Xona System
Technical Narrative

1 Introduction

Consistent with the FCC Part 25 rules, this Technical Narrative documents pertinent information of the Xona Space Systems, Inc. ("Xona") non-geostationary orbit ("NGSO"), low-Earth orbit ("LEO") system ("Xona System") and supplements the technical parameters specified in Xona's Schedule S. Xona will submit an orbital debris assessment report ("ODAR") after reaching critical design review ("CDR"), which Xona expects to finish in Q1 2024.

2 Constellation

The Xona System will ultimately include 258 simultaneously operational satellites deployed in a tiered Walker Delta configuration at a 1080 km altitude. The system will be deployed in a staged approach that will incrementally expand the coverage of Xona's position, navigation, and timing ("PNT") service offerings.

Xona's deployment will first focus on providing service over population centers in North America and parts of Europe in the Initial Phase and will reach global coverage at the Final Phase. Xona will deploy two satellites for early intermittent services before reaching the full Initial Phase of 34 satellites. The Initial Phase is designed so that customers in the target service area will have continuous service provided by at least one Xona satellite. Once the Initial Phase is deployed and fully operational, Xona will continue launching satellites toward achieving its Final Phase of 258 satellites. The Final Phase will expand coverage to ensure at least four Xona satellites are in view for any user globally for positioning and provide GPS-level satellite visibility. Figure 1 summarizes the deployment phases. Figure 2 visualizes each deployment phase. Table 1 captures the orbital parameters, plane counts, and satellites per plane for each planned phase.

Figure 1: Xona's Deployment Phases and Services.

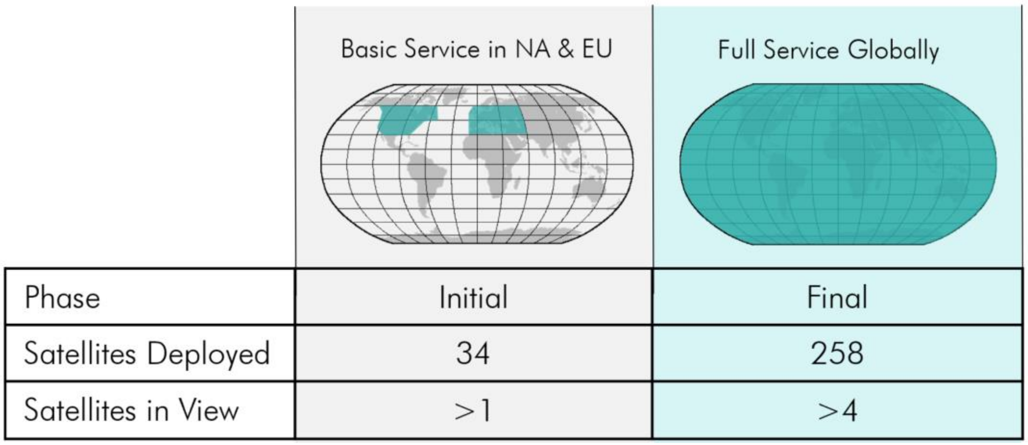


Figure 2: Each Xona System Deployment Phase.

