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March 14, 2018

Jose Albuquerque
Chief, Satellite Division
International Bureau
Federal Communications Commission
445 12th Street, SW
Washington, DC 20554

Re: Astro Digital US, Inc.
File No. SAT-LOA-20170508-00071
Call Sign S3014

Dear Mr. Albuquerque:

Astro Digital US, Inc. ("Astro Digital"), by its counsel, submits the attached technical document showing how its operations in the 29.9-30.0 GHz band will be conducted on a non-interference basis with respect to co-frequency Mobile Satellite Service ("MSS") and Fixed Satellite Service ("FSS") operators, including licensees and grantees of U.S. market access in that band.[1] Astro Digital has reviewed all of the license applications and requests for market access submitted to the Federal Communication Commission proposing to use the 29.5-30.0 GHz band and has devised a methodology for mitigating interference to these and other systems, in accordance with Condition 4 of the Astro Digital license application grant and consistent with the use of the band on a secondary basis.[2]

Specifically, the attached technical demonstration summarizes the analysis of the Landmapper Earth station-to-OneWeb satellite constellation case and outlines a step-by-step procedure for interference mitigation. Astro Digital proposes to follow this procedure, which will be supported by Kongsberg Satellite Services ("KSAT"), the mutual ground station operator in Svalbard, Norway for both the OneWeb and the Landmapper systems.

[1] *See* Public Notice, Satellite Branch Policy Information, *OneWeb Petition Accepted for Filing; Cut-Off Established for Additional NGSO-like Satellite Applications or Petitions for Operations in the 107-12.7 GHz, 14.0-14.5 GHz, 17.8-18.6 GHz, 18.8-19.3 GH, 27.5-28.35 GHz, 28.35-29.1 GHz, and 29.5-30.0 GHz Bands*, 31 FCC Rcd 7666 (July 15, 2016).
[2] *See* Astro Digital Application, File No. SAT-LOA 20170508-00071, at Condition 4 (granted in part Dec. 14, 2017, as corrected Dec. 21, 2017).

The methodology, however, can be extrapolated to additional operators and their respective systems, as they deploy. To the extent that operators deploy a large number of satellites in this band operating with facilities at or near Svalbard and Astro Digital's interference mitigation procedure becomes unworkable, Astro Digital can operationally shift uplink frequencies to a less congested band, such as the 29.3-29.5 GHz, and in that event will seek appropriate FCC authority for an appropriate modification to its license.

Please direct any questions regarding this submission to the undersigned.

Respectfully submitted,

*/s/ Tony Lin*

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Attachment

cc: Stephen Duall (with attachment)

**CERTIFICATE OF SERVICE**

I, Sarah Leggin, hereby certify that on March 14, 2018, a true and correct copy of this letter was sent by United States mail, first class postage prepaid, to the following:

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*/s/ Sarah Leggin*

Sarah Leggin

**Astro Digital Implementation Plan to Avoid Interference to Perspective NGSO-FSS Operators in the Recent FCC Processing Round from the Landmapper EESS System in the Frequency Band 29.9 to 30.0 GHz**
**-Revision 5.1 -**

In granting Astro Digital U.S., Inc. (Astro Digital) a license to operate the Landmapper remote sensing system, the Commission has placed Condition 4 as a term to be satisfied by this licensee.[1] Condition 4, included here for completeness, is as follows:

## 1.0 **FCC Grant Condition 4**

4. In the 29.9-30.0 GHz band, we grant Astro Digital's request to waive the United States Table of Frequency Allocations to permit EESS operations in this band as proposed.[4] Operations, however, must be conducted on a non-interference basis with respect to Mobile Satellite Service (MSS) and Fixed Satellite Service (FSS), including licensees and grantees of U.S. market access in the NGSO FSS processing round.[5] Further, Astro Digital shall not claim protections from systems operating in accordance with the U.S. Table of Frequency Allocations. *See* 47 CFR § 2.106. Within 30 days of grant of this authorization, Astro Digital must submit a showing indicating how its operations will comply with the requirements of this condition.

