Exhibit 43
Astro Digital US, Inc.
License Application
FCC Form 312

Description of Application (Executive Summary)

With this application, Astro Digital US, Inc. (Astro Digital) requests authority to launch and operate an Earth Observation satellite system in low-Earth, non-geostationary orbit (LEO/NGSO). As detailed in the application below, the satellite system will consist of a constellation of up to 30 operational satellites consisting of two satellite types, differentiated by their optical properties (most notably their ground surface resolution). This satellite constellation will be known as the Landmapper® system. Astro Digital anticipates that each satellite will operate (based on its design lifetime) for 5 years in orbit. Satellites that reach their end-of-lifetime will be promptly replaced. Accordingly, Astro Digital requests authority to launch a total of up to 100 satellites over the 15-year term of the requested satellite license. To be clear, at no time will the Landmapper satellite constellation in orbit exceed 30 operational spacecraft.

Astro Digital is a U.S. company headquartered and operating in Mt. View, California at the NASA Ames Research Park. Astro Digital will provide imagery and imagery products from its own satellite system described herein.

The Landmapper constellation will operate on a non-common carrier basis.

Astro Digital anticipates the launch of a 30-satellite constellation consisting of 10 broad-area coverage (BC) spacecraft (identified as CORVUS-BC type), having a ground sampling distance (GSD) resolution of 22 meters and 20 high definition (HD) spacecraft (identified as CORVUS-HD type), having a GSD resolution of 2.5 meters.

Both satellite types, forming the whole Landmapper system, will use the same nominal orbit set. However, since our satellites are too small to require the full use of a launch vehicle, these spacecraft will share a launch with a primary spacecraft customer. This business constraint requires that we remain somewhat flexible regarding the exact orbit we can obtain as well as the launch date when new services can commence. In order to demonstrate compliance with regulatory and technical provisions covering the range of possible operating altitudes, upper and lower case bounds are presented for parameters such as orbital lifetime, power flux density limits, link budgets, and predicted EIRP and G/T contours.

We note that for link budget analysis we have used the worst-case high orbit at 625 km (with worst case eccentricity). However, for PFD analysis to Earth stations we have used a worst-case low orbit of 300 km. A baseline orbit of 585 km is used for most remaining calculations as the most likely (or nominal orbit altitude). All of these orbits are sun-synchronous in inclination. The Schedule S portion of FCC Form 312, and this exhibit with its associated attachments should be used as the complete information package where limitations in the application forms prohibit inputting a range of values.[1] Astro Digital has already commenced construction of the LEO NGSO system.[2] We anticipate launching the first 2 of the CORVUS-BC spacecraft by the end of 2Q2017 and the 3rd and 4th satellites in 3Q2017 to 4Q2017. These spacecraft will operate under two experimental licenses until such time as this application has been granted.

Astro Digital has submitted an application for license from the National Oceanic and Atmospheric Administration (NOAA) to operate the Landmapper constellation (both BC and HD components). Astro Digital has already received the license from NOAA to operate the CORVUS-BC portion of the system and anticipates receiving license the CORVUS-HD portion by of the end of 2Q 2017.

Timely deployment of the Landmapper constellation will enable Astro Digital to begin to offer its unique data subscription services to customers in the U.S. and around the world. It will also allow more frequent imaging of all land areas of the Earth than has been possible in the past. To the extent necessary to enable Commission action prior to the deployment of the Landmapper constellation as early as October 2017, Astro Digital respectfully requests expedited consideration of this request for launch and operation authority.

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[1] *See* Stamp Grant, DG Consents Sub, Inc., SAT-MOD-20120710-00111 (granted January 24, 2013).

[2] Notification of commencement of space station construction is included as Attachment A.

I. Description of the Applicant

Astro Digital US, Inc. is a private U.S. company headquartered in Mt. View, California. The original name of the company was Aquila Space, Incorporated, which was incorporated in Delaware in December 2014. The company made a simple name change in March of 2016 for branding purposes. No material change to the company's business plan, operations or financial status occurred at the time of this name change. Astro Digital is a vertically integrated remote sensing company. We design, construct, and operate small Earth imaging satellites and distribute images and many other data products derived from our imaging data base, on a commercial basis. Our initial clients are users of agricultural imaging data products intended to enhance crop production and efficiency.

Astro Digital has launched and is successfully operating two small proof-of-concept spacecraft, which are validating many of the key satellite and ground station technologies to be used by our operational satellites.[3] Four additional spacecraft, to be operated under FCC/OET Experimental (Part 5) licenses, already granted, will validate the remainder of our imaging, attitude control and Ka-band transmission systems.[4] The first two of these systems is expected to be in orbit by July 2017.

[3] See FCC OET file number 0032-EX-PL-2014.
[4] See FCC OET file numbers 0021-EX-CM-2016 and 0024-EX-CM-2016, respectively.

II. Information Required Under Section 25.114(d) of the Commission's Rules

A. Public Interest Considerations

The grant of this application will permit Astro Digital to launch and operate a state-of-the-art remote sensing system that will help empower individual users, companies, and government agencies to make better data driven decisions and enable a more sustainable planet. Astro Digital will provide scientific quality, multi-spectral data with an unprecedented daily refresh rate over the global landmass. This is a capability that is currently unavailable from private sector or government remote sensing providers. The trend analytics made possible with Landmapper data will enable monitoring of all arable land, forests, and fresh water sources for a truly global understanding of society's most precious resources and how they change over time.

B. General Description of Overall Facilities, Operations and Services

1. Space Segment Facilities: The Landmapper constellation will consist of a space segment comprised of up to 30 operational spacecraft (10 BC satellites with 22 m GSD resolution and 20 HD satellites with 2.5 m GSD resolution). The BC and HD spacecraft are three axis stabilized using reaction wheels and magnetorquers for actuation and using star trackers, rate sensors, sun sensors and magnetometers as sensors. NADIR tracking mode, ground target tracking mode and inertial tracking modes are supported by the ACS systems in both Landmapper satellite types. Each satellite will be fully commissioned after ejection from its launch vehicle. Extensive telemetry capability exists on-board each spacecraft and it is possible to fully control each spacecraft via ground command, including extensive adjustments to the flight software data load. Non-real-time (programmed) commanding is also used as required. The early Landmapper satellites will not carry propulsion systems for orbit adjustment or decommissioning purposes, however, they can perform station keeping and collision avoidance maneuver's using differential drag techniques.[5] Astro Digital will request FCC authority at a later date to modify its satellites to include a propulsion system at approximately the beginning of Phase 3 of our program.

2. Ground Station and Control Facilities: Each satellite is designed to receive commands and issue telemetry from/to a ground station at one location and downlink imagery data stored on-board the satellite at a different station, ideally (but, not essentially) located at an Earth polar location.

- Satellite control and all T&C[6] functions are carried out via our facilities at Ames Research Park in Mt. View, CA. This includes command

[5] *See* Attachment F to Exhibit 43.
[6] The term T & C is used here since the 2nd "T" (tracking) in the ubiquitous term "TT&C" is no longer relevant due to our use of GPS for tracking services. In other words, our space operations does not include tracking as a function requiring a separate assignment of radio spectrum.

transmission and telemetry reception via UHF and S-band RF facilities on-site, as well as the preparation and organization of our imagery data base. Customer order processing and service requests are also handled from this location. Our primary database itself is in the Cloud.

- High-speed imagery and some image quality information (meta data) is downlinked to our Ka-band link at the Kongsberg Satellite Services (KSAT) Earth station at Svalbard, Norway.

The Mt. View T&C station is capable of receiving telemetry signals from all space stations in the constellation throughout the band at 399.9-403 MHz and will be capable of commanding all space stations via two links:

- Using a primary link in the 2025-2110 MHz SRS (E-s) band, and
- Using a secondary link in the 399.9-403 MHz EESS region of the spectrum.

The primary data downlink at 26.800 GHz (Ka-band) will be received at Svalbard, Norway only. There is a companion Earth-to-space link, which will be used for DVB-S2 downlink flow control using this standard's ACM mode, as well as being used as a request channel for packet retransmission in the event of lost information. This link is proposed in the secondary EESS (E-to-s) allocation at 29.90 – 30.00 GHz.

Astro Digital may in the future seek to operate additional ground stations for high-speed data reception at Ka-band and will coordinate such use with NTIA and NOAA, as applicable. Astro Digital acknowledges that its Earth station at Svalbard shall not claim protection from stations in the fixed and mobile satellite services (Earth-to-space) operated by other administrations and that such earth stations must be operated taking into account the most recent version of ITU Recommendation ITU-R SA-1862. *See* 47 C.F.R. § 2.106; footnote 5.536A.

3. Launch Facilities and Services

The Landmapper satellites will be launched entirely using Secondary Payload Launch Service Providers. The nominal launch dates; launch vehicle and orbit details are shown in Table 1. Launch dates and launch manifest conditions can and will likely change with respect to Table 1.

Table 1: Landmapper Constellation Launch Schedule and Plan

Landmapper ®Launch Schedule and Plan									
Constellation Size:	Satellite Type:	# Sats per L/V:	Launch Date:	Launch Vehicle:	Primary Mission:	LTAN/LTDN: (hours)	Altitude: (km)	Incination: (degrees)	Orbit Period: (minutes)
2	BC	2	15-Jul-17	Soyuz	Kanopus-V	11:20	600	97.79	96.687
4	BC	2	17-Sep-17	PSLV	PSLV-7	9:30	500	97.40	94.616
8	BC	4	28-Feb-18	Soyuz	Kanopus-VI	11:00-11:30	585	97.73	96.376
10	BC	2	30-Sep-18	Falcon-9	SSO-B	10:30-13:30	500	97.40	94.616
Constellation Count (BC):		10							
1	HD	1	28-Feb-18	Soyuz	Kanopus-VI	11:00-11:30	585	97.73	96.376
3	HD	2	30-Jun-18	Vega	To be Announced	10:30-13:30	600	97.79	96.687
5	HD	2	30-Sep-18	Falcon-9	SSO-B	10:30-13:30	500	97.40	94.616
8	HD	3	30-Sep-18	Rocket Labs/Vega	To be Announced	6:00	500	97.40	94.616
14	HD	6	30-Jun-19	Falcon-9	SSO-C	6:00	600	97.79	96.687
20	HD	6	3-Sep-19	Falcon-9	SSO-E	13:30	600 X 830	98.25	99.087
Constellation Count (HD):		20							
TOTAL CONSTELLATION COUNT:		30	Dec-19						

We will continue to advise the Commission of such changes as they are confirmed to us.

4. Globalstar Services

There are also means to operate the system via inter-satellite links using the Globalstar MSS system. Each CORVUS satellite contains an L-band (telemetry) and S-band (command) modem along with appropriate antennas for this purpose. This does require an inter-satellite link between the two systems. This full-duplex link will be demonstrated using modems installed on the CORVUS-BC, -1, -2, -3 and -4 satellites as an element of our experimental program. This is discussed in some detail in the **D. Technical Description** of this application.

C. Description of Types of Services and Areas to be Served

Astro Digital's mission is to produce high temporal resolution, multi-spectral data for a global area of interest and to remove the barriers to entry for broad commercial adoption of remote sensing data products. The Landmapper system (Space and Ground Segments) has been designed and tuned for "monitoring" all commercially active land use in the world and for reducing the complexities associated with accessing and processing the data.

The Landmapper-BC satellite system will image the Earth's entire landmass every single day at 22 meter GSD in the Green, Red and Near-Infrared spectral bands. The

Landmapper-HD satellite system will image all the commercially active land on Earth at 2.5 meter GSD in the Blue, Green, Red, Red Edge and Near-Infrared spectral bands. The Landmapper-BC and Landmapper-HD data streams will provide complementary insights for multiple commercial and government applications. The large swath and broad area coverage of the Landmapper-BC satellites will provide context and constant trend monitoring leading to data driven decisions about land-use and management in the natural resources markets. The higher resolution of the Landmapper-HD satellites will reveal the next level of insights for more specific areas of interest using the Landmapper-BC system for context and informed collection.