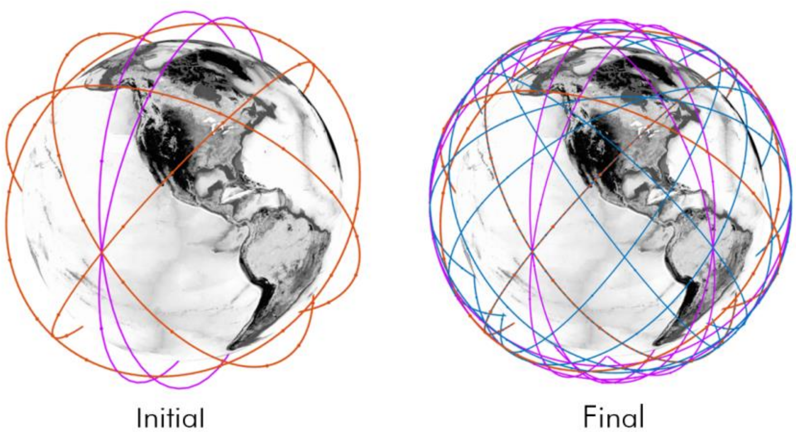


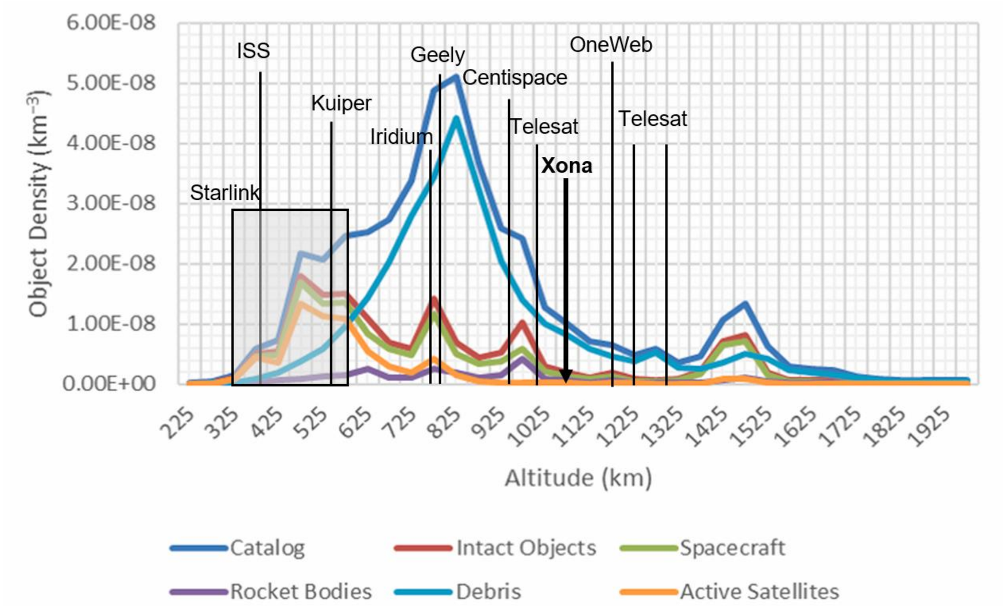
Table 1: Xona System Orbital Parameters.

Phase	Satellite Distribution per Phase				Number of Satellites Added	Total Satellites
	Inclination=53° ("Inclined")		Inclination=~97° ("Polar")			
	N_{planes}	$N_{sats/plane}$	N_{planes}	$N_{sats/plane}$		
Initial	4	8	2	1	34	34
Final	12	16	6	11	224	258

Xona selected a circular orbit at 1080 km, as it provides ideal service capability for PNT, while avoiding the altitude that other constellation shells populate. This altitude also avoids the Iridium-COSMOS collision and the Fengyun and Russian anti-satellite testing debris fields. Figure

3 depicts the density of orbital objects as a function of altitude to show further that 1080 km houses relatively fewer objects than other altitudes and avoids planned large NGSO constellations.

Figure 3: Density of Orbital Objects,[1] Constellation Shells, and Xona's Proposed Regime.[2]



In operation, Xona will have meter-level position knowledge of each satellite in the constellation. Xona commits to coordinating with other networks to share Xona orbital information and utilizing on-board propulsion capability to take any step necessary to avoid and mitigate risk of collision.

2.1 Space Segment

Xona is currently conducting a source selection for satellite buses and expects to select vendors in Q3 2023.[3] Once Xona selects the manufacturer(s), it will update this application with satellite bus parameters and related ODAR after CDR. An on-board propulsion system will support

[1] Carmen Pardini et al., *Evaluating the impact of space activities in low Earth orbit*, 184 Acta Astronaut 11 (2021).

[2] Geely and Centispace are current commercial RNSS competitors from China.

[3] Each satellite will be larger than 10 cm in its smallest dimension and is therefore assumed to be trackable under 47 C.F.R. § 25.114(d)(14)(v).

orbit raising, station keeping, collision avoidance, and deorbiting. Each spacecraft's payload includes the necessary equipment to generate and transmit Xona's PNT service link and monitor and maintain payload functionality. Rather than a bent-pipe or regenerative payload configuration, like most broadband networks deploy, the Xona System Earth-to-space frequencies carry commands and are not connected to the downlink broadcast signal that has a completely independent radiofrequency ("RF") path.

2.2 Frequency Plan

The Xona System includes radionavigation-satellite service ("RNSS"); telemetry, tracking and command ("TT&C"); feeder; and intersatellite links. Each of the first 34 Xona satellites will transmit two service links in L-band, called X1 and X5, (see Table 2) as part of its commercial service offering. Subsequent Xona satellites will transmit three service links: two in L-band, X1 and X5, and one in C-band, called XC (see Table 2). Xona satellites will further transmit and receive TT&C, receive feeder link, and transmit and receive intersatellite link information in the bands shown in Table 3 for satellite monitoring and tasking.[4]

Table 2: Xona's System Service Link Information.

	X5 (space-to-Earth)	**X1 (space-to-Earth)**	**XC (space-to-Earth)**
Frequency Band (MHz)	1180.51625-1200.51625	1591.3225-1595.3225	5011.3725-5029.3725
Center Frequency (MHz)	1190.51625	1593.3225	5020.3725
Channel Bandwidth (MHz)	20	4	18
Emission Designator	20M0G1D	4M0G1D	18M0G1D

[4] The feeder link is a low-latency, uplink-only link that provides service data support information. Service data support information is used by the payload and is incorporated into the service link's data.