## 2.0 Review of perspective NGSO-FSS operators applications and market access filings

We have reviewed all of the applications and market access filings for the FCC's NGSO-FSS recent processing round. We are also familiar with the applicable rules regarding in-line interference to Ka-band satellite receivers of different non-geostationary satellite systems. The ITU requires that co-primary NGSO-FSS operators coordinate their in-line transmissions, giving "notification-date" first-come, first served (FCFS) preference to systems, but does not specify an

[1] Astro Digital received an extension of time to submit this showing by March 14, 2018. *See* Stamp Grant, Letter from Tony Lin, Counsel to Astro Digital, to Jose Albuquerque, Chief of the Satellite Division, Federal Communications Commission (granted February 15, 2018).

interference protection limit. The FCC essentially provides equal spectrum usage rights to all first-round processing round participants, irrespective of date of bringing in to service. If relevant parties cannot reach a coordination agreement and there is a delta T/T >6%, then each network affected will retreat to a non-overlapping "home spectrum" during each event. 47 C.F.R. § 25.261. The bandwidth of each home-spectrum channel is found by dividing the band in question equally among the authorized first-round participants that are operating a network. We note here that Astro Digital was not an NGSO-FSS participant in the processing round and does not operate in the band on a primary basis, meaning Astro Digital does not possess FCC rights to a home spectrum channel. These requirements are specific to NGSO satellite networks serving the U.S., independent of ITU notifying administration.

**3.0 Summary of Findings:** We note that there are very few similarities between the perspective systems participating in the most recent NGSO-FSS processing round. Orbits, bands of use for services, bands of use for feeder links and bands of use for TT&C operations are all different. Clearly, this places an additional burden on others sharing the spectrum with these perspective users. We appreciate that the ITU and ITU-R are actively engaged in answering this very question. In the interim, our proposed interference mitigation plan is detailed below.

3.1 *Assessment of Using the 29.9-30.0 GHz band*: After reviewing all of the perspective operators' Schedule S submissions, including frequency utilization, beam and orbit plans (see Section 2.0), we conclude that:

a) A likely viable set of strategies exist that would allow Landmapper to operate in the top 10 to 30 MHz of the band 29.9 – 30.0 GHz.

b) By using adaptable and dynamic frequency and bandwidth adjustments, it will be practically possible to avoid interference to NGSO-FSS systems by operating within what would be the guard bands between transponders in the case of some systems and portions of the spectrum not used by other NGSO-FSS operators.

c) To do this, in some instances, will require us to run forward propagation simulations of orbits for many of the systems in order to plan dynamic adjustments to bandwidths and frequencies of operation of the Landmapper Uplinking Earth Station at KSAT/Svalbard. This would be done in order to adapt to conjunction (line-of-sight) events that will occur from time-to-time. These events could be quite frequent for some systems, if they are implemented in accordance with their proposed perspective systems. During these events we would operate our uplink system in gaps (*interstices*) between transponders or between the upper most transponder of a system and the top of the band at 30.000 GHz.

d) We have observed that many perspective systems use high gain receive beams within this frequency band and if these systems are not using these beams for service links to users at Svalbard, Norway or if they have no gateway or TT&C links at Svalbard, then there is no opportunity for interference to occur to those systems from our Astro Digital Earth Station. This then removes these perspective operators from the list of entities with which Astro Digital must coordinate.

e) We would call special attention to the OneWeb system, which is expected to use KSAT/Svalbard for some gateway operations. Indeed, their command operations are fully carried out from this location for all space stations. Their telecommand, however, is situated some 500 MHz below what would be our proposed operating frequency channel. But, in addition, there are gateway service transponders that approach the upper band limit at 30.000 GHz. Nonetheless, in the case of OneWeb, there is sufficient guard-band margin to operate a link in the interstitial channel between their satellite transponder roll-off and the top of the band.

f) While we fully believe that by dynamically adjusting our operating bandwidth we can accommodate all of the perspective operators in the processing round without conducting a S.1503-type (Article 22) analysis, we would be willing to carry out such analyses if, during the discussions with perspective operators, it is found to be necessary. However, this would only be necessary if there is a direct overlap between our frequency plan and the victim satellite's channelization plan and during a conjunction (line-of-sight) event and if the system plans to use Svalbard as a gateway or TT&C facility or provides service links in this band with their satellite antennas directed toward Svalbard.

