telemetry (*i.e.* downlink) channels each have a bandwidth of up to 20 kHz, and channel information is provided in Table 1. During initial contact and spacecraft emergencies a subset of the Earth stations will transmit up to approximately 12 times per day. The TT&C link on UHF uplink/downlink employs two identical monopole antennas.

[3] See the NTIA Space Record Data form for additional detail.

The S-band telecommand (*i.e.* uplink) channel has a bandwidth of up to 3.5 MHz, and channel information is provided in Table 1. The S-band TT&C uplink will transmit up to approximately 27 times per day across all ground stations during commissioning and spacecraft emergencies, and approximately 6 times per day across all ground stations during nominal operations.

The S-band telemetry (*i.e.* downlink) channel has a bandwidth of up to 4.0 MHz, and channel information is provided in Table 1. The S-band TT&C uplink will transmit up to approximately 27 times per day across all ground stations during commissioning and spacecraft emergencies, and approximately 6 times per day across all ground stations during nominal operations.

The X-band mission data downlink is used for payload downlink. The X-band channel has a bandwidth of 38 MHz, and channel information is provided in Table 1. The X-band mission data downlink will transmit up to approximately 8 times per day across all ground stations during nominal operations.

All Earth stations are listed in Exhibit D.

The spacecraft will use a sufficiently unique telemetry marker with different center frequencies and unique encryption keys at deployment to ensure that its telemetry stream can be unambiguously identified.

## IV. Cessation of Transmissions and Stop Buzzer

ANDURIL-216 will be capable of immediately ceasing operations in compliance with section 25.207 of the Commission's rules upon becoming aware of harmful interference to another operator. As required under section 25.271 of the Commission's rules, the "Stop Buzzer" point of contact for this mission is:

Tristan Latchu
Principal Systems Engineer, Space
Anduril Industries, Inc.
spectrum@anduril.com
(949) 891-1607

## V. Frequency Sharing Analysis

Interference between ANDURIL-216 and other systems is deemed to be unlikely, on the basis of frequency coordination, satisfaction of in-band power limits, and likelihood of straying into an active transmission beam. The spacecraft may communicate only in short periods of time during which it has geometric access to its Earth stations (typically less than 8 minutes for a single pass). For interference to occur, either: a) another operator's satellite must transit the antenna beam of ANDURIL-216's serving Earth station; or b) the ANDURIL-216 satellite must transit the antenna beam of the other operator's serving Earth station; and both systems would need to transmit at the same time on overlapping frequencies. In such a very unlikely event, interference avoidance is possible by coordinating the communications so that they do not occur simultaneously in time, space, or frequency domains. Further, as demonstrated in the following subsections, ANDURIL-216 satisfies in-band power limits as defined by NTIA in Chapter 8 of the "Redbook".

### A. In-Band Power Limit Analysis

#### 1. Downlink: 2250.0 MHz

Power Flux Density (PFD) limits are specified in ITU Radio Regulations, Article 21, Table 21-4. Anduril calculated the maximum PFD levels for the ANDURIL-216 transmissions and determined that the downlink PFD levels from the SDA frequency beam do not exceed the ITU limits. Figure 1 below illustrates the PFD analysis results for the ANDURIL-216 spacecraft downlinking in a configuration that maximizes its power flux density at a worst-case altitude of 480 km during the mission life and a nominal bandwidth of 1.75 MHz, within the ITU reference

bandwidth of 4 kHz. When operating at worst-case bandwidths or at lower altitudes expected during post-mission disposal, ANDURIL-216 will decrease the transmit power as necessary to stay within the prescribed limit. For example, Figure 2 shows the PFD produced in the 156.25 kHz channel at 480 km altitude when the EIRP is reduced by 8 dB (from 4.41 dBW to -3.59 dBW). Although elevation angles are shown down to 0°, ANDURIL-216 will enforce elevation masks to limit communications to opportunities with higher elevation angles.