Astro Digital offers platform services allowing customers to request processed imagery of their areas of interest while also setting up alerts or special instructions for what to do with new data collected from the satellites. The platform service is subscription-based for customer-defined areas of interest. The high temporal resolution of the satellites is tuned for trend analysis for applications ranging from predicting and tracking vegetation stages, monitoring vegetation growth in environmentally sensitive areas to mapping urban growth in cities around the globe. Astro Digital's customers come from all over the world and include, enterprise end users, government agencies and non-government organizations.

D. Technical Description

The telecommunication systems for the two types of spacecraft (CORVUS-BC and CORVUS-HD) are essentially the same. Both spacecraft types have three methods of providing telemetry and command communications but, the satellite types only differ slightly in their RF characteristics. Tables 2A – 2C summarizes our proposed use of the radio spectrum for the Landmapper constellation over time. We are dividing our commercial program into 3 phases (also as characterized in Tables 2A – 2C). However, for the Landmapper system these phases represent *technology enhancement* steps achieved in our program. These phases will not exactly coincide with a particular number of satellites within each phase. Rather, a phase change is carried out as soon as a new technology can be committed to flight. In effect, over time, we will advance the amount of data we deliver from the satellites to Earth via the data links using ever-improving radio frequency technology. And this, of course, modifies our utilization of the spectrum. While we propose to increase our utilization of the Ka-band spectrum, for instance, by a factor of seven (7) over two years, we will increase our downlink data rate also by the same factor while using a peak spectral efficiency of as high as 4.453 bits/Hz. Corresponding changes are also required to our T & C links in order to quality check our data products and to transmit missed packet information and adjust data rates for optimum performance. Table 2 summarizes our frequency utilization proposal and defines our phased program. A description of each link follows.

Table 2A: Landmapper Frequency Utilization; (Phase 1)

Program Phase 1 (2017-2018) – CORVUS BC			
Link Direction:*	Frequency Band:	Bandwidth Occupied:	Max. Data Rate:
Uplink (Command)	399.90 – 400.05 MHz	40 kHz	38.4 kbps
Uplink (Command)	400.05 – 400.15 MHz	40 kHz	38.4 kbps
Uplink (Command)	400.15-401.00 MHz	40 kHz	38.4 kbps
Uplink (Command)	401.00-402.00 MHz	40 kHz	38.4 kbps
Uplink (Command)	402.00–403.00 MHz	40 kHz	38.4 kbps
Downlink (Telemetry)	399.90 – 400.05 MHz	40 kHz	38.4 kbps
Downlink (Telemetry)	400.05 – 400.15 MHz	40 kHz	38.4 kbps
Downlink (Telemetry)	400.15-401.00 MHz	40 kHz	38.4 kbps
Downlink (Telemetry)	401.00-402.00 MHz	40 kHz	38.4 kbps
Downlink (Telemetry)	402.00–403.00 MHz	40 kHz	38.4 kbps
Downlink (H.S. Data)	25.50 – 27.00 GHz	86.40 MHz	320.6 Mbps
Crosslink FWD (CMD)-B/U	2483.50-2500.00 MHz	1.2288 MHz	9600 bps
Crosslink RTN (TLM)-B/U	1616.50-1626.50 MHz	1.2288 MHz	9600 bps

LEGEND

	UHF Uplink & Downlink Frequency Options
	EESS High Speed Data Link Proposed Frequencies
	S-Band Command Uplink Proposed Frequency
	Globalstar Inter-Satellite Link Frequency Bands

Table 2B: Landmapper Frequency Utilization; (Phase 2)

Program Phase 2 (2018 - 2019) – CORVUS BC and HD			
Link Direction:*	Frequency Band:	Bandwidth Occupied:	Max. Data Rate:
Uplink (CMD)-Backup	399.90 – 400.05 MHz	40 kHz	38.4 kbps
Uplink (CMD)-Backup	400.05 – 400.15 MHz	40 kHz	38.4 kbps
Uplink (CMD)-Backup	400.15-401.00 MHz	40 kHz	38.4 kbps
Uplink (CMD)-Backup	401.00-402.00 MHz	40 kHz	38.4 kbps
Uplink (CMD)-Backup	402.00–403.00 MHz	40 kHz	38.4 kbps
Downlink (Telemetry)	399.90 – 400.05 MHz	40 kHz	38.4 kbps
Downlink (Telemetry)	400.05 – 400.15 MHz	40 kHz	38.4 kbps
Downlink (Telemetry)	400.15-401.00 MHz	40 kHz	38.4 kbps
Downlink (Telemetry)	401.00-402.00 MHz	40 kHz	38.4 kbps
Downlink (Telemetry)	402.00–403.00 MHz	40 kHz	38.4 kbps
Uplink (CMD) - Primary	2025.0-2110.0 MHz	300 kHz	300 kbps
Downlink (H.S. Data)	25.50 – 27.00 GHz	220 MHz	816.39 Mbps
Uplink (Data Flow Control)	29.90 – 30.00 GHz	15 MHz	56.66 Mbps
Crosslink FWD (CMD)-B/U	2483.50-2500.00 MHz	1.2288 MHz	9600 bps
Crosslink RTN (TLM)-B/U	1616.50-1626.50 MHz	1.2288 MHz	9600 bps

Table 2C: Landmapper Frequency Utilization (Phase 3)

Program Phase 3 (2019- Beyond) – CORVUS BC and HD			
Link Direction:*	Frequency Band:	Bandwidth Occupied:	Max. Data Rate:
Uplink (CMD)-Backup	399.90 – 400.05 MHz	40 kHz	38.4 kbps
Uplink (CMD)-Backup	400.05 – 400.15 MHz	40 kHz	38.4 kbps
Uplink (CMD)-Backup	400.15-401.00 MHz	40 kHz	38.4 kbps
Uplink (CMD)-Backup	401.00-402.00 MHz	40 kHz	38.4 kbps
Uplink (CMD)-Backup	402.00–403.00 MHz	40 kHz	38.4 kbps
Downlink (Telemetry)	399.90 – 400.05 MHz	40 kHz	38.4 kbps
Downlink (Telemetry)	400.05 – 400.15 MHz	40 kHz	38.4 kbps
Downlink (Telemetry)	400.15-401.00 MHz	40 kHz	38.4 kbps
Downlink (Telemetry)	401.00-402.00 MHz	40 kHz	38.4 kbps
Downlink (Telemetry)	402.00–403.00 MHz	40 kHz	38.4 kbps
Uplink (CMD) - Primary	2025.0-2110.0 MHz	800 kHz	800 kbps
Downlink (H.S. Data)	25.50 – 27.00 GHz	600 MHz	2,226.51 Mbps
Uplink (Date Flow Control)	29.90 – 30.00 GHz	30 MHz	111.33 Mbps
Crosslink FWD (CMD)-B/U	2483.50-2500.00 MHz	1.2288 MHz	9600 bps
Crosslink RTN (TLM)-B/U	1616.50-1626.50 MHz	1.2288 MHz	9600 bps

* NOTE 1: The CORVUS satellite UHF Radio System operates in half-duplex mode (i.e. it switches between transmit and receive alternately). Our system is capable of operating on any frequency within any of the bands shown above and it is also possible for the transmitter and receiver to share the same frequency. Any or all of the bands listed for UHF uplink and downlink could be assigned to the Landmapper system. Assignment(s) could even be dynamic, in principle.

Each Landmapper constellation satellite's RF system consists of:

1. A primary command receiver operating at a center frequency of 2025.6 MHz will operate at an ultimate data rate of 800 kbps (in Phase 3) and with a transmission bandwidth of 1000 kHz. [2025.6 ± 0.500 MHz]. Two patch antennas located on the NADIR and Zenith surfaces of each spacecraft type (-Z and +Z respectively) will be summed together, so that both antennas can simultaneously receive signals. The polarization of both patch antennas is RHCP.

2. A secondary command receiver and a primary telemetry transmitter operating in the UHF frequency band and centered at preferred frequencies of 402.600 MHz (E-s) and 400.175 MHz (s-E), respectively. (See optional UHF frequency discussion immediately below). These emissions each have a bandwidth of 40 kHz and can be operated at 9600, 19,200 or 38,400 bps. These act together as a half-duplex transceiver. [400.175 ± 0.020 MHz (s-E) and 402.600 ± 0.020 MHz (E-s); preferred].

While Astro Digital believes we can make a strong case for operating within the correct category of service for both the uplink and downlink frequency bands, given the frequencies we have chosen and have used in our experimental program, we do understand that there are many users from both private industry and U.S. government that share the two bands we propose to use for our T&C links. For that reason we believe we should make clear that our T & C transceiver utilizes a form of software defined radio technology. As such it is capable of:

- Operating (transmit and receive) over a frequency range centered on approximately 401.5 MHz by an amount of approximately ±2.5 MHz.[7]
- Operating (transmit and receive) on the same frequency channel (true half-duplex operation).
- Changing transmit or receive frequency after launch over this same range of about 5 MHz.
- Changing other parameters such as data rate, power output and operating bandwidth, after launch.

Given this capability we wish to advise the Commission that we can accept the following assignment conditions for our T & C links in the 400 MHz UHF portion of the radio spectrum, pursuant to this application:

a.) Astro Digital can accept an assignment of our Command link (Earth-to-space) and/or our Telemetry link (space-to-Earth) in any of the following bands:

- 399.90 – 400.05 MHz
- 400.05 – 400.15 MHz
- 400.15- 401.00 MHz

[7] Our bandwidth limitation is primarily set by the bandwidth of our antenna matching network.

- 401.00 – 402.00 MHz
- 402.00 – 403.00 MHz

b.) We can accept a half-duplex assignment whereby we will execute our Command link and Telemetry link on the same center frequency.

c.) We can accept a dynamically changing frequency assignment that changes within the 5 MHz frequency block suggested above, over time, given reasonable notice of a pending change.

We note that depending on the option that may work best for the Commission or other affected U.S. government agencies, we may be required to operate under certain waivers to the Commission's rules or waivers to regulations of the ITU. Such waiver requests are outlined in Section III. of this application. We further request that, should the Commission find that the best option for our operations would be in the MSS band 399.90 – 400.05 MHz (Earth-space) our preferred operating frequency in that band would be 400.010 MHz (with a bandwidth of 40 kHz), if it were available. We finally wish to note that the UHF frequency bands proposed for our Command operations, will be used only as a backup to our proposed S-band Command link after the beginning of our Phase-2 program. Our Telemetry downlink, however, is proposed to remain in the 400 MHz portion of the spectrum for the duration of the Landmapper program.