g) We have some concerns about our ability to carry out such an analysis with the SpaceX constellation simply because of the sheer number of satellites proposed by that entity to be deployed. Also, the channelization plan, as presented in the SpaceX Schedule S showing, shows beams GU4 (RHCP) and GU8 (LHCP) both occupying the entire 500 MHz band from 29.5 GHz to 30.0 GHz with no guard bands indicated. This is an unusual channelization scheme and may be an error. Further, these are identified as service beams, not feeder link beams, and they also employ highly directive beams [having 41 dBi gain -> ≈ 1.46° beamwidth]. Thus, these beams would have to be dedicated to reception of subscriber data from Svalbard itself, in order for us to cause interference to their satellite system. Certainly, some SpaceX satellites may operate so as to provide service to Svalbard (ignoring the fact that the only town on the island, Longyearbyen, already has the highest speed, lowest cost Internet service of any city in the world). However, we doubt that very many satellites will direct their narrow beams in the direction of the Landmapper Earth Station, given the volume of traffic that could be offered by user terminals on Svalbard. In any case, we will plan to operate in the interstice between the roll-off of their highest frequency transponder and the top end of the band. This will make a line-of-sight analysis unnecessary so long as it can be demonstrated that our use of the spectrum does not overlap any SpaceX channel. This analysis can be carried out at a later time when the SpaceX system is ready to be deployed and Astro Digital has a better understanding of the SpaceX transponder plan.

## 4.0 Adjustments Proposed to Landmapper Ka-band Receive System Based on Review of NGSO-FSS Systems from the Commission Licensing Round

As in our application, Astro Digital proposes to use the band 29.9 – 30.0 GHz for an Earth-to-space link to provide feedback to our spacecraft. This will allow adjustment of the transmitted data rate and will control the resending of missed data packets when they do occur. The necessary bandwidth of this emission during Phase 2 of the Astro Digital technology program is 15 MHz. Phase 3 of our program would begin in 2019 as per our filing. When Astro Digital advances to this phase in technology we propose to increase our necessary bandwidth to 30 MHz. This is summarized in Table 4-1. These uplinks employ DVB-S2 operating in ACM mode.

**Table 4-1: Data Flow Control Channel Characteristics (as Filed)**

| Landmapper Phase: | Necessary Bandwidth: | Symbol Rate: | Peak Data Rate: |
|---|---|---|---|
| Phase 2 | 15 MHz | 12.5 Msps | 55.663 Mbps |
| Phase 3 | 30 MHz | 25 Msps | 111.326 Mbps |

Given our current understanding of the perspective operators' plans to use the band, and our need to share, we believe it is necessary to use satellite receivers in compliance with our Phase 2 and Phase 3 plans. However, they will be modified to also provide additional lower bandwidth (channel) options. These lower bandwidth options (organized in powers of 2) will be employed and adjusted dynamically as described in this document at §5.1. This may be required during conjunction events with some applicant's satellites in order to avoid co-channel interference. This new set of receiver bandwidths being proposed here will not, in any case, exceed the requested bandwidths as outlined in our filing but, in some instances, the Landmapper Ka-band receivers will occupy *less* bandwidth and will operate at lower data speeds than per our application during certain periods of time. This narrower channel operation will only occur at times when there could be an overlap in channels during conjunctions between Landmapper and other NGSO-FSS systems. Table 4-2 summarizes the new configuration of our adjustable Ka-band receiver. We've also adjusted our data filter (Nyquist) performance from *20% to 10% roll-off rate (from α = 0.20 to α = 0.10)*, improving our rate-of-reduction of our emission levels over frequency (*i.e.*, the filter skirts roll off faster with frequency than as proposed in our filing). This revised Landmapper receiver system will now allow us to adjust our occupied bandwidth over a range of 16X, once Landmapper enters technology Phase 3.