*Figure 1: S-Band Power Flux Spectral Density (4 kHz) vs. Limit at 480 km*

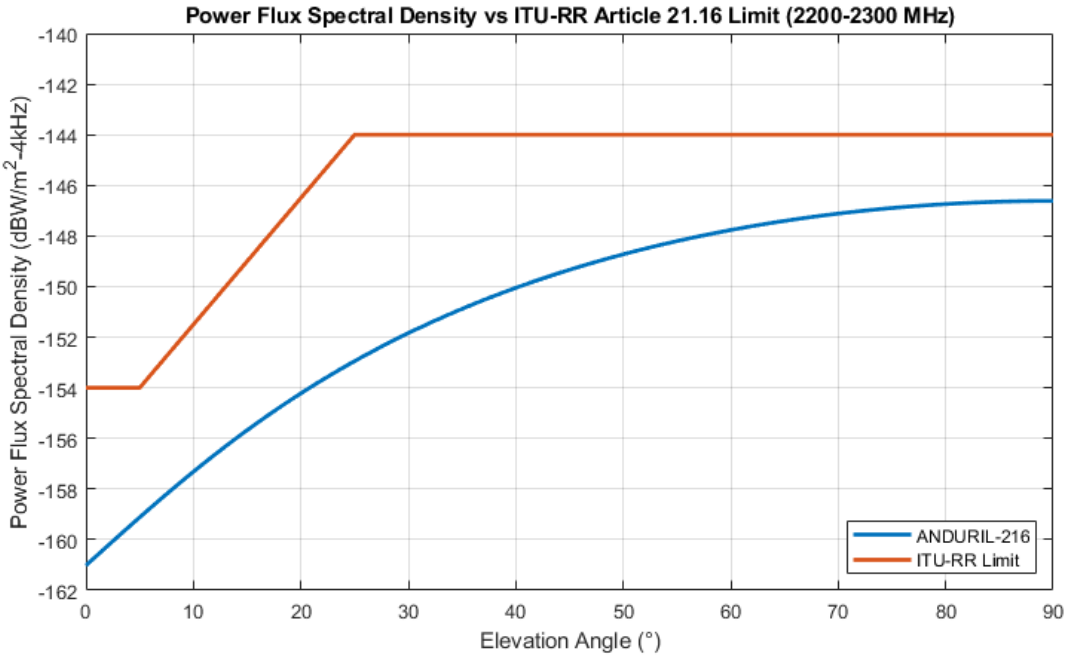
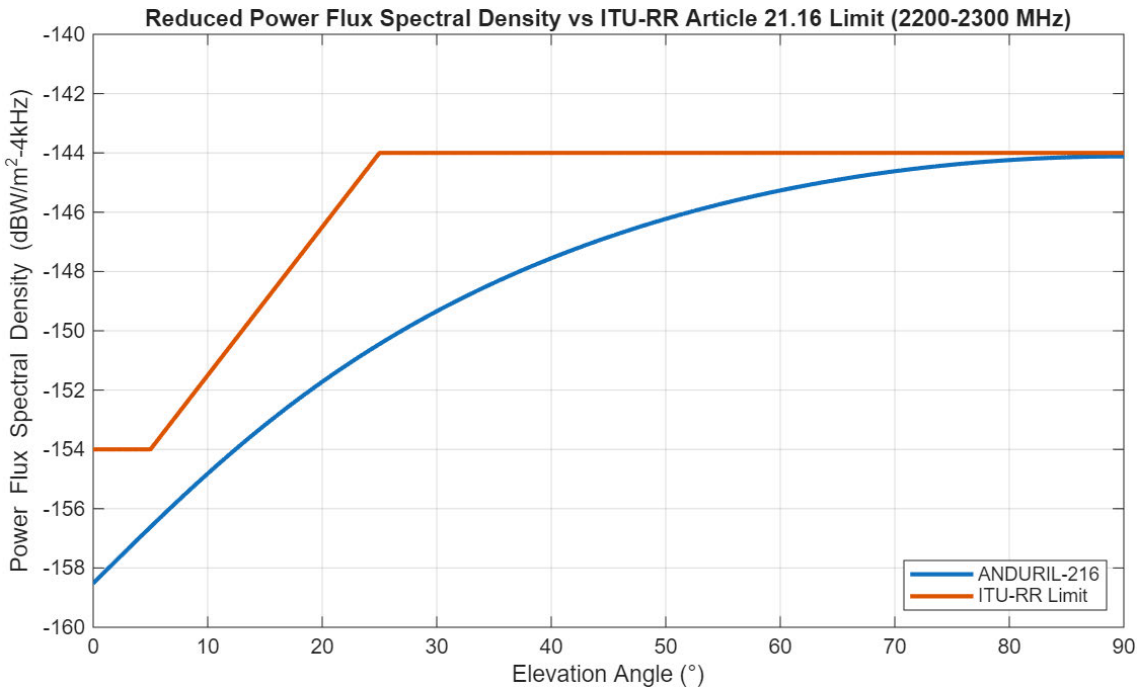