3.. A tertiary T&C link operates using the Globalstar MSS constellation at L-band and S-band. The CORVUS spacecraft use a conventional (but, space-hardened)

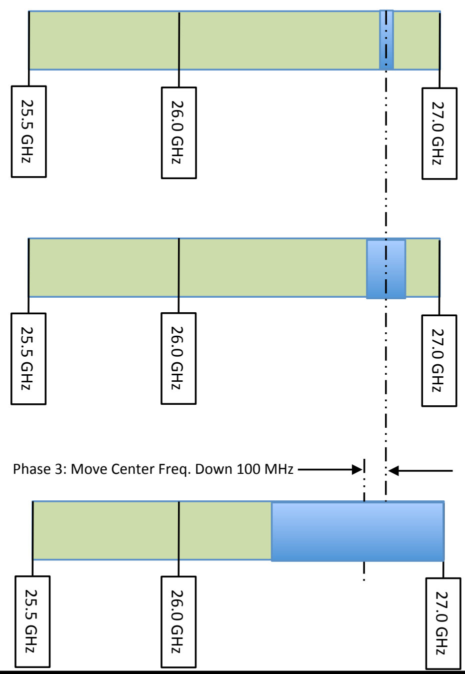
GSP-1720 Modem (FCC type-approved) operating as a satellite transceiver. The transceiver will operate on a Globalstar assigned channel within the band segment 1615-1618.725 MHz in order to avoid potential interference with the Radio Astronomy Service (RAS). The satellite transceiver will be dynamically assigned a corresponding frequency channel in the forward (command link) direction within the band segment 2483.5 to 2500.0 MHz. This frequency assignment, as well as power control is conducted via the Globalstar network by Globalstar, Inc. The gross data rate of these transmissions (in both link directions) is 9600 bps and is 8550 bps after the removal of overhead bits. The Landmapper satellites will use one patch antenna for transmission at L-band and a very similar patch for reception at S-band. Both antennas are circularly polarized (LHCP) and face away from Earth (Zenith direction) during normal operations. Using the Globalstar system allows for control of the satellites in the Landmapper constellation in regions of the Earth out-of-range to the Mt. View T&C facilities.

Astro Digital is aware that the ITU will consider emissions between Landmapper spacecraft and the Globalstar constellation to be operations within the Inter-Satellite Service (ISS). As the L-band and S-band frequencies used by Globalstar are MSS-only links, Globalstar, Inc. will have to apply for and receive a waiver for the commercial use of these links for inter-satellite communications. Discussions between Globalstar, Inc. and Astro Digital, regarding this topic have commenced. It is our understanding that the grant of this waiver would be required from the French administration as the space station license for GB-2 (2nd generation

Globalstar) is authorized by France. We have included in this application a waiver request for the use of the Globalstar system in the Inter-satellite Service as opposed to the MSS.

4. To allow high-speed data flow in the downlink (space-to-Earth) direction both satellite types will employ a Ka-band transceiver. The Ka-band transceiver can operate at any elevation angle at Svalbard above 5°. This includes during rain and other meteorological events up to and including 99.5% link availability conditions at that location. The transceiver transmitter operates on a center frequency of 26.800 MHz and will initially use a bandwidth of 86.4 MHz and a symbol rate of 72.0 Msps (20% Nyquist roll-off rate). This is during Program Phase 1. Phase 1 satellites will have no Ka-band receiver. The system complies with the data standards for DVB-S2. As the Landmapper program matures the symbol rate and bandwidth of the transmitter will be increased in two finite steps. These are shown in Table 2D below.

Table 2D: Evolution of Spectrum Utilization During Landmapper Phases (1-3)



Landmapper Phase 1: (2017 - 2018)

Center Frequency:	Necessary Bandwidth:	Symbol Rate:	Peak Data Rate:
26.800 GHz	86.4 MHz	72.00 Msps	320.62 Mbps

Landmapper Phase 2: (2018 - 2019)

Center Frequency:	Necessary Bandwidth:	Symbol Rate:	Peak Data Rate:
26.800 GHz	220.0 MHz	183.33 Msps	816.39 Mbps

Landmapper Phase 3: (2019 - Beyond)

Center Frequency:	Necessary Bandwidth:	Symbol Rate:	Peak Data Rate:
26.700 GHz	600.0 MHz	500.0 Msps	2.2265 Gbps

In order to keep the satellite emissions within the EESS allocation, during program Phase 3, it will be necessary to move the frequency downward in the band to at least 26.700 GHz.

The overall link C/N and the corresponding PFD will remain nearly constant throughout these phase changes. Satellite EIRP will increase with increasing bandwidth. Hence, no changes in ground station antenna or receiver performance will be required. It is also noted that no significant PFD changes approach regulatory limits due to these changes.

5. In order to implement DVB-S2 ACM (adaptive coding and modulation) mode and flow control from Svalbard, during Phase 2 deployment, a high- speed data receiver will be implemented within the current envelope of the Ka-band TX, making this unit, technically a *transceiver*. This will provide a companion receive channel with a peak data rate of approximately 100 Mbps. The receiver could be assigned to other frequencies within the allocation provided for by ITU FN 5.541, however, we propose an operating frequency for the space-born receiver of 29.950 GHz. We note that EESS is a secondary allocation in the band 29.9-30.0 GHz in all three ITU regions and is to be used for data transfer from the Earth to the spacecraft and not for passive or active sensing purposes. This means our use of the band is in compliance with FN 5.541. We do note, however, that this ITU footnote has not been brought into the U.S. domestic table on either the government or non-government side. We therefor will request a domestic waiver which would allow us to use this footnote, at least when we are in range of our primary high speed data site at Svalbard, Norway, and under the circumstances that we do not cause harmful interference to other FSS or MSS operations in this band.

We anticipate the development of this receiver to be completed by the beginning of 2018 (start of Phase 2). All Landmapper satellites launched after that date will then carry this capability. At that point in time we will convert the operating mode of the Ka-band DVB-S2 transmitters equipped with this receiver to ACM mode from its initial operation in VCM mode.

The technical characteristics of the proposed Landmapper Satellite Constellation are further detailed in the Schedule S portion of FCC Form 312 of this Application. The proposed satellite system's link budgets are included as Attachment B to this application. Attachment D shows predicted gain contours as required by Section 25.114(d)(3) of CFR §47 for the Earth Station Sites at Mt. View, CA and Svalbard, Norway. Elevation angles are assumed to be 90° for those projections.

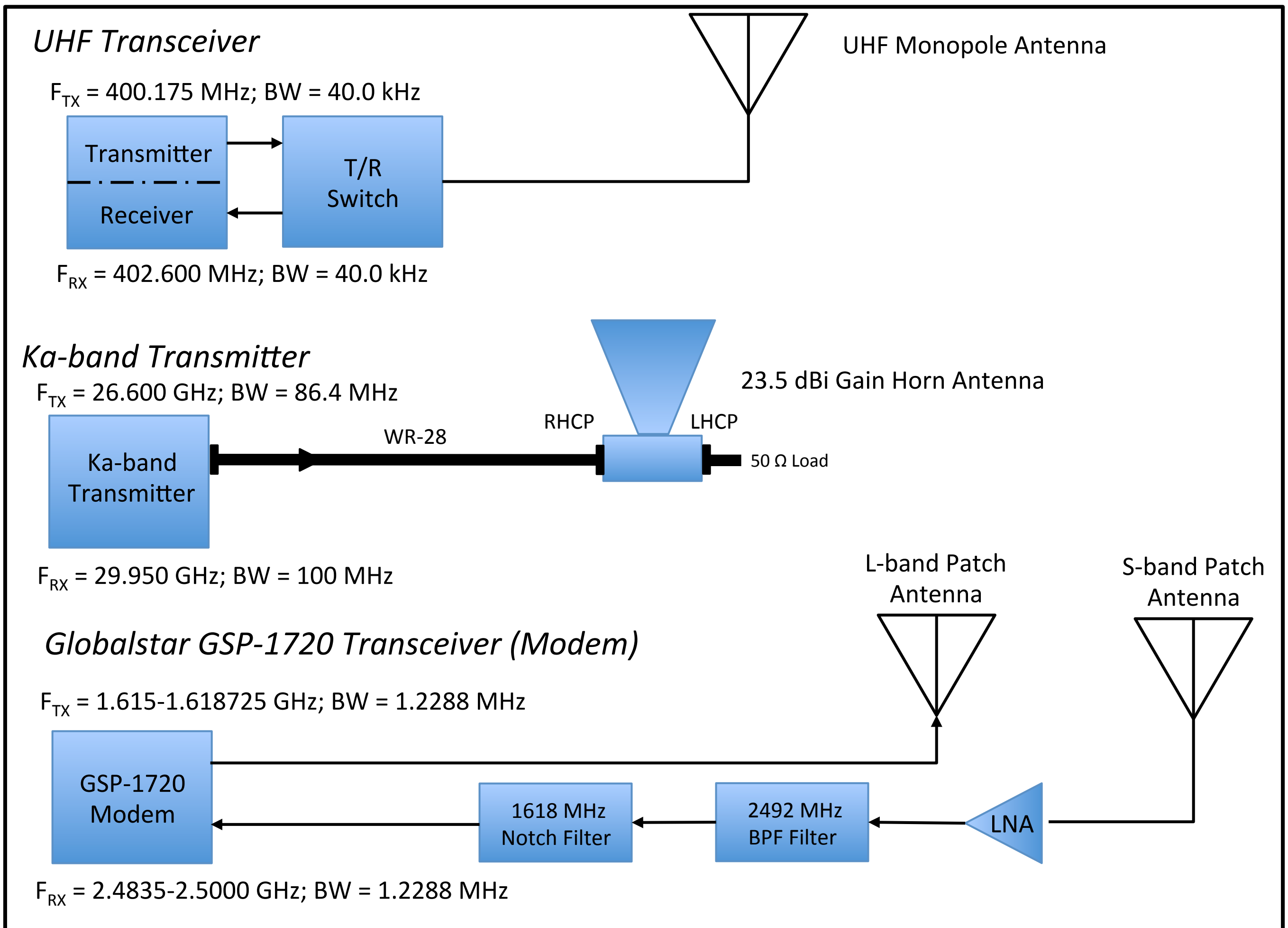


Figure 1A: CORVUS-BC and CORVUS-HD Communications Block Diagram (Phase 1)

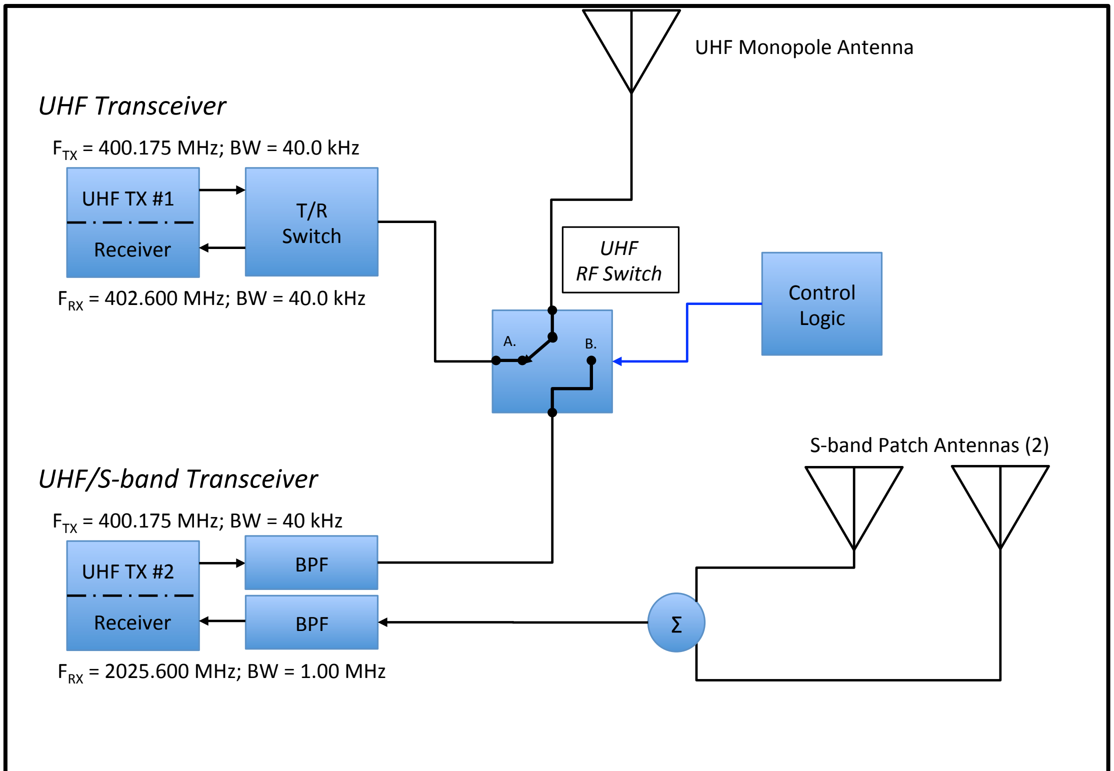


Figure 1B: CORVUS-BC and CORVUS-HD Communications T &C Block Diagram (Phase 2 and Phase 3)