	X5 (space-to-Earth)	X1 (space-to-Earth)	XC (space-to-Earth)
Polarization	RHCP	RHCP	RHCP
Modulation	Phase (QPSK)	Phase (QPSK)	Phase (QPSK)
Coverage	Global (all users for elevations ≥ 5 degrees)		

Table 3: Xona TT&C and Feeder Link Spectrum Plan.[5]

Band (MHz)	Link Direction	Link Type
1525-1559	space-to-space (GEO-to-LEO)	TT&C feeder
1626.5-1660.5	space-to-space (LEO-to-GEO)	TT&C
2025-2110	Earth-to-space	TT&C
2200-2290	space-to-Earth	TT&C (outside U.S. only)
5000-5010[6]	Earth-to-space	feeder
8025-8400	space-to-Earth	TT&C

The Xona System will operate efficiently. Consistent with 47 C.F.R. § 25.202(g)(2), Xona will utilize the minimum bandwidth necessary to meet its mission goals to ensure overall efficient use of spectrum resources and minimize interference into other radiocommunication systems.[7]

2.3 Ground Segment

Xona will work with third-party ground station network ("GSN") providers to procure and operate ground stations as a service with the combination of their existing ground antenna network and with any necessary new ground sites or antennas to meet TT&C and feeder link requirements

[5] Xona will only passively monitor the readily accessible civilian GPS L1 (center frequency of 1575.42 MHz), L2 (center frequency of 1227.60 MHz), and L5 (center frequency of 1176.45 MHz) and Galileo E1 (center frequency of 1575.42 MHz) and E5 (center frequency of 1191.795 MHz) signals.

[6] Being less of a commercial standard, C-band feeder links will take time to deploy. In the interim, the Xona System will utilize a commercially available inter-satellite links with authorized and coordinated Inmarsat geostationary orbit ("GSO") satellites.

[7] Additionally, the service links will incorporate frequency reuse through orthogonal ranging codes.

appropriately. The final locations will depend on the satellite and GSN partner, and Xona will confirm the ultimate ground station plan. For the Initial Phase, Table 4 shows two potential ground antenna deployment examples.

Table 4: Initial Phase Ground Station Locations.

Deployment Example	Ground Antenna Site	Number of Antenna per site	Minimum Elevation	Antenna Size (meters)
Example 1	CONUS (Los Angeles, CA)[8]	5	5°	3.7
	Europe (Puertollano, Spain)	5		
	Asia (Jeju, South Korea)	5		
Example 2	Oceania (Mingenew, Australia)	5		
	Europe (Puertollano, Spain)	5		
	Asia (Jeju, South Korea)	5		

Figure 4 and Figure 5 illustrate the two examples. Figure 4 shows the ground antenna deployment with one site located in the CONUS (Los Angeles) and other two in Europe (Puertollano) and Asia (Jeju). Figure 5 shows ground antenna deployment in Europe (Puertollano), Asia (Jeju), and Oceania (Mingenew).

[8] CONUS is the contiguous United States.

Figure 4: Ground Antenna Deployment in CONUS (Los Angeles), Europe (Puertollano) & Asia (Jeju).

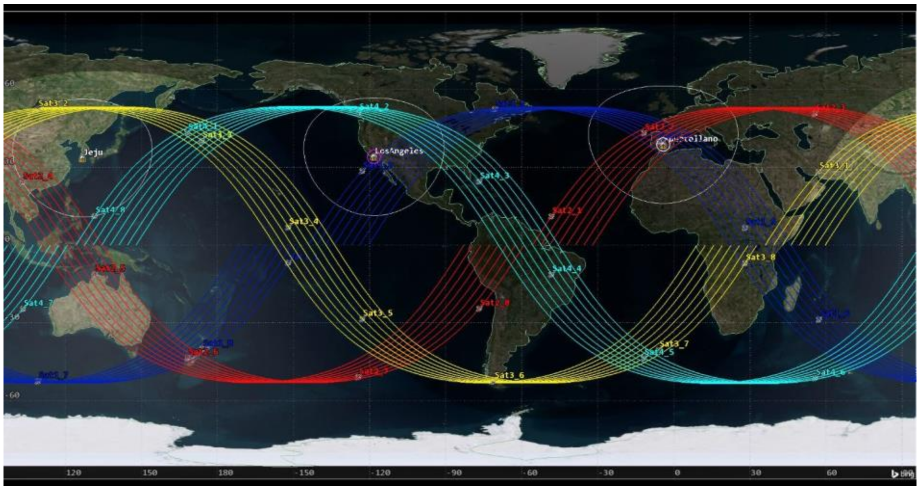
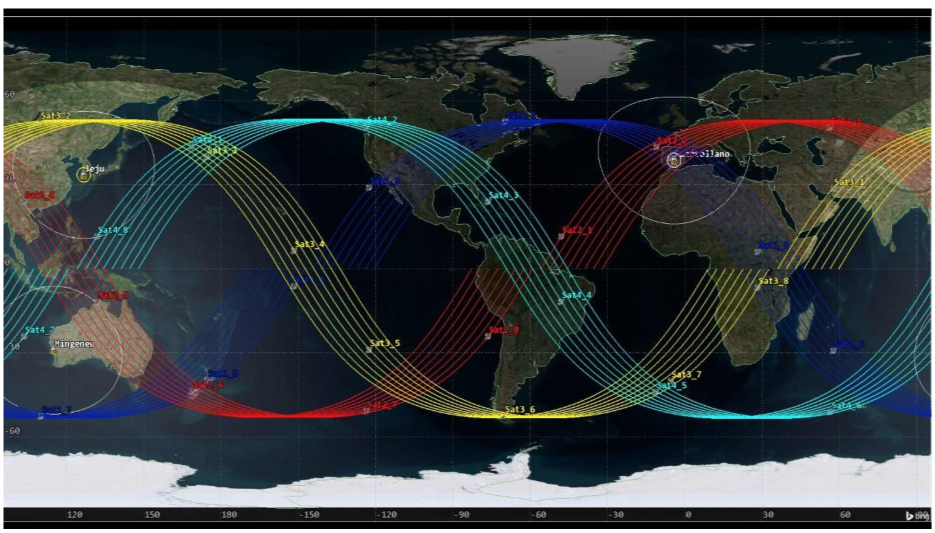


Figure 5: Ground Antenna Deployment: Europe (Puertollano), Asia (Jeju) & Oceania (Mingenew).