*Figure 2: S-Band Power Flux Spectral Density (4 kHz) vs. Limit at Reduced Bandwidth*




**2. Downlink: 8075 MHz**

In this band, PFD limits apply at the Earth's surface and at the geostationary orbit ("GSO") arc.

*PFD at Earth's surface.* PFD limits are again specified in ITU Radio Regulations, Article 21, Table 21-4. Anduril calculated the maximum PFD levels for the ANDURIL-216 transmissions and determined that the downlink PFD levels from the XDA frequency beam do not exceed the ITU limits. Figure 3 illustrates the PFD analysis results for the ANDURIL-216 spacecraft downlinking in a configuration that maximizes its power flux density at a worst-case altitude of 480 km during the mission life and a worst-case bandwidth of 25 MHz, within the ITU reference bandwidth of 4 kHz. Figure 4 repeats the analysis, but at a nominal channel bandwidth of 38 MHz. Given the nature of the X-band frequency beam's use for returning payload data, Anduril does not expect to operate the X-band link at lower altitudes which would be observed during post-mission disposal. However, if Anduril does choose to operate the X-

band link at such altitudes, ANDURIL-216 will decrease the transmit power as necessary to stay within the prescribed limit.

*Figure 3: X-Band Power Flux Spectral Density (4 kHz), 25MHz Channel vs. Limit at 480 km*