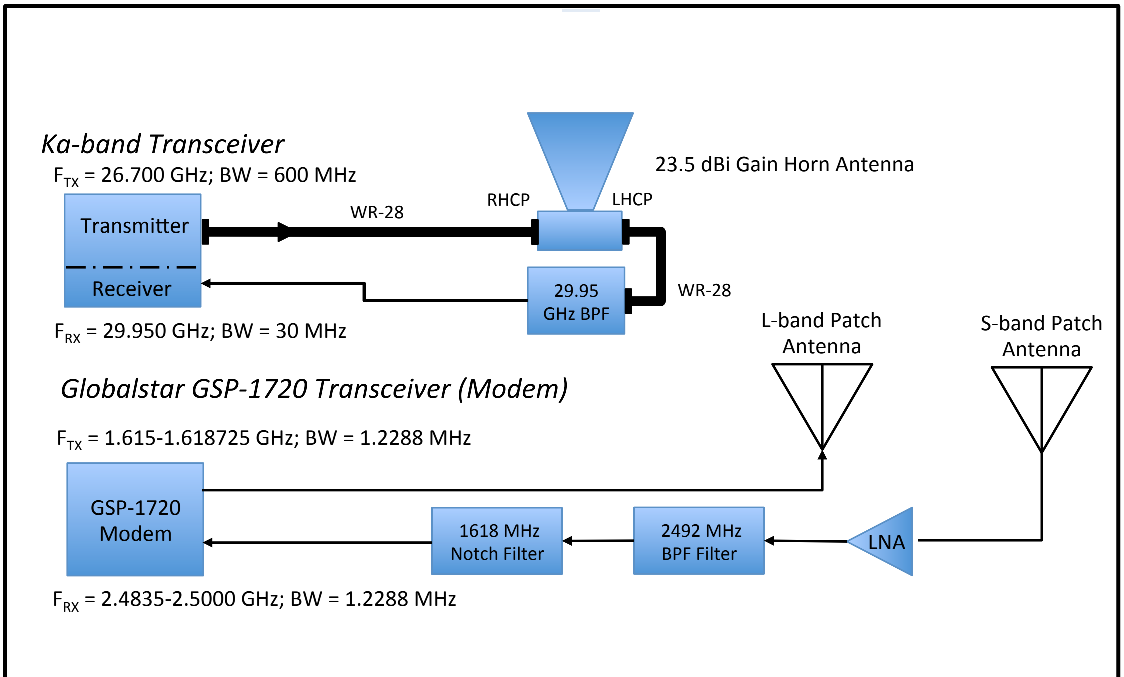
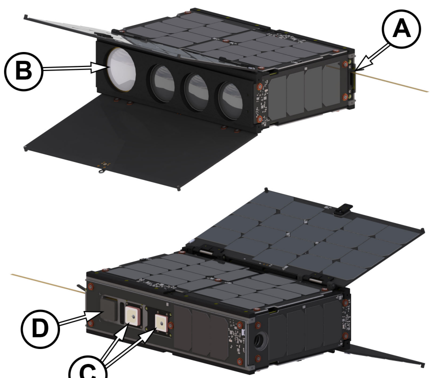
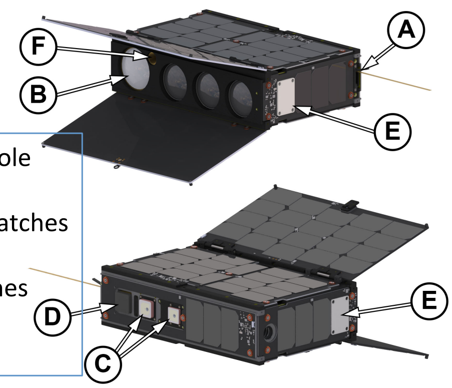


Figure 1C: CORVUS-BC and CORVUS-HD Communications Block Diagram (Circa 2018 -> Beyond)
High Speed Ka-band Communications Transceiver and Globalstar Modem

Corvus-BC Antenna Placement

Phase-1: 2017 - 2018	Phase-2,3: 2018 - Beyond



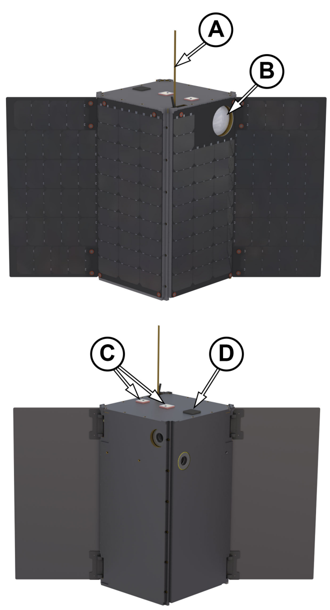


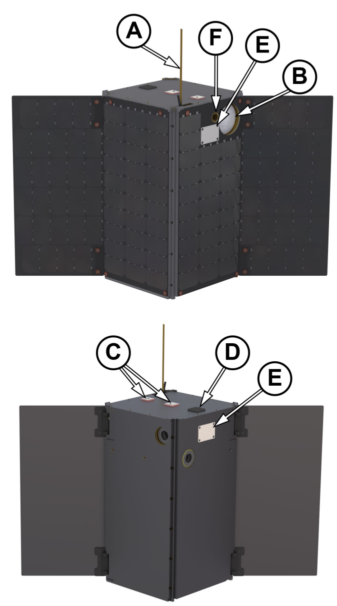
A: UHF Monopole
B: Ka TX horn
C: Globalstar patches
D: GPS patch
E: S band patches
F: Ka RX horn

Figure 2A: Corvus-BC Antenna Placement

Corvus-HD Antenna Placement

Phase-1: 2017 - 2018	Phase-2,3: 2018 - Beyond





A: UHF Monopole
B: Ka TX horn
C: Globalstar patches
D: GPS patch
E: S band patches
F: Ka RX horn

Figure 2B: Corvus-HD Antenna Placement

E. Cessation of Emissions and Frequency Tolerance of Emissions

Section 25.207 of the Commission's rules state that, "Space stations shall be made capable of ceasing radio emissions by the use of appropriate devices (battery life, timing devices, ground command, etc.), which will ensure definite cessation of emissions." Astro Digital utilizes multiple, redundant methods via several on-board receivers to control the operations of all its spacecraft and this particularly includes means to allow cessation of all RF emissions from the satellites. We fully comply with the §25.207 requirement regarding cessation of our space station emissions.

Additionally, Astro Digital will comply with the frequency tolerance requirements of section 25.202(e) and the emission limitations of section 25.202(f). *See* 47 C.F.R. §§ 25.202(e),(f).

F. Power Flux Density Calculations

Section 25.208 of the Commission's rules require that power flux density at the Earth's surface produced by emissions from a space station in the Earth Exploration Satellite Service in the band 25.5-27.0 GHz, for all conditions and for all methods of modulation to not exceed the following values:

- -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(δ -5) dB(W/m^2) in any 1 MHz band for angles of arrival (δ measured in degrees) between 5 and 25 degrees above the horizontal plane;

- -105 dB(W/m^2) in any 1 MHz band for angles of arrival between 25 and 90 degrees above the horizontal plane.

where δ is the angle between the boresight of the victim antenna and the horizontal plane. The PFD in a reference bandwidth of 1.0 MHz may be calculated using the relationship:

$$PFD\ [dB(W/m^2/1\ MHz)] = EIRP(dBW) - 71.0 - 20\log_{10}(D) - 10\log_{10}(BW)$$

Where:

- EIRP is the maximum EIRP of the transmission, in dBW = 23.4 dBW
- D is the distance in km between the satellite and the victim antenna (or surface area of interest)
- BW is the symbol bandwidth of the transmission, in MHz

These limits refer to the PFD that would be obtained under assumed free-space propagation conditions only (no excess path loss of any kind is assumed). This corresponds to worst-case conditions for our system as excess path loss at Ka-band mmW frequencies for space systems never approaches zero under any practical link conditions, at any elevation angle. Figure 3 and Table 3 below provide calculations for the worst-case scenario for PFD on the Earth's surface for both the CORVUS-BC and CORVUS-HD satellite types, as a function of elevation angle. Two conditions are presented:

a). Case 1: For both spacecraft models at 500 km circular orbit altitude (lowest starting [beginning of life] altitude for any member of the constellation).

b). Case 2: For both spacecraft models at 300 km circular orbit altitude (lowest end-of-life altitude currently envisioned for the operation of any member of the constellation).

We note that our Ka-band TX, operating at 26.800 GHz, may be adjusted in output power, by ground control, from the maximum power level of 1.0 watt (as was used to calculate the PFD values given in Table 3) to levels as much as 20 dB below this level (or a transmit power equal to 10 mW). Hence it is always possible for our system to reduce emission EIRP in order to satisfy regulatory PFD requirements, regardless of spacecraft altitude or, otherwise, in order to deal with practical interference problems that could possibly arise.

Table 3: PFD vs. Elevation Angle for CORVUS-BC and –HD Spacecraft

Power Flux Density (PFD) vs. Elevation Angle for CORVUS-BC & -HD Spacecraft at 500 km and 300 km Altitude							
FCC/ITU Limit:	*Elevation Angle:* (degrees)	*Upper Limit Orbit Altitude:*		500.000 km	Lower Limit Orbit Altitude:		300.000 km
		Range:	*PFD in 1 MHz:*	*Margin w.r.t. Limit:*	Range:	PFD in 1 MHz:	Margin w.r.t. Limit:
-115	0	2574.52 km	-134.4	19.4 dB	1979.11 km	-132.1	17.1 dB
-115	5	2077.96 km	-132.5	17.5 dB	1499.81 km	-129.7	14.7 dB
-112.5	10	1695.09 km	-130.8	18.3 dB	1160.39 km	-127.5	15.0 dB
-110	15	1407.52 km	-129.1	19.1 dB	926.42 km	-125.5	15.5 dB
-107.5	20	1192.99 km	-127.7	20.2 dB	763.99 km	-123.8	16.3 dB
-105	25	1031.94 km	-126.4	21.4 dB	648.54 km	-122.4	17.4 dB
-105	30	909.50 km	-125.3	20.3 dB	564.20 km	-121.2	16.2 dB
-105	35	815.09 km	-124.4	19.4 dB	501.03 km	-120.2	15.2 dB
-105	40	741.33 km	-123.6	18.6 dB	452.70 km	-119.3	14.3 dB
-105	45	683.09 km	-122.9	17.9 dB	415.14 km	-118.5	13.5 dB
-105	50	636.79 km	-122.3	17.3 dB	385.62 km	-117.9	12.9 dB
-105	55	599.87 km	-121.7	16.7 dB	362.28 km	-117.4	12.4 dB
-105	60	570.52 km	-121.3	16.3 dB	343.85 km	-116.9	11.9 dB
-105	65	547.40 km	-120.9	15.9 dB	329.41 km	-116.5	11.5 dB
-105	70	529.55 km	-120.7	15.7 dB	318.31 km	-116.2	11.2 dB
-105	75	516.29 km	-120.4	15.4 dB	310.08 km	-116.0	11.0 dB
-105	80	507.14 km	-120.3	15.3 dB	304.42 km	-115.8	10.8 dB
-105	85	501.77 km	-120.2	15.2 dB	301.09 km	-115.7	10.7 dB
-105	90	500.00 km	-120.2	15.2 dB	300.00 km	-115.7	10.7 dB
$dBW/m^2/MHz$	--		$dBW/m^2/MHz$			$dBW/m^2/MHz$	