**Table 4-2: Data Flow Control Channel (Modified Configuration)**

| Landmapper | Necessary | Symbol | Min. Data | Max. Data |
|---|---|---|---|---|

| Phase: | Bandwidth: | Rate: | Rate: | Rate: |
|---|---|---|---|---|
| Phase 3 | 30 MHz | 25 Msps | 13.370 Mbps | 121.446 Mbps |
| Phases 2 & 3 | 15 MHz | 12.5 Msps | 6.686 Mbps | 60.723 Mbps |
| Phases 2 & 3 | 7.5 MHz | 6.25 Msps | 3.343 Mbps | 30.362 Mbps |
| Phases 2 & 3 | 3.75 MHz | 3.125 Msps | 1.671 Mbps | 15.181 Mbps |
| Phases 2 & 3: | 1.875 MHz | 1.5625 Msps | 0.8356 Mbps | 7.590 Mbps |

The system can maintain a significant fraction of its uplink operating speed by using higher MODCOD steps during periods of lower bandwidth occupation. Our system already has the capability of moving the receiver uplink frequency anywhere within the 29.0 to 30.0 GHz band with a resolution of a few Hz. Also, our uplink transmitter will be capable of uplink EIRP agility, making it possible to adjust the link level received by a Landmapper satellite. This power control can also be used to reduce the EPFD level at the OneWeb victim satellites (which will have the effect of reducing the *interference beamwidth* of our uplinking Earth station antenna).

## 5.0 Strategy for Avoiding Interference to Perspective Operators

### *5.1 Avoiding Interference to OneWeb:*

Our plan to implement a reliable and interference-free uplink at Ka-band from our Landmapper system to OneWeb as a victim system is as follows:

a) *STEP #1:* We will confirm with OneWeb that it intends to operate both TT&C and Feeder Links from Svalbard. (We have, in fact, already done so and we can confirm this outcome). We will confirm that its satellites will have their high gain satellite receive antennas directed at Svalbard during all (or nearly all) passes. The OneWeb command channel(s) are located at 29.505 GHz; hence we could not cause interference to their command operations. However, their system has two directive receive beams (GU8 using RHCP and GU16 using LHCP) situated at a center frequency of 28.875 MHz and with a bandwidth of nominally 250 MHz. This means their receiver would occupy the entire top 250 MHz of the 29.5 to 30.0 GHz band. However, in order to avoid ACI issues the system's actual bandwidth is approximately 240 MHz at -3 dB roll-off. Figures 4-1a and 4-1b show a plot of the roll-off characteristics of the OneWeb transponder and the Landmapper emission when it is placed in the interstice between the top of the highest frequency transponder and the top of the frequency band at 30.000 GHz. Figures 4-1a and 4-1b shows a plot of the roll-off characteristics of the OneWeb transponder and the Landmapper emission when it is place in the interstice between the top of the highest frequency transponder and the top of the frequency band at 30.000 GHz. Figure 4-1a depicts the emission when the Landmapper uplink control channel is selected to be 3.75 MHz and Figure 4-1b depicts the emission when the uplink control channel is selected to be 1.875 MHz. During periods when an in-line condition exists between the two Earth stations, a OneWeb satellite, and a Landmapper satellite, it would be necessary for AD to operate within the frequency gap between 29.995 GHz and the top of the band, or within the interstice that exists at 29.750 GHz in order to avoid interference to the OneWeb satellite in such a position. We note that the interstice at this lower frequency is twice as wide as the one on the high frequency side, as it is "two-sided" (there is a transponder roll-off on either side of that frequency). However, this is outside the band proposed