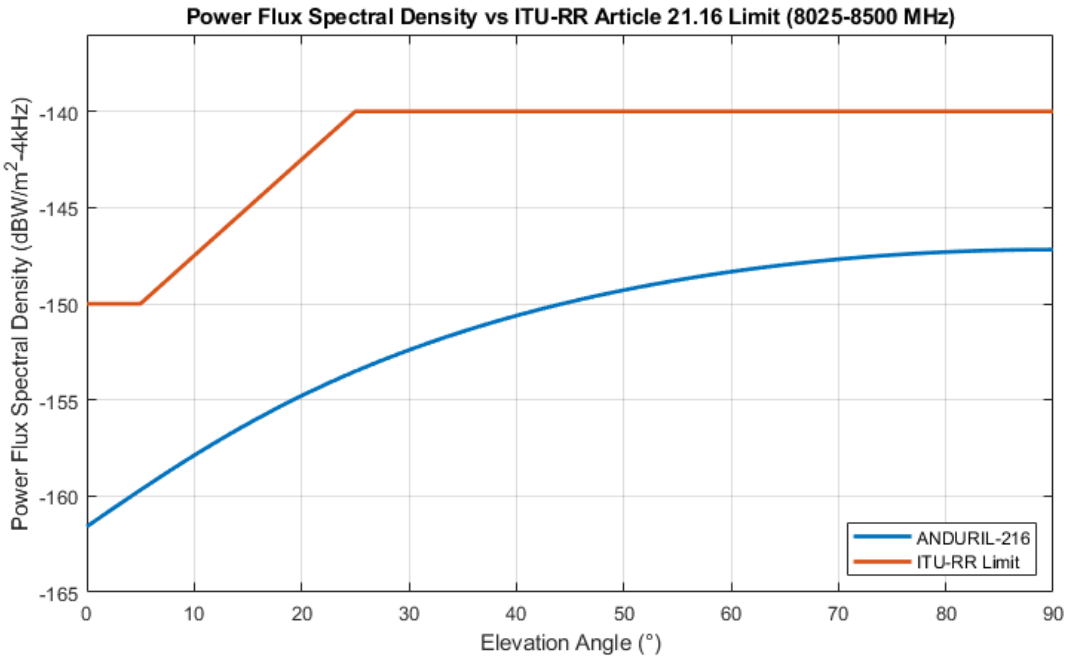
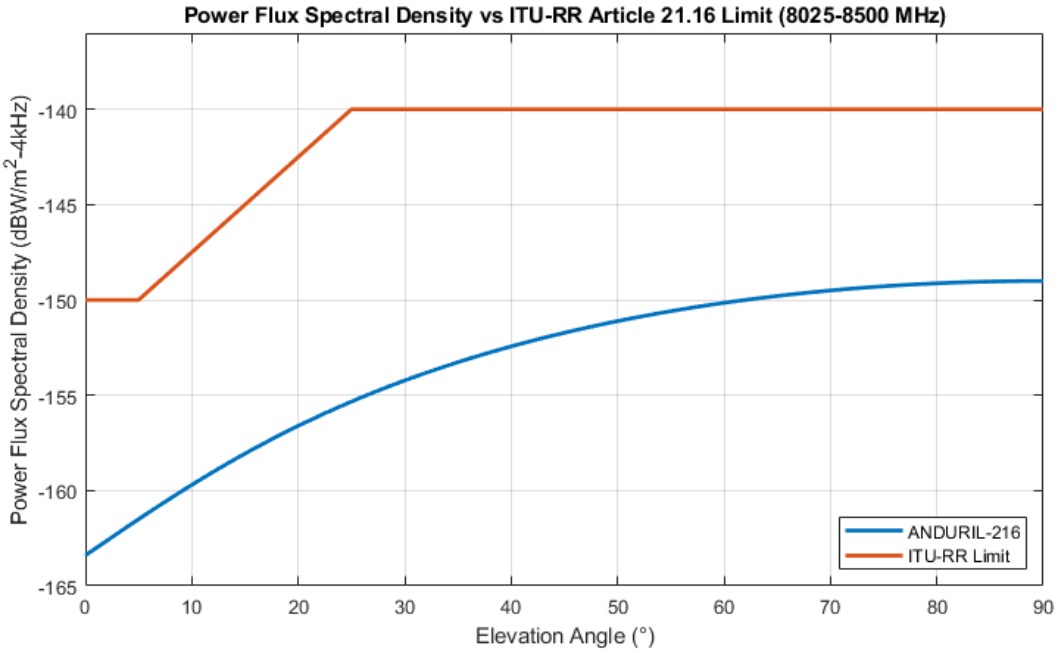


*Figure 4: X-Band Power Flux Spectral Density (4 kHz), 38MHz Channel vs. Limit at 480 km*




*PFD at GSO arc.* ITU Radio Regulations, Article 22.5 specifies that in the 8025-8400 MHz band, the maximum PFD produced at the GSO by any EES service shall not exceed -174 dBW/m$^2$ in any 4 kHz. The calculation below shows that the emissions produced by ANDURIL-216 would not exceed that limit even in the worst case. At the highest potential altitude orbit of 570 km, the distance to the geostationary orbit would be 35,216 km. At this slant range, an antenna pointed directly toward the GSO arc having a conservative EIRP of 16.89 dBW (1.5 dB higher than the maximum expected EIRP from ANDURIL-216) using a worst case 25-MHz bandwidth, the maximum PFD at the GSO arc would be approximately -183.00 dBW/m$^2$ per 4 kHz.[4]

[4] This operation mode is atypical because the NGSO antenna will point toward Earth during nominal operations. The X-band beam will also nominally have a lower PFD given the higher channel BW expected during operations, and the results for nominal operations are therefore bounded by the analysis presented herein.