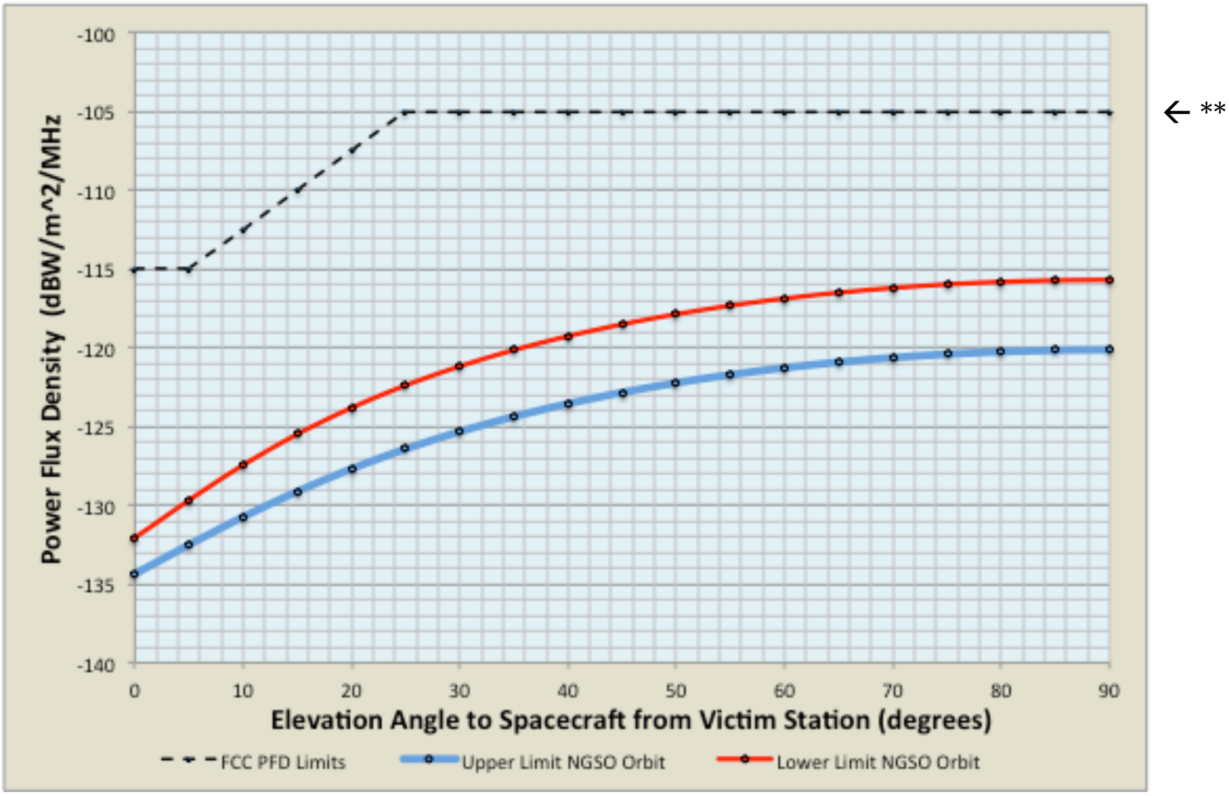


Figure 3: PFD vs. Elevation Angle for Upper and Lower Limit CORVUS Spacecraft

* * PFD Limit: FCC Part 25.208(p); ITU Article 21, Table 21-4

It can be seen that significant margin exists between our worst-case achieved PFD levels vs. those limits imposed by 25.208(p) such that, as long as our spacecraft are actually in Earth orbit (altitude >160 km), the PFD limit would not be exceeded. Hence this control capability is not essential to the discussion of PFD exceedance. Figure 3 demonstrates this even more clearly.

As we noted in our **D. Technical Description** section above, as our constellation is deployed we propose to increase our emission bandwidth in two steps. For satellites launched in Phase-2 of our program we will increase our operating bandwidth from 86.4 MHz to 220 MHz. For satellites launched in this time frame, we will likely increase the satellite Ka-band transmitter power output to 2.0 watts and consequently both the link C/N and the PFD will *increase* by +5.2 dB - $10Log_{10}(86.4/220)$ = +1.1 dB. However, in Phase-3 we will begin to launch the remaining satellites in the constellation (as well as their replacements) using new transmitters having a bandwidth of 600 MHz and with a power output of 4.0 watts. As noted above, this increase in bandwidth is offset by a corresponding increase in power resulting in very nearly the same C/N and PFD performance as is represented by this application. Consequently, under worst-case conditions, when one of these spacecraft might be at 90° elevation angle w.r.t. the victim receiving station, the PFD received by the victim receiver would be:

a.) -122.5 dB(W/$m^{2)}$/MHz for satellites in a 500 km circular SSO

b.) -118.7 dB(W/m^2/MHz for satellites in a 300 km circular SSO

As can be seen, the PFD level does not change dramatically, with this increase in bandwidth and power and is well within FCC/ITU limit requirements.

G. Interference Analysis

1. Interference between EESS systems operating in the band 25.5-27.0 GHz EESS band.

Interference between the Landmapper constellation satellites and those of other EESS systems is unlikely because:

a.) Even by the time that the Landmapper satellite constellation is mature, the system will use only 600 MHz of the 1500 MHz available in the EESS band at 25.5-27.0 GHz. Hence only other systems occupying the same or overlapping portions of this band could be subject to interference from the Landmapper system.

b.) Other EESS systems operating in the 25.5-27.0 GHz band, like Landmapper, normally transmit only in short periods of time while they are visible from dedicated receiving Earth stations.

c.) The Landmapper constellation exclusively uses Earth stations located at very high latitude (e.g. , Svalbard, Norway at 78° N), thus emissions will not be in view of other EESS Earth stations located at much lower latitudes.

d.) The Landmapper space station transmitter produces a directive antenna beam with a -3 dB beamwidth of 10.2°. Thus, the Landmapper satellites will only illuminate a small region on the Earth's surface at any time. The spacecraft antenna must be directed toward the receiving Earth station in order to complete the link. Other receiving stations outside of this beam footprint will not be caused harmful interference due to the very low PFD level achieved outside this beam footprint on the Earth's surface.

e.) The intended Earth station at Svalbard has a -3 dB beamwidth of 0.28° and is a parabolic dish with a diameter of 2.8 meters. Similar or even larger antennas will be required to receive other EESS satellite system in this frequency band when similar data rates are achieved. In order for the

Landmapper system to cause interference to such an Earth station would require that the Landmapper system be within this very narrow beam or very close to it.   Assuming this station is receiving an EESS spacecraft from another system, it is highly unlikely that the Earth station will have both space stations in the common beamwidth of the antenna at the same time.

In summary, for interference to another EESS system to occur would require the following simultaneous conditions to be satisfied:

- The victim ground station would have to be using at least a partially overlapping spectrum assignment within the EESS band at 25.5-27.0 GHz.
- The victim station would have to be in view of a Landmapper satellite (situated at high latitude) AND with its transmitter ON.
- The Landmapper satellite beam would have to be directed toward the victim station (which would require the victum site to be within only a few hundred kilometers of our Svalbard Earth Station. Otherwise, that Earth station would be outside of the Landmapper satellite's directed beam.
- And most unlikely, the victim Earth station antenna would have to have its highly directive beam directed at the downlinking Landmapper space station.

This aggregate and simultaneous set of circumstances is highly unlikely and if such circumstances did occur, they would occur for only a very brief time (a few seconds) as one spacecraft moved past another in two different orbits. In such an unlikely event, the interference could still be avoided by coordinating the satellite transmissions between two conflicting EESS users, prior to the event, so that these conditions do not occur simultaneously.

2. Interference to U.S. Government DRO and EESS Systems from the Landmapper System

Federal DRO Systems: Federal regulations[8] specifically require that protection be given to federal satellites using the geostationary orbit for DRS (data relay satellites) like TDRSS. ITU Recommendation SA.1862, under "recommends (5)" states:

> **5** that EESS and SRS satellites in non-geostationary orbits with space-to-Earth satellite links should not produce a PFD greater than −133 dB(W/(m^2 · MHz)) at any DRS satellite location on the geostationary orbit. This limit may be exceeded no more than 0.1% of the time for non-GSO systems with altitudes greater than 1 370 km (see Annex 2).

And, further, ITU Recommendation SA.1278 states in the relevant portions of that document:

[8] 47 CFR, Parts 25.202 in conjunction with 2.106 and footnotes US-258 and 5.536 are applicable. As the band 25.5-27.0 GHz is allocated on a co-primary basis between Federal and non-Federal space stations, US-258 requires that, "In the bands 8025-8400 MHz and 25.5-27 GHz, the Earth exploration-satellite service (space-to-Earth) is allocated on a primary basis for non-Federal use. Authorizations are subject to a case-by-case electromagnetic compatibility analysis.

noting

a) that due to the small number of expected EESS earth stations to be deployed worldwide (10-40 stations), coordination between fixed and land mobile systems and the EESS stations would not put undue constraints on either of the services,

recommends

1 that sharing between transmitting EESS satellites and receiving data relay satellites (DRS) operating in the ISS near 26 GHz is feasible given the following constraints:

– EESS satellites in sun-synchronous orbit or in an orbit that is proximate to the orbits of the DRS user satellites shall not produce a power-flux-density (pfd) greater than –155 dB(W/m^2) in 1 MHz at any location on the geostationary orbit (GSO) for more than 0.1% of the time (see Note 1);

– EESS satellites in orbits other than that mentioned above shall not produce a pfd greater than –155 dB(W/m^2) in 1 MHz at any location on the GSO for more than 1% of the time;

2 that, when designing EESS systems, the probability of receiving brief periods of interference from DRS user satellites in the ISS should be taken into account. This interference should exist for less than 0.1% of the time;

3 that EESS systems be designed to operate within the currently applicable pfd limits in the band:

Limit (dB(W/m^2)) in 1 MHz bandwidth for angle of arrival, φ, above the horizontal plane		
0° - 5°	5° - 25°	25° - 90°
–115	–115 + 0.5(φ–5)	–105

We note that the more restrictive of these two documents is SA.1278, Recommends 1 and this imposes an Inter-satellite Service restriction on EESS NGSO systems that could cause harmful interference to DROs operating in GEO orbit. The limit imposed, without limitation to the duration of the emission from the NGSO is -155 dBW/m^2/MHz. While it is not certain whether SA.1278 has been withdrawn from ITU-R or is still applicable, our Attachment E to this application performs an analysis in order to determine if our system could cause interference under the worst-case terms given in SA.1278.

The Landmapper system only turns on it's 26.8 GHz transmitter in the vicinity of Svalbard, Norway. When one of the CORVUS satellites is to the North of Svalbard and at very low elevation angles to that Earth station there is the potential for interference to space systems in the GEO arc. The geometry in this circumstance aligns the Ka-band antenna of a CORVUS satellite with a view toward the GEO arc, albeit at very low elevation angles (never exceeding 3°). However, our analysis concludes that under worst-case conditions (where no excess path loss is taken for atmospheric absorption at these mmW frequencies) the PFD at the GEO arc in the vicinity of a slot at 15 E would still never exceed -159 dBW/m^2/MHz. Further this alignment of conditions would only occur for seconds per orbit during some orbits of the day. This condition could occur over a range of GEO arc locations depending on the relationship between the EESS-NGSO satellite and Svalbard station. [See Example 1, Attachment E]. The range of the geostationary arc where such visibility exists, from Landmapper EESS-NGSOs to the GEO arc, is between slots at 26.7° W and 57.5° E longitude. The remainder of the GEO arc is below the horizon for all other downlinking CORVUS satellites beaming in the direction of the arc. Due to the low PFD produced, we thus conclude that there is NO interference case where Landmapper satellites could interfere with TDRSS or other future DRS systems operating under the same conditions. [See Attachment E for more detailed calculations].