3 Facilities, Operations, and Services

This section defines the Xona System's facilities, operations (including launch, deployment, in-orbit, and end of life), and services.

3.1 Facilities

All Xona mission operations centers ("MOCs") will be properly secured and maintained against unauthorized access to ensure the security of all satellite commands. Xona will also establish backup operations capability should a need exist to swap operations for some time. The backup will be hosted on a separate system from the primary operations.

Service link support information may include third-party and/or Xona-generated PNT data. All such data will pass through Xona MOCs for monitoring and transmission to the satellite and ground assets over near-zero latency feeder links. The Xona System's design and construction will focus on automated operations to ensure real-time monitoring of the data streams and near-zero latency transfer of service link support information from their origin source to the destinations.

3.2 Operations

This section documents the launch, in-orbit, and end-of-life mission operations of the Xona System.

3.2.1 Launch and Deployment

Before launch, Xona will register with the U.S. Space Force's 18th Space Defense Squadron ("18th SDS") or the appropriate successor entity (47 C.F.R. § 25.114(d)(14)(v)(B)) and share information regarding initial spacecraft deployment, ephemeris, and planned maneuver information. Xona will also participate in commercially standardized orbit ephemeris and maneuver information sharing agreements.

Xona will launch its first two satellites leveraging opportunities on available rideshare missions, such as Space-X Falcon-9 Transporter missions. The first satellite will launch Q4 of 2024, and the second satellite will launch within six months of the first launch. After these two satellites, Xona will begin to leverage increased launch capability, including dedicated launch options. Due to the variable capabilities between different launch providers, satellites may either be launched to an initial altitude below 1080 km and raised to their final orbit altitude or to the final orbit at 1080 km via direct insertion. In cases where multiple satellite planes can be launched simultaneously, satellites will be launched to an initial phasing orbit where bus commissioning will be conducted. After successful bus commissioning, the satellites will be phased and orbit-raised to their final orbit. In the event of unsuccessful bus commissioning, the satellite will be deorbited from the phasing orbit.

In compliance with 47 C.F.R. § 25.114(d)(14)(v)(A), initial spacecraft identification will be provided by correlating the launch vehicle supplied ephemeris with the publicly available two-line element ("TLE") orbit data via Space-Track.org. Additional verification will be provided by the downlink of telemetry, which carries the unique spacecraft identification. Orbit determination will also be conducted based on GPS and Galileo raw data that will further refine the spacecraft position and identification.

3.2.2 In-Orbit Operations

After separation from the launch vehicle, each spacecraft will autonomously de-tumble and enter a safe sun-tracking mode. Attitude modes use a combination of sensors and actuators (magnetometers, gyroscopes, sun-sensors, reaction wheels, torque rods, thrusters, and star trackers) to perform maneuvers and orient the spacecraft. During nominal operations, each spacecraft will maintain an Earth pointing attitude that keeps the service link transmission antenna pointed nadir towards the Earth.

Xona will utilize its on-board propulsion capabilities to maintain specific orbital parameters consistent with 47 C.F.R. § 25.114(d)(14)(iv)(A)(4). Perigee and apogee will be actively controlled to within ±20 km of the target orbit altitude of 1080 km to maintain the relative separation between the constellation members. Altitude control will also provide relative in-track satellite position (mean anomaly) control, which is not expected to exceed 1.0° from its idealized position, maintaining both service coverage and relative constellation separation. Orbital inclination, eccentricity, argument of perigee, and right ascension of the ascending node will be corrected, as needed, to maintain the constellation configuration. These parameters, however, are expected to require less active control given their natural, long-term stability. Inclination is planned to stay within ±0.2 deg and eccentricity to be less than 0.0015 at any point during the mission. Argument of perigee and right ascension of the ascending node ("RAAN") will vary throughout the mission due to constellation drift, with RAAN not expected to deviate more than ±0.5° from its expected location between stationkeeping maneuvers. Relative in-track separation is expected to be within ±1° between maneuvers.

Consistent with 47 C.F.R. § 25.114(d)(14)(v)(A), Xona will monitor the satellites' location passively by utilizing TLEs and the GNSS module which outputs GNSS measurements utilized in orbit determination. At appropriate intervals, Xona will also propagate trajectories of all spacecraft to enhance the quality of conjunction predictions with other satellites consistent with 47 C.F.R. § 25.114(d)(14)(iv)(A)(2).