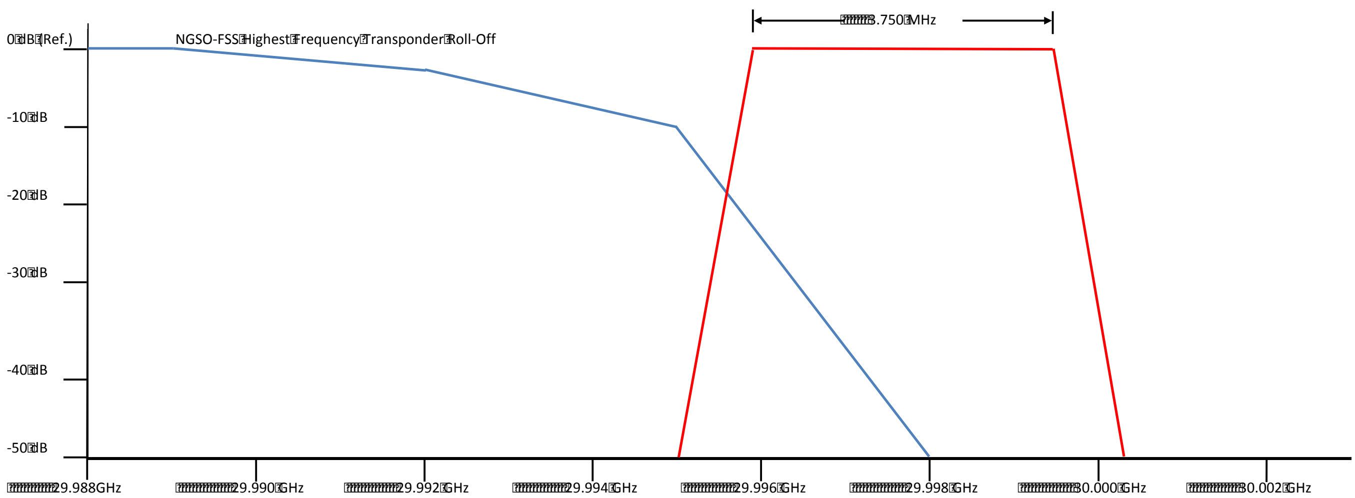


**Figure 4-1a: OneWeb Feeder Link Transponder Passband (Typical) and Landmapper Control Channel 3.750 MHz Emission**

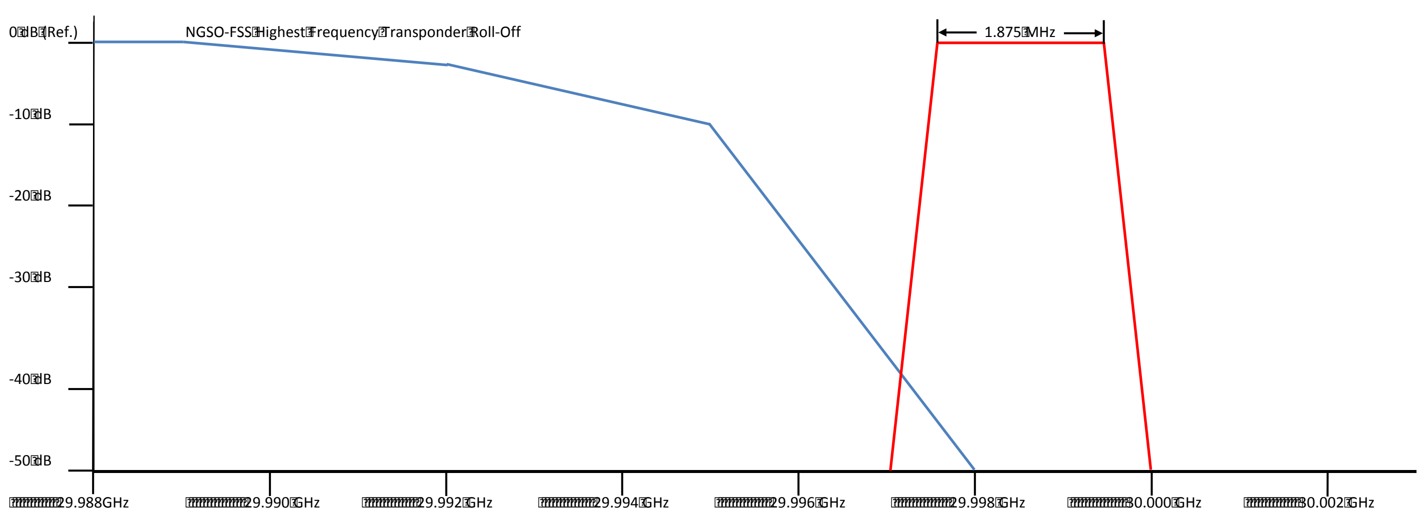


**Figure 4-1b: OneWeb Feeder Link Transponder Passband (Typical) and Landmapper Control Channel 1.875 MHz Emission**

for operation by Astro Digital. While there is still more information to be gathered regarding the OneWeb system, we have sufficient information to confirm the overall system operating parameters provided in this description.