Federal EESS NGSO Systems: Some Federal remote sensing satellites are under development that plan to make use of the frequency band 25.5-27.0 GHz for EESS space-to-Earth transmissions.[9] For such systems, our analysis in Section II.F. is fully applicable. All five conditions we identified in that section would have to be

[9] NOAA's JPSS satellite system, anticipated to be launched in 2Q2017.

simultaneously satisfied in order for interference from a Landmapper spacecraft to occur to a Federal EESS Earth station. If such a condition could occur, it could be forecast to be at a specified time in the future. Thus, a pre-coordination activity could prevent even the very short interference events that might transpire. Astro Digital has already initiated discussions with NOAA regarding the JPSS Mission, which plans to use a center frequency of 26.700 MHz with a bandwidth of 300 MHz. [We note that this emission does, indeed, overlap with the Landmapper proposed Ka-band transmitter assignment during all three of our mission phases]. Further, our discussions with NOAA suggest that they plan to also use an Earth station at Svalbard, Norway as a downlink location for their system. In this instance, then, at least 3 of our 5 conditions for interference are satisfied. Even so, it is still very unlikely that interference will occur due to the difference in arrival time of the satellites at the Earth stations and the very low probability that both Earth stations at Svalbard will be directed at the same small point in the sky at the same time due to the very narrow beamwidths of both tracking antennas. However, in this instance, we are working closely with NOAA in order to coordinate our constellation emissions. As of February 24, 2017 two separate interference analyses have been carried out under the direction of the NOAA frequency manger. These studies, using the Visualyse analysis tool, reviewed the potential for a Landmapper satellite to cause interference to the JPSS Earth station at Svalbard. These NOAA spacecraft (4 in number) are anticipated to be in orbit within the next two years. The conclusion of these analyses, to date, suggest that at least for the first satellite of the

Landmapper constellation, no interference is anticipated.[10] We will continue this pre-coordination and Astro Digital has proposed to perform joint tests with NOAA at Svalbard that should mitigate any further concerns regarding band sharing. This type of analysis can also apply to other Federal EESS system missions, which may need to use the 25.5-27.0 GHz EESS/SRS band in the future.

3. Interference to U.S. Government Fixed and Mobile Systems from the Landmapper System

As we know of no specific regulations, which apply only to Federal Fixed or Mobile users of the band 25.5-27.0 GHz, we assume that the general PFD limits addressed in 47 CFR, Part 25.208 apply to ALL fixed and mobile services operating in this band. As discussed in detail in II.E. of this Exhibit, our system fully complies with PFD limits at all elevation angles w.r.t. terrestrial user systems based on the limits required by 25.208, and with considerable margin. Thus, we anticipate no interference conditions with respect to Federal Fixed or Mobile users, based on our interpretation of the radio regulations.

H. Orbit Considerations

We identify in Table 4 for the Commission, the range of orbit parameters we can accept for satellites within our constellation. These are driven by business and physical constraints related to image gathering.

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[10] The conclusion of the report, in part was: "Thus, the Astro Digital Ka-band downlink will not interfere with the JPSS Ka-band downlink for one Astro Digital satellite. Multiple Astro Digital satellites will need to be analyzed if applicable."

Table 4: Landmapper Constellation Orbit Parameters

Orbit Parameter:	Minimum:	Maximum:
Altitude*:	475 km	625 km
Inclination:	97.4 deg.	97.9 deg.[11]
Period:	94.6 min.	97.2 min.
Longitude of Ascending Node:	8:30 AM	3:30 PM
Eccentricity:	0.000	0.0033[12]

* $h = (h_a + h_p)/2$; where: h_a = apogee altitude, h_p = perigee altitude

The system will continue to operate as the individual satellite orbits decay until the satellites reach an altitude of 300 km. The lifetime of these orbits were analyzed in our ODAR submission and are reported in **Attachment J: Orbit Debris Mitigation** of this application.

Schedule S of FCC Form 312 anticipates that all constellations filed under Part 25 will have a systematic and regular (non-statistical) behavior, similar to the properties of a Walker constellation.[13] In such systems, satellites are distributed in regularly spaced planes with equally spaced satellites within each plane. Fundamentally, small satellites launched as secondary payloads, with very limited or no propulsion capability, cannot achieve this form of rigorous constellation

[11] Inclination will be consistent with a sun-synchronous orbit (SSO) characteristic.
[12] This value is consistent with our maximum SSO of 625 km having apsides of 602 km perigee and 648 km apogee. Alternatively, our lowest orbit of 475 km would have a perigee of 452 km and an apogee of 498 km.
[13] Walker, J.G., *Satellite Constellations*, British Interplanetary Society, Journal (Space Technology) (ISSN 0007-084X), vol. 37, Dec. 1984, p. 559-572.

management. So, within the scope of the on-line Schedule-S scheme, we have done our best to describe the Landmapper constellation. This section of our Exhibit describes how we intend that the information in our Schedule-S be interpreted. Figure 4 shows a very simplified polar view of the constellation to be used only for interpretation of our plan.

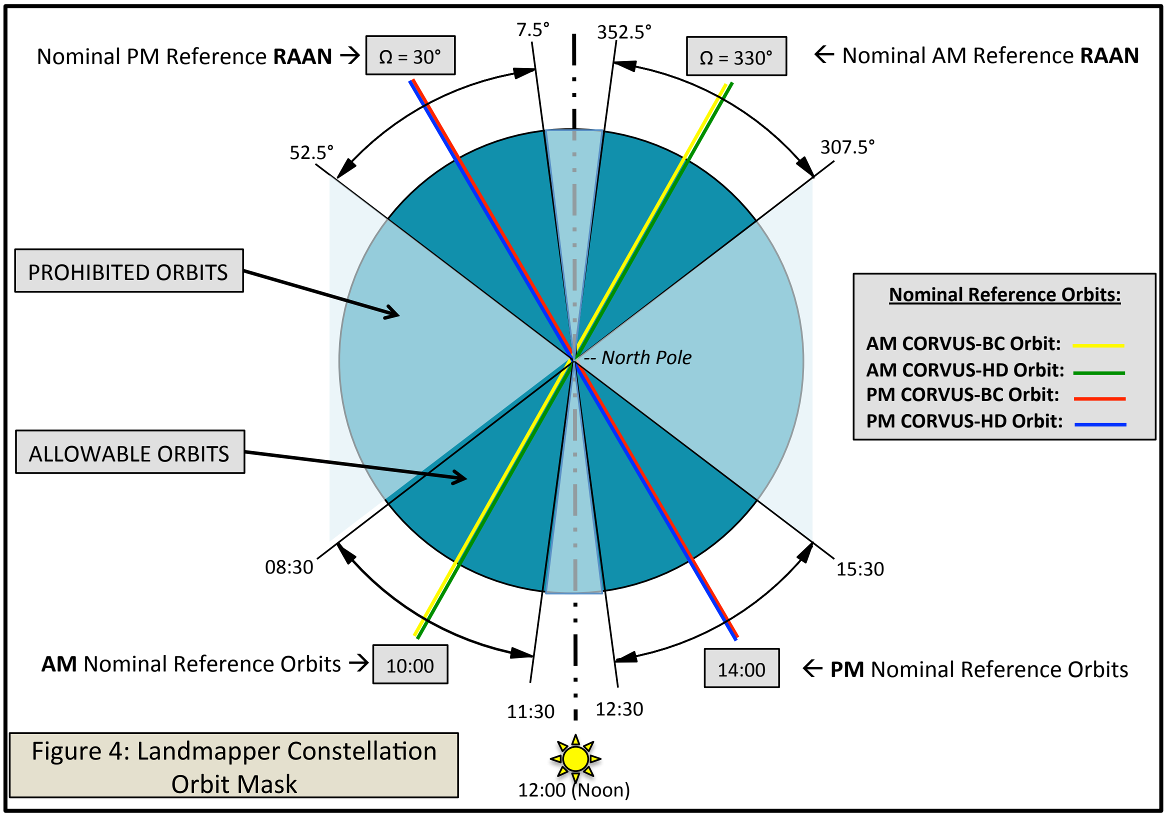

Figure 4: Landmapper Constellation Orbit Mask

Our constellation can be considered to be composed of four nominal planes of satellites.   Two of the planes have orbit positions such that they have AM ascending nodes and two of the planes have PM ascending nodes. In both the AM and PM orbit cases, the two planes are identical in ascending node time (RAAN[14] values are equal) and in altitude (semi-major axes are equal). These shall be referred to as the *nominal reference orbits*. One of the AM orbits contains 5 CORVUS-BC satellites, equally-spaced around the obit. The second AM orbit contains 10 CORVUS-HD satellites, also equally-spaced around their orbit. There need not be any precise angular difference between the satellites in these two planes. This can be a free variable and, hence, these two planes can be said to be independent in terms of *orbit phasing between the planes*. The PM portion of our system is the same. There are two nominal reference orbits of equal altitude and RAAN value. Again, one orbit plane contains 5 CORVUS-BC satellites, equally-spaced and the second plane contains 10 CORVUS-HD satellites, also equally-spaced. What now explains our constellation best, given these 4 reference orbit planes we have defined in Schedule S, is a random distribution of satellites injected into orbit about these nominal reference planes. The orbit of each individual satellite (or what could be a group of up to six satellites) can and will be achieved using different launchers and having different primary customer payloads. The result of Astro Digital not being unable to select our exact intended orbit, launch time and date is the creation of a constellation of nearly randomly distributed orbits, which can only be controlled by selecting a range of real orbits that center about the nominal reference orbits. We *purchase* launches so that each satellite's actual orbit can be allowed to vary by no more than ±1.5 hours in LTAN (or ± 22.5° in RAAN). Similarly, the initial orbit altitude of each satellite's orbit is only allowed to vary from 625 km to as low as 475

[14] RAAN is an acronym for Right Ascension of Ascending Node. The RAAN must be tied to an epoch (time) when the RAAN value is true (accurate). Also RAAN = Ω.

km. [Note: these orbits are also nominally circular]. However, we believe the most likely altitude we can obtain (procure) is 585 km. This is not centered, as might be expected, at 550km. The extreme orbit cases are as expressed in Table 4 above. The PM orbits have the same allowable dispersion around their nominal reference orbits. This dispersion in our "allowable" obits about the nominal reference orbits is summarized in Table 5. We note from Figure 4, there is a gap near local noon where there will be no orbit coverage. This is intentional as orbits that ascend near noon have unfavorable lighting/shadowing conditions. Orbits with LTAN times near twilight (6AM-6PM) are also avoided for the same reason. We also note that the AM orbit's local ascending node times can be from 8:30 to 11:30 AM and that the PM orbit local ascending node times can be from 12:30 PM to 3:30 PM.