Xona will work throughout the course of its mission to update orbital information with the 18th SDS (see 47 C.F.R. § 25.114(d)(14)(v)(C)), and upon receipt of a space situational conjunction warning, Xona will review and take all possible steps to assess and, if necessary, mitigate collision risks consistent with 47 C.F.R. § 25.114(d)(iv)(A)(5). As part of Xona's standard mission operations process, constant conjunction assessments will be performed against the publicly available database of orbiting objects (Space-Track.org), as well as higher fidelity position data provided from other spacecraft operators, including 18th SDS conjunction data messages. For any conjunctions that exceed a pre-determined probability of conjunction ("Pc") threshold for a given miss distance, Xona will plan and execute a collision avoidance ("COLA") maneuver as soon as possible from detection to maximize the reduction in Pc while ensuring that no other near-term conjunctions are generated as a result. Additionally, early COLA maneuvers will reduce the delta-V amount; therefore, propellant is required. Maneuver error covariances will also be assessed to ensure that the planned maneuver is sized appropriately to avoid the conjunction. COLA maneuver planning and execution will be coordinated with other spacecraft operators (where possible) such that Xona will not be performing maneuvers "in the blind." Xona will also maintain a complete and accurate set of current and planned RF transmissions and will provide any necessary technical information to other satellite operators to identify and promptly resolve any potential RF interference between systems.

Consistent with 47 C.F.R. § 25.207, each Xona satellite will utilize appropriate devices including battery life, timing devices, and ground command to cease radio emissions that will ensure definite cessation of emissions. Furthermore, Xona will not transmit in any manner that causes unacceptable interference and will maintain complete and accurate technical details of current and planned transmissions over time.

3.2.3 End-of-Life

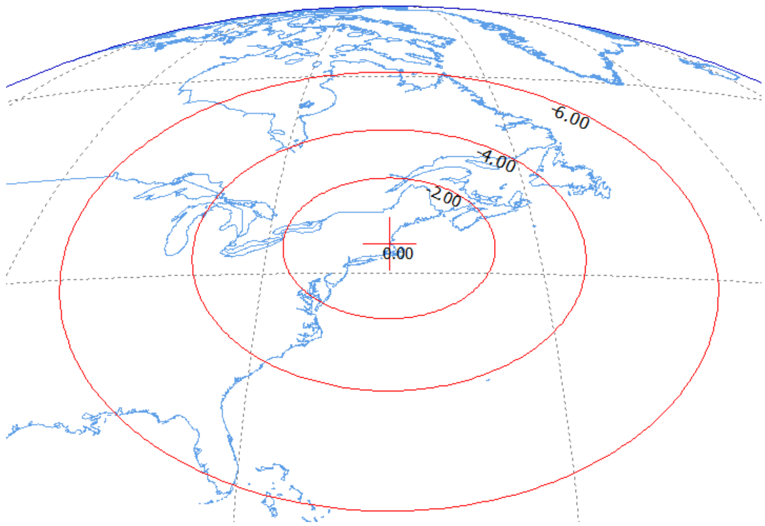
Each Xona satellite's operational lifetime is expected to be five years. Xona plans to dispose of the satellites through atmospheric reentry at end of life consistent with 47 C.F.R. § 25.283. Upon mission completion, planned disposal will occur via propulsive maneuvers, exhausting all remaining propellant, utilizing atmospheric drag to initiate and ensure orbital decay, and leading to uncontrolled atmospheric re-entry consistent with 47 C.F.R. § 25.114(d)(14)(vii)(D)(2)(i). Deorbit maneuvers will lower the bus to a perigee of less than 250 km altitude where the atmospheric drag will lead to re-entry in months. Deorbit maneuvers will consume >250m/s of delta-V, which will be factored into the mission propellant budget plus contingency. During the orbital decay period, the satellite will be decommissioned in a safe state where stored energy in reaction wheels will be dissipated and batteries will be discharged to a safe level and powered down. The spacecraft will utilize propulsion and employ differential drag techniques to adjust the rate of orbital decay. Xona will also continue to provide updated ephemeris data to 18th SDS, any successor entity, and any other operators involved in a conjunction warning.

Xona will ensure a deorbit reliability of 99% or greater through the use of reliable systems, heritage, and redundancy. The time to deorbit following completion of mission execution using the methodology above will be under five years and therefore satisfies the recently adopted associated requirement (see 47 C.F.R. § 25.114(d)(14)(vii)(D)(1) and FCC 22-74).