b) *STEP #2*: We will request that OneWeb operate their satellites with the RHCP transponder (GU8) off during Svalbard passes if there is insufficient traffic to require the operation of this particular transponder in that region. While this may sound drastic upon first reflection, we note that there are a total of 16 transponders, each with 460+ Mbps of capacity on-board. And, that is the case for each OneWeb satellite. During these times the OneWeb victim satellite will be in the vicinity of the North Pole. Turning the GU8 transponder OFF will also reduce the energy requirements of each satellite on an orbit-average basis. OneWeb is, of course, not obliged to comply with our request. However, if this can be achieved then we can operate our system without operational coordination between satellite systems, as the cross polarization isolation between systems will be sufficient to allow both to perform with margin; even given there is some overlap of the channels. Astro Digital will, however, perform an analysis to confirm that this is the case. During this set of circumstances the Landmapper satellites would operate using the full 30 MHz (during Phase 3) and 15 MHz (during Phase 2), nominally at a frequency of 29.985 GHz. If STEP #2 is acceptable to OneWeb, no further operational coordination will be necessary (however, an analysis and a testing program will be used to verify successful co-channel use).

c) *STEP #3*: Assuming OneWeb does not agree with our proposal in STEP #2, Astro Digital proposes to work with KSAT to run periodic conjunction forecasts, which will identify all in-line events between our system and the OneWeb satellite constellation during any one-week operational period. This can be accomplished in advance of the conjunction events, and thus, we can plan the Landmapper system configuration accordingly. A schedule will then be created, which KSAT would then execute for that operating period. The most likely software to be used for this analysis is *Visualyze.* Under the circumstances when:

i) A OneWeb satellite is ON and is line-of-sight to (in range of) Svalbard

and

ii) That satellite's transponder GU8 is ON

and

iii) There is a conjunction period (when both a Landmapper satellite and the OneWeb victim satellite is within the *interference beamwidth* of the Landmapper uplinking antenna), then during the period of time while the conjunction lasts:

i) The Landmapper uplink EIRP will be adjusted to comply with the pre-calculated uplink EIRP in order to achieve the pre-agreed *interference beamwidth*. This action will remove any possibility of adjacent channel interference to the OneWeb satellite transponder GU8.

ii) The Landmapper Earth station transmitter frequency and the Landmapper spacecraft receiving frequency will be changed to place the Landmapper uplinking carrier within the interstice between the GU8 transponder roll-off frequency and the top of the band (this will be at a frequency of approximately 29.998 MHz).

iii) The Landmapper uplinking transmitter and the Landmapper Ka-band receiver will be commanded to operate at a DVB-S2 bandwidth of either 3.75 MHz or 1.875 MHz (whichever is most appropriate).

iii) After the conjunction event is over, the Landmapper Earth station transmitter and spacecraft Ka-band receiver will be returned to their nominal bandwidth of 15/30 MHz and a frequency of 29.985 GHz. During this *narrowband-operating* period the Landmapper receiver system will be free to adjust it's MODCOD value to the highest available value achievable under link conditions, as this has no impact on interference level (EPFD) at the victim's satellite. At this time the system will operate in ACM mode, in fact.

d) *STEP #4*: Independent of STEP #2 and STEP #3, Astro Digital will work informally with OneWeb to conduct an interference analysis and written procedures, which are acceptable to both companies. Additionally, we will conduct a series of satellite tests at the Svalbard site used by both operators, in order to verify compatibility between the two systems using our proposed methods of operation. KSAT working in cooperation with both companies will carry out these tests.

e) STEP #5: We hold in reserve the option, if all else fails, to cease emissions from our transmitter at Svalbard, should any unforeseen interference occur to one or more OneWeb satellite during a conjunction or at any other time. We have also considered, as noted here, the option to simply reduce our power output (at reduced link margin or performance on our uplink) as a means of reducing the effective interference beam size or to reduce the EPFD toward the OneWeb satellites.