Orbit Type:			Altitude:	RAAN:	LTAN:	Eccentricity:
Nominal Reference Orbit		AM	585 km	330°	10:00	0.0000
		PM	585 km	30°	14:00	0.0000
At Launch	Allowable Orbit Dispersions:		+40/-110 km	±22.5°	±90 min	0.0033
	Highest Possible Orbit: (Worst Case Eccentricity)		h_a= 648 km h_p = 602 km	----------	----------	0.0033
	Lowest Possible Orbit: (Worst Case Eccentricity)		h_a= 498 km h_p = 452 km	----------	----------- -	0.0033
	Earliest AM Orbit:		----------------	307.5°	08:30	-------------
	Latest AM Orbit:		----------------	352.5°	11:30	-------------
	Earliest PM Orbit:		----------------	7.5°	12:30	-------------
	Latest PM Orbit :		----------------	52.5°	15:30	-------------
	ALL ORBITS ARE SUN-SYNCHRONOUS					

Table 5: Landmapper Constellation Orbit Summary

A final comment must be made about orbit phasing. As the orbits about the nominal reference orbits cannot be equal in period, regular Walker-like phasing *between planes* will not be possible. However, we do have the ability (via the use of differential drag) to phase satellites within their orbit planes. For the N satellites (where N=2 to 6), which may be launched into any given single orbit, Astro Digital will utilize equally spaced phasing between satellites. And, if patterns in phasing do emerge between satellites in two different AM or PM orbits, this phasing pattern will be exploited in an effort to optimize coverage and minimize image repeat time.

<u>Replacement satellites</u>: As noted in our introduction to this application, we intend to operate the Landmapper constellation for the 15 year duration of the requested license period. During this time, it is very likely that operational satellites will need to be replaced due to either satellite failures, normal satellite wear-out mechanisms or orbit decay (in the event that lower starting orbits must be purchased). While it is likely that we eventually will be able to purchase a launch to our precisely required orbit over the next few years, it is not possible to achieve this goal for small space systems today. Therefore, Astro Digital will make every attempt to replace the type of satellite that has gone out-of-service (either a –BC or –HD type) with the closest match possible to the same orbit. However, obtaining the same orbit with a short turn-around time may be difficult. As a minimum, we will launch a replacement to one of the AM planes or PM planes depending on which plane requires an additional spacecraft. We believe that over the 15 year period of the license, in order to maintain 30 satellites in operational service, we may require that

up to 100 spacecraft be launched. For emphasis, we will not operate more than 30 active spacecraft at any one time into the constellation. Our space segment construction plan is based on this number of manufactured units.

I. Orbit Debris Mitigation

The Landmapper satellites will be deployed from various commercial launch vehicles in accordance with Table 1 in groups of from one (1) to six (6). Launch dates and final achieved orbits could vary but, will be firmly planned to be within the range given in Table 5 above.

Astro Digital has conducted an Orbital Debris Assessment Report ("ODAR") for the Landmapper constellation, in compliance with NASA-STD-8719.14, Attachment A, which is attached as Attachment J to this exhibit. As discussed in the submitted ODAR, the Landmapper system is compliant with all applicable NASA orbital debris requirements. Following is a summary report:

Astro Digital confirms that the Landmapper satellites will not undergo any planned release of debris. In addition, all separation and deployment mechanism and any other potential source of debris will be retained by the satellites, launch vehicles or deployment mechanisms. Astro Digital has assessed the probability of the satellites becoming sources of debris by collision with both large and small objects using NASA's Debris Assessment Software (DAS) v2.02 and has found the Landmapper constellation to be fully compliant.

Astro Digital has specifically conducted a collision risk analysis using the DAS software for the following scenario: *Assessment of Spacecraft Compliance with Requirement 4.7-1: Limit the risk of human casualty.*[15] Landmapper was found to be compliant with all variants of this case. Astro Digital has also engaged the Joint Space Operations Center (JSpOC) to receive conjunction threat reports to better coordinate collision avoidance (conjunction) events. As a part of our current operational procedures we continuously utilize these reports to assess collision events affecting our two test spacecraft currently operating in very similar orbits to those to be used by the Landmapper system.[16]

It has been brought to our attention that China's Tiangong-1 space module and Bigelow Aerospace's inhabitable space stations are other man-rated space objects that require a high level of coordination for collision mitigation. We realize that other international administrations may, in the future, have manned orbiting stations, which may require special level of coordination. In consideration of this situation, we will provide the responsible organizations with the information necessary to assess risks and ensure safe flight profiles. Astro Digital will provide a Point-of-Contact that will be available 24 hours per day/7 days per week to coordinate collision avoidance measures.

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[15] Per NASA-STD-8719.14 section and DAS v2.02

[16] Perseus-M1 and –M2 are operating under a Part 5 license under call sign WH2XCA. See FCC OET file number 0032-EX-PL-2014.

In addition to coordination and sequencing efforts, each of the Landmapper satellite will have the capability to perform collision avoidance using differential drag maneuvering techniques. Both Landmapper-BC and –HD spacecraft have deployable wing solar panels. This means that the spacecraft have significant asymmetry in terms of their ballistic coefficient. By reorienting the spacecraft when they are not collecting data, downlinking data or recharging batteries (such as during eclipse) the attitude of each spacecraft can be reoriented using on-board reaction wheels and magnetorquers. The ratio between the minimum and maximum drag configuration is given in Table 6 below. At all operational altitudes, any of the Landmapper satellites of both types (BC and HD) can perform a collision avoidance maneuver given approximately 2.0 days' notice (the warning time required depending on the specific orbit into which a given CORVUS is currently being operated and whether it is a BC or an HD spacecraft). This includes even the worst-case orbit (i.e., the orbit with the highest altitude/lowest drag), which is at 625 km altitude. We have prepared a detailed Differential Drag Collision Avoidance Analysis, which provides the detailed methods used for the avoidance maneuver and compares the two CORVUS spacecraft drag characteristics against other small EESS systems in orbit as well as CubeSat standard spacecraft.[17] We hereby incorporate this analysis into our application as a key exhibit regarding our debris mitigation strategy. It is included as Attachment F to Exhibit 43. It is important to note in this application that this very useful method of collision avoidance can be utilized by any constellation of spacecraft, large or small, so long as the ratio of drag

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[17] Cooper, Brian, *Differential Drag Collision Avoidance Analysis,* Astro Digital Report No. 120 10478 001, Rev. B.

coefficients for the different aspect ratios of the satellites (i.e. the view of the spacecraft along different axes) are significantly different. For spacecraft with deployable solar panels this is almost always the case. Thus, Astro Digital maintains that the use of differential drag should be an effective tool for collision avoidance for almost any space system with suitable attitude adjustment capability. As a 3-axis attitude control is required for directing imaging systems toward their target in any case, almost all EESS space systems would have the ability to perform such maneuvers. Hence, provided that JSpOC can issue reasonable advanced warning of a potential conjunction event, it should always be possible to avoid such a collision.

Table 6: CORVUS BC & HD Mass and Drag Characteristics

Parameter:🡣 / Satellite Type: ➔	**CORVUS-BC:**	**CORVUS-HD:**
Satellite Mass:	**11.5 Kg**	**21.5 Kg**
Average Drag Area:	**0.124 m^2**	**0.260 m^2**
Maximum Drag Area:	**0.142 m^2**	**0.345 m^2**
Minimum Drag Area:	**0.024 m^2**	**0.062 m^2**
Average Ballistic Coefficient:	**42.15 Kg/m^2**	**37.59 Kg/m^2**

Astro Digital notes in it's differential drag analysis (Attachment F), that executing a differential drag maneuver for any given Landmapper satellite will cause the loss of approximately 1 full day's worth of observational (imaging) data. While the drag maneuvers are being performed normal battery charging, imaging and data downlinking tasks cannot take place. Under certain circumstances, as much as 10.4% of the constellation's data could be lost to these maneuvers, in a worst case scenario. In summary, Astro Digital will utilize differential drag in conjunction with JSpOC advanced conjunction warnings as a primary means of avoiding Landmapper constellation space hardware collisions. Satellite re-entry will be via nominal orbit drag conditions as defined in our ODAR report. Astro Digital will request FCC authority at a later date to modify its satellites to include a propulsion system at approximately the beginning of Phase 3 of our program, as this will significantly improve operational efficiency of our space segment without increasing the risk of generating orbit debris.

J. Extent of Communications with Landmapper Satellites During Decent Through the Atmosphere

Astro Digital will turn off its Landmapper satellites once they decay to an altitude below 300 km. [18]

III. Additional/General Considerations

A. Waiver of §25.156 and §25.157

Astro Digital requests that this application be processed pursuant to the first-come, first-serve procedure adopted for "GSO-like satellite systems" under Section 25.158 of the Commission's rules. [19] To the extent necessary to allow for such processing, Astro Digital also requests waiver of Sections 25.156 and 25.157 of the

[18] These decaying satellites may be switched ON occasionally to obtain altitude and telemetry data from them for diagnostic purposes and to monitor their further decay.

[19] *See* 47 C.F.R. § 25.158.

Commission's rules, which stipulate the processing of "NGSO-like satellite systems" under a modified processing round framework. [20]

The Commission may waive any of its rules if there is "good cause" to do so. [21] In general, waiver is appropriate if: (1) special circumstances warrant a deviation from the general rule; and (2) such deviation would better serve the public interest than would strict adherence to the general rule. [22] Generally, the Commission will grant a waiver of its rules in a particular case if the relief requested would not undermine the policy objective of the rule in question, and would otherwise serve the public interest. [23]

The Commission has previously waived the modified processing round requirement and allowed EESS NGSO satellite systems to be processed on a first-come, first-serve basis. In Space Imaging, LLC, the Commission concluded that authorizing Space Imaging to operate in its requested EESS frequency bands would not preclude other NGSO operators from operating in those bands because NGSO EESS operators are generally capable of sharing spectrum in the same frequency. [24] The Commission also cited the fact that "very few" U.S. licensed EESS NGSO systems operating in the band further reduced the possibility of interference with other operators in the

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[20] *See* 47 C.F.R. §25.156 and §25.157.

[21] *See* 47 C.F.R. §1.3; WAIT Radio v. FCC, 418 F.2d 1153 (D.C. Cir. 1969) ("WAIT Radio"); Northeast Cellular Telephone Co. v. FCC, 897 F.2d 1164 (DC. Cir. 1990)("Northeast Cellular").

[22] Northeast Cellular, 897 F.2d at 1166

[23] WAIT Radio, 418 F.2d at 1157

[24] *See* Space Imaging, LLC, 20 FCC Rcd 11964, 11968 (2005). *See* also Stamp Grant, Skybox Imaging, Inc., SAT-LOA-20120322-00058 (granted September 20, 2012).

8025-8400 MHz band. [25] This is all-the-more true in the EESS band proposed to be used by Astro Digital at 25.5-27.0 GHz for our high speed imaging downlink. In fact, we believe we are the first commercial user of this band for EESS imagery to implement narrow beam downlink antennas, which allow significant spatial frequency reuse. In light of these circumstances, even in the 8025-8400 MHz band, the Commission concluded that Space Imaging's application warranted GSO-like processing, and waived Sections 25.156 and 25.157 of it's rules. [26]

Similar to the EESS NGSO system of Space Imaging, Astro Digital's Landmapper system is fully capable of sharing with current and future NGSO systems operating in the same frequency bands. The 25.5 to 27.0 GHz band can, in fact, support narrower beam antennas on smaller platforms and has four times more bandwidth, allowing far more satellites to share this same valuable resource. For harmful interference to occur, satellites belonging to different systems would have to travel through the antenna beam of the receiving Earth station and transmit at exactly the same time. [27] In such an unlikely event, the resulting interference can still be avoided by coordinating the satellite transmissions so that they do not occur simultaneously. For these reasons, the waiver request here is fully warranted because waiving Sections 25.156 and 25.157 will not undermine the policy objectives of those rules.

[25] Id. at 11968.
[26] Id. See also Digital Globe, Inc., 20 FCC Red 15696, 15699 (2005) (waiving Section 25.156 and 25.157). See also Stamp Grant, Skybox Imaging, Inc., SAT-LOA-20120322-00058 (granted September 20, 2012).
[27] See also Section II.F of this application for a more detailed explanation of interference criteria.