### B. Compliance with ITU-R SA.1157

International power spectral density limits protect deep space ground receivers that may operate adjacent to the 2200-2290 MHz and 8025-8400 MHz bands. ITU-R Recommendation SA.1157 specifies the spacecraft power spectral flux density falling within the deep space network band shall be less than -257 dBW/$m^2$/Hz in 2290-2300 MHz and less than -255.1 dB(W/$m^2$/Hz) in 8400-8450 MHz. The ANDURIL-216 mission will comply with these limits.

## VI. Earth Station

The ground stations are listed in Exhibit D. The characteristics of the specific earth stations are summarized in Tables 2 and 3.

*Table 2: KSAT Antenna Characteristics*

| | **S-band (TX)** | **S-band (RX)** | **X-band (RX)** |
|---|---|---|---|
| **Reflector Size** | 3.7m | 3.7m | 3.7m |
| **Downlink Band** | NA | 2220 - 2300 MHz | 8000 - 8400 MHz |
| **G/T (20-deg elevation)** | NA | 12.6 dB/K | 26.5 dB/K |
| **Polarization** | LHCP / RHCP | LHCP / RHCP | LHCP / RHCP |
| **Uplink Band** | 2025 - 2110 MHz | NA | NA |
| **EIRP** | 43.8 dBW | NA | NA |

*Table 3: RBC Signals Antenna Characteristics*

| | UHF (Tx) | UHF (Rx) | S-band (TX) | S-band (RX) | X-band (RX) |
|---|---|---|---|---|---|
| **Reflector Size** | NA | NA | 3.7m | 3.7m | 3.7m |
| **Downlink Band** | NA | 401 – 402 MHz | NA | 2200 - 2300 MHz | 8000 - 8400 MHz |
| **G/T (20-deg elevation)** | NA | -10 dB/K | NA | 12.00 dB/K | 24.00 dB/K |
| **Polarization** | Linear | Linear | LHCP / RHCP | LHCP / RHCP | LHCP / RHCP |
| **Uplink Band** | 400.15 - 401.0 MHz | NA | 2025 - 2120 MHz | NA | NA |
| **EIRP** | -4 dBW | NA | 48 dBW | NA | NA |

## VII. Orbital Debris Risk Mitigation Plan

### A. Planned Debris Release

Anduril confirms that ANDURIL-216 will not undergo any planned release of debris during normal operations. In addition, all separation and deployment mechanisms, and any other potential debris source, will be retained by the spacecraft.[5]

### B. Collision with Small Debris or Meteoroids

The Commission's rules require that applicants indicate whether they have "assessed and limited the probability that the space station(s) will become a source of debris by collision with small debris or meteoroids that would cause loss of control and prevent disposal," including

[5] *See* 47 C.F.R. § 25.114(d)(14)(i).

indicating whether this probability for an individual space station is 0.01 or less.[6] This assessment applies to maneuverable spacecrafts. As discussed below and in the Orbital Debris Assessment Report ("ODAR") included at Exhibit B, the ANDURIL-216 satellite will not carry any propulsion systems and will complete post-mission disposal through passive atmospheric reentry. Accordingly, this assessment does not apply to the ANDURIL-216 mission.

**C. Minimizing Accidental Explosions**

Anduril is designing its ANDURIL-216 spacecraft in a manner that limits the probability of accidental explosion or release of liquids that would persist in droplet form.[7] Anduril has assessed the possibility of accidental explosions and such liquid release during and after completion of mission operations through failure mode verification analysis. As part of the satellite manufacturing process, Anduril has taken steps to ensure that debris generation will not result from the conversion of energy sources onboard ANDURIL-216 into energy that fragments the spacecraft. All sources of stored energy onboard the spacecraft will have been depleted or safely contained when no longer required for mission operations or post-mission disposal.