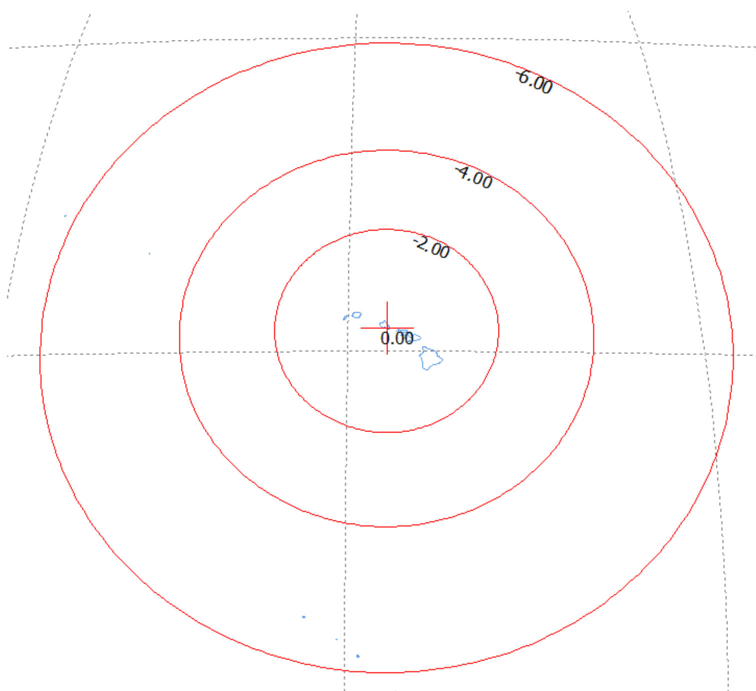
4 Space Station Antenna Gain Contours

As the Commission requires in 47 C.F.R. § 25.114(c)(4)(vi)(B), this section provides the predicted antenna gain contours for each unique orbital plane for each transmit and receive beam. Contours are depicted on an area map with the beam shown on the surface of the Earth with the satellites' peak antenna gain pointed at nadir to a latitude and longitude within the proposed service area. Furthermore, each contour is shown at 2 dB intervals down to either 4 dB or 6 dB below the peak gain. While the regulation states to show intervals of 2 dB down to 10 dB below the peak gain and at 5 dB intervals between 10-20 dB below the peak gain, the nature of the antenna and orbital altitude of the spacecraft limit the visibility of the contours in the schematics. Gain contours data are also embedded as GXT files in the Schedule S. Representative receive and transmit gain contours are provided in Figure 6 (a, b) and Figure 7 (a, b, c, d, e), respectively, over various locations.

Figure 6: Receive Uplink Gain Contours over Various U.S. Locations (Orbit Altitude 1080 km) at (a) Boston, Massachusetts and (b) Honolulu, Hawaii.

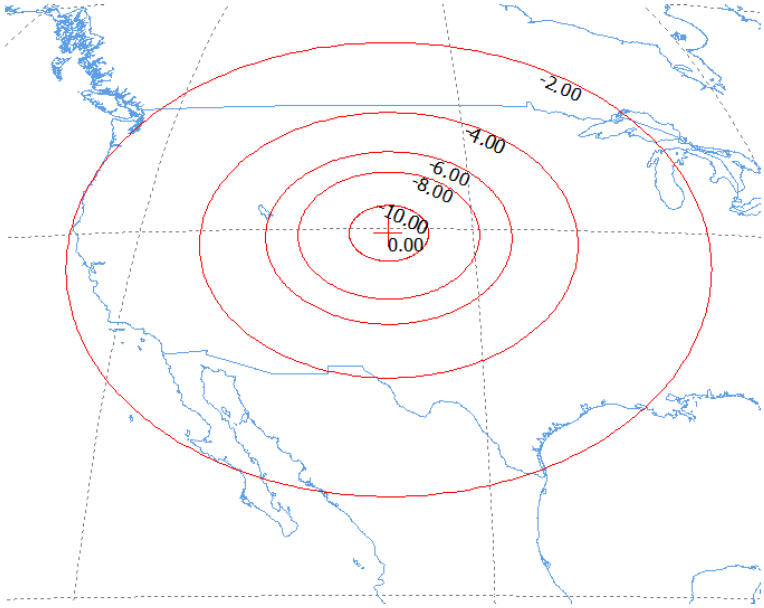


(a) CUL1, CUR1 Uplink Beam Projections over Boston, Massachusetts.

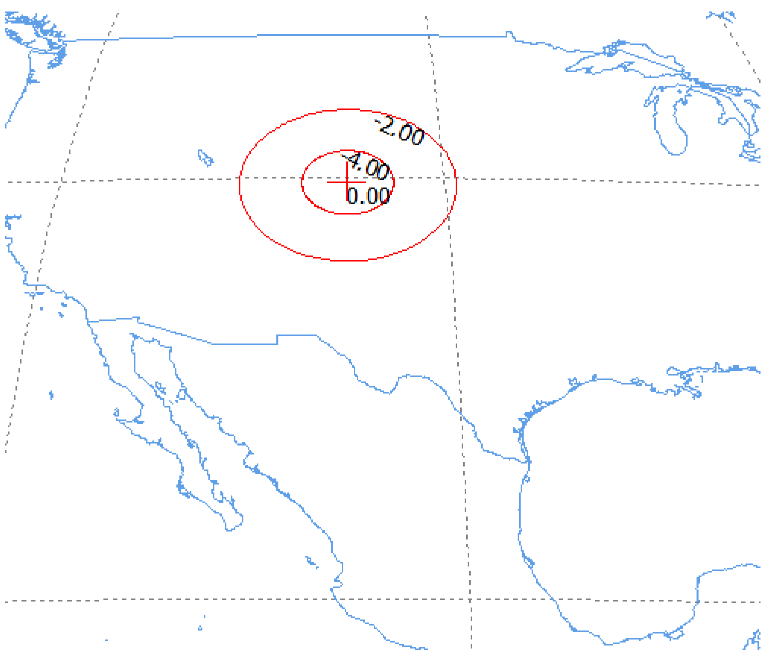


(b) SUL1, SUR1 Uplink Beam Projections over Honolulu, Hawaii.