B. Waiver Requests for Non-Compliance with Category of Service for UHF Telemetry and Command Links

As we noted in Section II.(D.)(b.) above, the operation of our T & C links in the UHF bands as we proposed are within their proper categories of service. If the Commission grants this application as request, no waiver requests will be required due to non-compliance with any category of service. However, we have noted a variety of possible adjustments to our proposal that would result in moving these links slightly in frequency.[28] These adjustments, by the Commission would be acceptable and within the operating range of our current radio system. By doing so, however, we would require a waiver of category-of-service in some instances. The following waivers would be required, based on the selection of these certain specific options by the Commission:

1. Telemetry or Command Operations within the Band 399.9 - 400.05 MHz

As this band is allocated to the Mobile Satellite Service (Earth-space) we would require a waiver to operate our Command and Telemetry links as Space Operations Service space stations. The Telemetry downlink would have to be allowed to use the band as a space-to-Earth operating station instead of Earth-to-space.

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[28] See this application at Section II.D.b.

2. Telemetry or Command Operations within the Band 400.05 – 400.15 MHz

As this band is allocated exclusively in all three ITU regions as, Standard Frequency and Time Service-Satellite we would require a waiver to operate our Command and Telemetry links as Space Operations Service space stations in this band. This band, as it was previously used by Navy-Navsat was used as a space-to-Earth link. If used by Landmapper as a telemetry link, this link direction would be the same. If used by Landmapper as a command link, the link direction may require an additional waiver component to be used Earth-to-space.

3. Command Operations within the Band 400.15-401.00 MHz

As this band is allocated to the Space Operations Service only on a secondary basis and in the space-to-Earth direction, we would require a waiver to operate our Command link in this band as an Earth-to-space link. We note that additionally, we may run into opposition using this frequency for Space Operations (as our main telemetry link) since this band is also allocated on a primary basis to Mobile Satellite Service (space-to-Earth). This choice could set up a potential commercial conflict or need to coordinate. However, we are not currently aware that this frequency is in use by MSS operators and it seems unlikely that any licenses that have been granted will be brought into use within the required time limits.

4. Telemetry or Command Operations within the Band 401.00 to 402.00 MHz

As this band is allocated on a primary basis to both Space Operations (space-to-Earth) and Earth Exploration Satellite Service (Earth-to-space) we maintain that we would not require any change in category-of-service and could operate both Command and Telemetry links in this band. This is because the uplink would be used, routinely, to modify camera settings of our primary instrument. We note that the allocation in Space Operations is primary to non-government users but, that the EESS allocation is only secondary to non-government users.

5. Telemetry or Command Operations within the Band 402.00 to 403. MHz

As this band is allocated on a secondary basis to Earth Exploration Satellite Service (Earth-to-space) but, Space Operations is not allowed in this band segment, we would require a waiver if Landmapper were assigned a telemetry downlink in this band, while we would maintain that our EESS uplink was operating within its proper category of service. We also note that this band is also shared with Meteorological Satellites on a Co-Primary basis.

6. Waiver of U.S. FN384

Our preferred frequency for early (Phase 1) command operations is 402.600 MHz. This frequency has been used by our experimental satellites, to date, without any notifications from the U.S. government (in particular NOAA) of harmful interference received by Federal stations. However, our interests are commercial and for longer duration. Astro Digital is aware that NOAA has an important communications service operating on its GOES geostationary satellite systems, known as the Data Collection System (DCS). This system occupies a receive band from 401.7 – 402.4 MHz.[29] As Astro Digital is aware that this system has been in service for nearly 40 years and is used at many thousands of terrestrial user sites for critical meteorological and safety-of-life purposes, we selected a frequency above this GOES-DCS uplink band, at 402.600 MHz. This frequency is thus, separated from GOES DCS by 200 kHz on the high side of that band. Our transmitter bandwidth is 40 kHz and accounting for Doppler effects of our carrier, we will still be 160 kHz above GOES DCS.

Non-the-less there is a U.S. footnote that protects the entire band from effectively being used for commercial purposes.[30] It is clear from assessing this footnote, our space stations would not qualify in any sense as a *Federal space stations*. We believe our use of this band for controlling our EESS camera system has effectively avoided the original purpose of this footnote, which was to protect the GOES system and other international meteorological satellites carrying DCS systems. Further, we believe that by operating only one station at Mt. View, CA and by using a narrow

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[29] Mistichelli, F., *Earth-to-space and space-to-Earth Frequencies (FORWARD) GSO Networks*, NOAA presentation at 1st Commercial Smallsat Spectrum Management Association Meeting, 16 Sept. 2016, Washington, DC, NOAA handout, Tab 2, p. 16.

[30] US384 States:

US384 In the band 401-403 MHz, the non-Federal Earth exploration-satellite (Earth-to-space) and meteorological-satellite (Earth-to-space) services are limited to earth stations transmitting to Federal space stations.

beam UHF uplink antenna system (10° beamwidth), we will not cause existing Federal systems harmful interference. Therefore we believe that granting this waiver would not result in harmful interference to Federal space stations.

7. Waiver Request to Allow the Utilization of ITU FN 5.541 for Landmapper Satellites

As discussed in Section II.D.1. of this application we propose to use a portion of the band 29.90-30.00 GHz as an EESS (Earth-to-space) data link. This link would only be utilized from our high-speed data transfer location at Svalbard, Norway using KSAT facilities. Our proposed use of this frequency, we believe, is in full compliance with ITU FN 5.541. We note that EESS (E-s) in this band is on a secondary basis in all three ITU Regions. However, it seems that this footnote has not been brought into use in the U.S. domestic table on either the government or non-government side. We therefore request a waiver to allow the Landmapper system to make use of 5.541 in accordance with the International Table. The transmission characteristics of our satellite and ground station beams for this link are as characterized in Attachments B, C and D to this Exhibit. We further agree that we will operate as a secondary user in this band: we will cease operations if we cause interference to MSS or FSS operations and we will not claim protection from primary allocation users in the in this band. We note that both the transmitter and receiver components of this link do use directive antennas. The uplinking station at Svalbard will have a beamwidth of 0.25°.

D. Waiver Request for Use of the Globalstar MSS System while Operating in the Inter-Satellite Service (ISS)

As described in Section II.D.3. of this application, Astro Digital proposes to use the Globalstar system as an alternative T&C system, allowing broader area coverage without the additional investment in dedicated ground stations for this purpose. This approach will also provide real-time coverage and collection of valuable information over regions of the Earth not possible by other means. While the Globalstar system is capable of operating cross-link to our satellites in both FWD and RTN link directions it would do so with both space station constellations operating in the ITU-defined "Inter-Satellite Service." The only practical concern associated with this application of use, is the potential for interference to terrestrial stations operating in the same or adjacent frequency bands from a Landmapper spacecraft, intending to communicate cross-link to a Globalstar spacecraft. These emissions could occur within the overall frequency band 1610-1626.5 MHz. However, to avoid interference, particularly to sensitive Radio Astronomy Service Earth stations, the emission band we would use on the Landmapper space stations has been restricted to 1615-1618.725 MHz While 47 CFR 25.213 addresses protection of Radio Astronomy from NGSO MSS systems, it does not establish specific PFD or EPFD limits within that section of the radio regulations. The ITU has addressed the issue of interference protection criteria for Radio Astronomy in several documents.[31] In order to establish the general feasibility of not causing

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[31] Of the ITU-R resolutions and recommendations addressing RA interference, we found Recommendation ITU-R RA 769-2 to be most comprehensive as it also cites

interference to Radio Astronomy stations we have performed a simple worst case analysis to determine the level of the Landmapper→Globalstar link to comply with RA protection criteria as given by Table 2 and §2.2 of ITU-R 760-2. Our results are provided as **Attachment I** to this Exhibit. While we have utilized a worst-case method involving applying a commercial OCDMA emission mask as a representation of the output of the transmit satellite modem in order to offset, for the time being, performing a more complex EPFD analysis, we note that significant margins appears to exist, protecting RAS from MSS service even while operating in an ISS mode. While more analysis and testing would be beneficial, by this analysis we have demonstrated that our system, if a certified version of the commercial GSP-1720 modem is used, Landmapper will not cause harmful interference to stations in the Radio Astronomy Service. All other stations using this band are less likely to receive interference from our system than radio astronomers. We therefor, request that the Commission grant this waiver to utilize the Globalstar system on its RETURN link while operating within the Inter-Satellite Service.

E. Waiver Request of Default Service Rules

Astro Digital requests a waiver of the default service rules under Section 25.217(b) of the Commission's rules. [32] The Commission has not adopted band-specific rules for EESS NGSO operations in the 25.5-27.0 GHz band. However, the Commission has previously granted a waiver of the default service rules contained in Section

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and utilizes procedures and methods from the other applicable ITU-R documents (most notably in our case, ITU-R M.1583 and ITU-R RA.1513).

[32] *See* 47 C.F.R. § 15.217.

25.217(b) to NGSO EESS system licensees, based on the fact that EESS operators are required to comply with technical requirements in Part 2 of the Commission's rules and applicable ITU rules.[33] In these cases, the Commission concluded that because the cited requirements had been sufficient to prevent harmful interference in the relevant band, there was no need to impose additional technical requirements on operations in that band, and therefore granted the waiver requests. For these same reasons, plus the potential for an even higher reuse factor in the 25.5-27.0 GHz band, resulting from the use of even narrower beamwidth space and Earth station antennas, the Commission should grant Astro Digital a waiver of the default service rules contained in Section 25.217(b).

F. Form 312, Schedule S

As required by the Commission's rules and policies, Astro Digital has completed, to the best of our abilities, the FCC Form 312, Schedule S submission that reflects the orbital and physical/electrical characteristics of the Landmapper Constellation. Due to certain limitations of the Commission's software, Astro Digital urges the Commission to refer to the data in this exhibit and it's attachments for the most accurate information pertaining to our system. We particularly request that you refer to our Attachment B: Link Budgets as the primary source of information regarding the radio frequency performance of the Landmapper links.

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[33] *See* Space Imaging, 20 FCC Rcd at 11973; Digital Globe, 20 FCC Rcd at 15701-02 (2005). *See* also Stamp Grant, Skybox Imaging, Inc., SAT-LOA-20120-322-00058 (granted September 20, 2012).

G. Implementation Milestones

Astro Digital intends to supply the Commission with information sufficient to demonstrate that it has already satisfied the first three (3) implementation milestones under Section 25.164(b) for NGSO systems in a separate submission. Astro Digital understands that in the absence of a favorable Commission determination of milestone compliance issued with the grant of this application or within 30 days thereafter, the full amount of the bond specified in Section 25.165(a)(1) will be required.

H. ITU Advanced Publication Materials and Cost Recovery

Astro Digital will provide the International Telecommunications Union (ITU) Advanced Publication Information (API) submission for its proposed non-geostationary EESS system to the Commission under separate cover. As a separate attachment to this application, Astro Digital is providing a letter acknowledging that it is responsible for any and all cost recovery fees associated with filings for the proposed system under ITU Council Decision 482 (modified in 2008), as it may be modified or succeeded in the future. Astro Digital also notes that it has submitted this same acknowledgement on multiple occasions in the past for all of it's experimental satellites (licensed under Part 5 of the Commission's rules), some of which may ultimately be incorporated into the Landmapper constellation.

In summary, Astro Digital, Inc. respectfully requests the Commission to grant the application for launch and operation authority as detailed herein. To the extent necessary, Astro Digital request expedited consideration of this Application in order to ensure favorable Commission action in advance of the scheduled September 2017 launch of the first commercial satellites in the Landmapper constellation seeking authorization under 47 C.F.R., Part 25.