**D. Safe Flight Profile**

Anduril has assessed and limited the probability of ANDURIL-216 becoming a debris source by accidental collisions with large debris or other operational spacecraft. As further demonstrated in the ODAR, using the NASA Debris Assessment Software, Anduril has estimated the probability of accidental collision with such large space objects to be 9.4144E-

[6] *See id*. § 25.114(d)(14)(ii).

[7] *See id*. § 25.114(d)(14)(iii).

05.[8] ANDURIL-216 will not attempt to actively maintain orbital tolerances, as there is no onboard propulsion system.[9]

Anduril will work closely with its launch provider to ensure that the satellite is deployed in such a way to minimize the potential for in-plane collision. Anduril has not identified other planned or operational space stations in Anduril's target orbit for the ANDURIL-216 mission.[10] During the de-orbit phase, the ANDURIL-216 satellite will transfer from an altitude greater than that of the International Space Station ("ISS") and other inhabitable spacecraft to an altitude below that of the ISS and other inhabitable spacecraft, and thus may transit through an orbit used by the ISS or another inhabitable spacecraft. As described in the ODAR, the ANDURIL-216 satellite can employ differential drag to minimize risk of collision. Anduril will work with the 18th Space Defense Squadron to plan and execute differential drag deorbit maneuvers while the ANDURIL-216 satellite passes through the orbits of the ISS and other inhabitable spacecraft to minimize the risk of collision.[11]

Anduril will track ANDURIL-216 passively using its GPS receiver and register the satellite with the 18th Space Control Squadron or successor entity.[12] Anduril will engage with owners/operators of other space stations in the same orbit to ensure safe and coordinated space operations. Anduril will provide all relevant agencies, the 18th Space Control Squadron or successor entity engaged in space situational awareness, and, as applicable, other operators with

[8] *See id*. § 25.114(d)(14)(iv)(A)(1).

[9] *See id*. § 25.114(d)(14)(iv)(A)(4).

[10] *See id*. § 25.114(d)(14)(iv)(A)(2).

[11] *See id*. § 25.114(d)(14)(iv)(A)(2).

[12] *See id*. § 25.114(d)(14)(v)(A)-(C).

any information they need to assess risks and ensure safe flight profiles (particularly for inhabitable space stations, as necessary), as well as contact information for Anduril personnel at its headquarters.[13]

Anduril certifies that upon receiving a space situational awareness conjunction warning, Anduril will review and take all possible steps to assess the collision risk and mitigate the collision risk if necessary, including by contacting the operator of any active spacecraft involved in such a warning, sharing ephemeris data and other appropriate operational information with any such operator, and modifying space station attitude and/or operations.[14]

**E. Post-Mission Disposal**

Disposal of the ANDURIL-216 satellite will occur through uncontrolled atmospheric re-entry.[15] The operational orbit of the satellite will decay due to atmospheric drag, and the satellite will eventually de-orbit by atmospheric reentry. Anduril has conducted the reentry risk analysis using NASA Debris Assessment Software (DAS) v3.2.6, the results of which are included in the ODAR. As modeled, the ANDURIL-216 will fully decay within 5 years of mission completion with a probability of success exceeding 0.9.[16] Some spacecraft components are expected to survive re-entry and impact the surface of the earth with a kinetic energy in excess of 15 joules; however, the calculated risk of human casualty from DAS is 1:20,100.[17]

[13] *See id*. § 25.114(d)(14)(v)(C).

[14] *See id*. § 25.114(d)(14)(iv)(A)(5).

[15] *See id*. § 25.114(d)(14)(vii)(D)(2)(i). Direct retrieval of the spacecraft will not be used. *See id*. § 25.114(d)(14)(vii)(B).

[16] *See id*. § 25.114(d)(14)(vii)(D)(1).

[17] *See id*. § 25.114(d)(14)(vii)(D)(2)(ii).

**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/ Tristan Latchu*

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