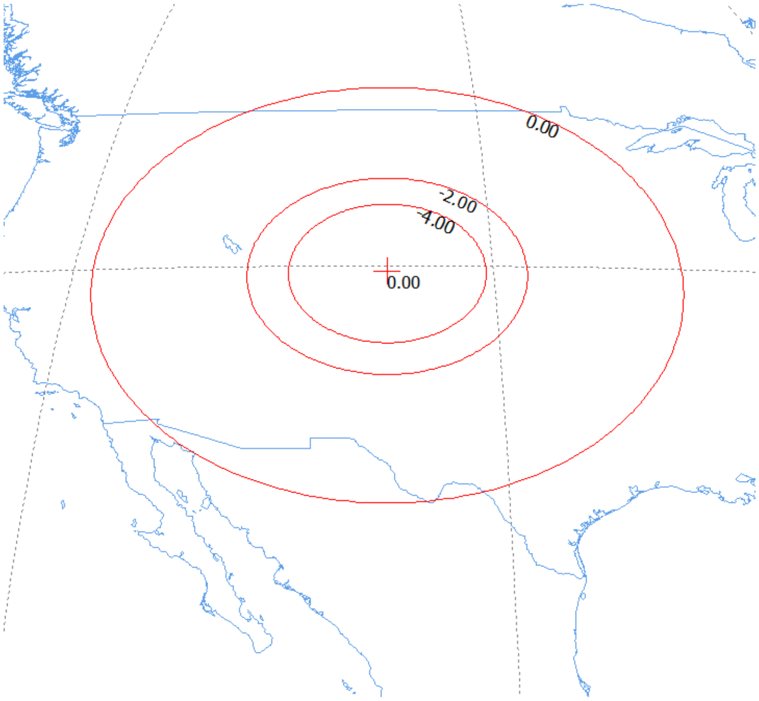
Figure 7: Transmit Downlink Gain Contours over Various (mostly) U.S. locations (Orbit Altitude 1080 km) at (a) Denver, Colorado; (b) Denver, Colorado; (c) Denver, Colorado; (d) Spain (No U.S. downlink for S-band); (e) Tucson, Arizona.



(a) X1, X1B Downlink Beam Projections over Denver, Colorado.

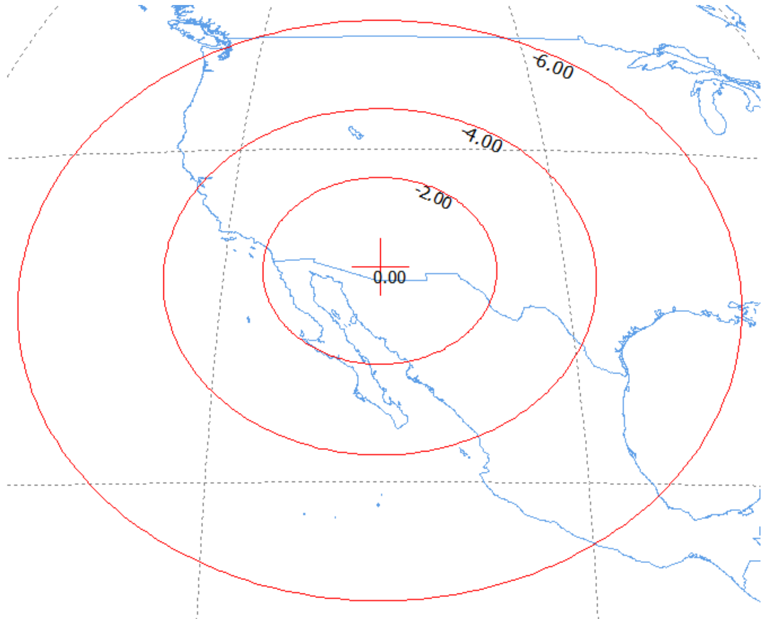


(b) X5, X5B Downlink Beam Projections over Denver, Colorado.



(c) XC Downlink Beam Projections over Denver, Colorado.

(d) SDL1, SDR1 Downlink Beam Projections over Spain (no S-band Downlink in the US).



(e) XDL1, XDR1 Downlink Beam Projections over Tucson, Arizona.

The X1, X5, and XC antenna patterns are provided in Figure 8, Figure 9, and Figure 10, respectively. The antennas are designed to provide near constant power from an isotropic receive antenna at the Earth's surface regardless of the geometric angle between the satellite and the receiver. Additionally, X5 tapers its antenna contour to maintain compatibility with aeronautical radionavigation service ("ARNS") systems (see section 5.5.3). Every Xona satellite is verified against the requirements for maximum EIRP (product of transmit power and antenna gains and losses) to ensure compliance to compatibility requirements.

Figure 8: X1 Antenna Patterns (Normalized to Boresight Gain).