5.2 *Avoiding Interference to Other NGSO-FSS Systems from the Landmapper System:*

Astro Digital will cooperate with other perspective NGSO-FSS system operators:

a) Who launch and operate satellites systems in Ka-band,

b) Who will make use of the band 29.900 – 30.000 GHz,

c) Who have satellite transponder systems or TT&C systems that operate in RHCP polarization,

d) Who have directive beams that can, and will, be directed to provide coverage of Svalbard, Norway, and,

e) Who operate during periods when the satellites are line-of-sight to Svalbard.

We will proceed in a manner similar to the processes we propose here for operational coordination (as a secondary user) with OneWeb. Astro Digital will, in fact, follow the same procedures as outlined in §5.1 of this document. In any case, we will contact all perspective operators to clarify/confirm their system characteristics, their intentions of operating in the polar region and how they intend to specifically occupy the band 29.900-30.000 GHz. Interference mitigation procedures will follow the same approach as outlined above, although specific frequencies, the location in frequency of transponder interstices and plans for dealing with conjunctions may vary in detail. Given the flexibility of the Landmapper system, as we have outlined in this document, we believe we will be able to make dynamic adjustments, as required.

5.3 *Avoiding Interference to NGSO-FSS Systems Using Omni-Directional Ka-band Satellite Antenna Systems from the Landmapper System:*

There is a final interference case, not yet discussed, which has been identified by Astro Digital. Some of the perspective NGOS-FSS operators may have TT&C equipment (i.e., command receivers):

i) That could receive signals within the frequency channel 29.900 to 30.000 GHz (and more specifically within the channel 29.970 – 30.000 GHz),

ii) That employs omnidirectional antennas associated with their command receiver(s),

iii) That has sufficiently good G/T to receive energy from the Landmapper uplink system,

iv) That operates using RHCP polarization,

v) But, are not expecting to receive telecommand information from Svalbard. Nor is the satellite's associated TT&C Earth station communicating with the satellite at the time of a pass over Svalbard.

Such conditions could occur for short durations when one of these satellites passes through our uplink control channel beam. This is a different form of interference where there is no simultaneous intended uplink from the system's gateway or TT&C Earth station, yet the satellite could be receiving a signal from Landmapper uplinking Earth station. This situation may not cause harm since the affected satellite would not likely respond to the Landmapper signal structure/protocol and there is no true interference as there was no intended uplink to the "victim" system at the same time. Astro Digital will work with all such operators identified to have such a capability prior to the deployment of such systems, on an individual basis, in order to determine the correct strategy for minimizing any issues caused by such RF energy reaching a victim's omnidirectional satellite command channel when there is no corresponding intended uplink signal.

*5.4 Alternative Frequency Assignment Option for the Landmapper Ka-band uplink:*

There is a possibility, particularly if the SpaceX system is implemented, if a full 500 MHz wide satellite transponder system is implemented on every space vehicle, with receivers covering the band 29.5-30.0 GHz **and** if the full SpaceX constellation is put in place, that even rapid dynamic adjustments to Landmapper emission bandwidth and periodic frequency adjustments may not be a practical method to avoid harmful interference to their system. In this case, we may move our uplink to an alternative adjacent frequency band, such as the 29.300 to 29.500 GHz band. We will seek all required authorizations, if such change becomes necessary.

**Technical Certification**

I, Jan A. King, hereby certify, under penalty of perjury, that I am the technically qualified person responsible for the preparation of the engineering information contained in the technical portions of the license condition demonstration, that I am familiar with Part 25 of the Commission's rules, and that the technical information is complete and accurate to the best of my knowledge and belief.

/s/ Jan King
Jan A. King
Chief Technical Officer
Astro Digital U.S., Inc.

Dated: March 14, 2018