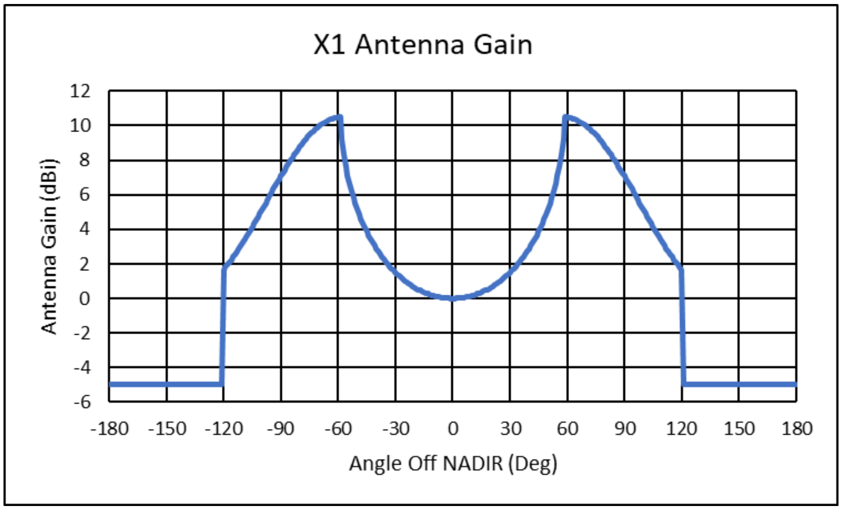


Figure 9: X5 Antenna Patterns (Normalized to Boresight Gain).

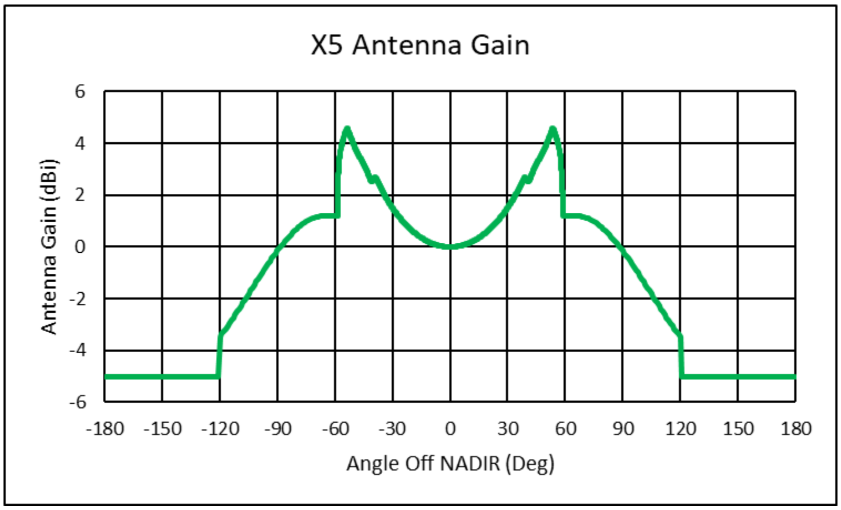
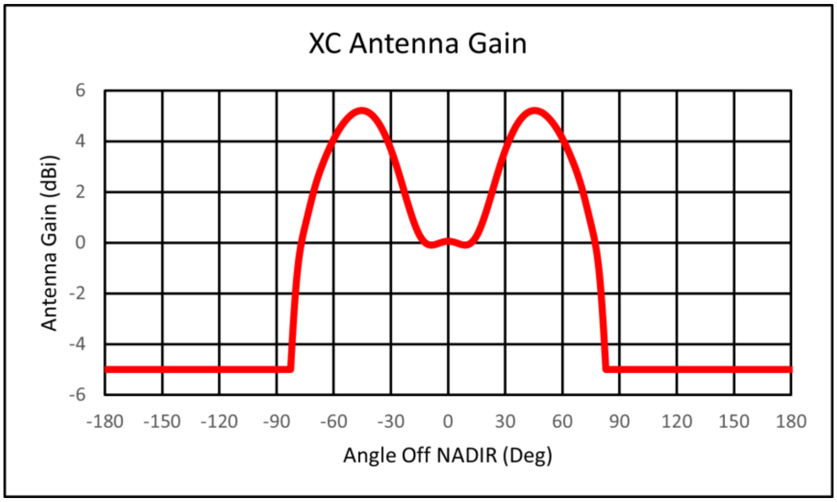


Figure 10: XC Antenna Patterns (Normalized to Boresight Gain).



5 Interference Mitigation and Coexistence

Xona remains committed to coordination and collaborative constellation operations and will optimize the efficient use of allocated spectrum to coexist with other space and terrestrial users without causing harmful interference.

5.1 Coordination

Xona has committed to coordinating its proposed operations, ground station locations, and frequency usage by already engaging government stakeholders, including the U.S. Space Force, Federal Aviation Administration, U.S. Air Force, U.S. Navy, National Telecommunications and Information Administration, National Oceanic and Atmospheric Administration, and National Aeronautics and Space Administration for pre-coordination. Xona has previously worked alongside Spaceflight for the Sherpa-AC1, which is hosting Xona's RNSS demonstration payload, on a FCC Part 25 application and has conducted related coordination. Xona, therefore, is aware of and dedicated to the necessary steps for collaboratively engaging with other operators.

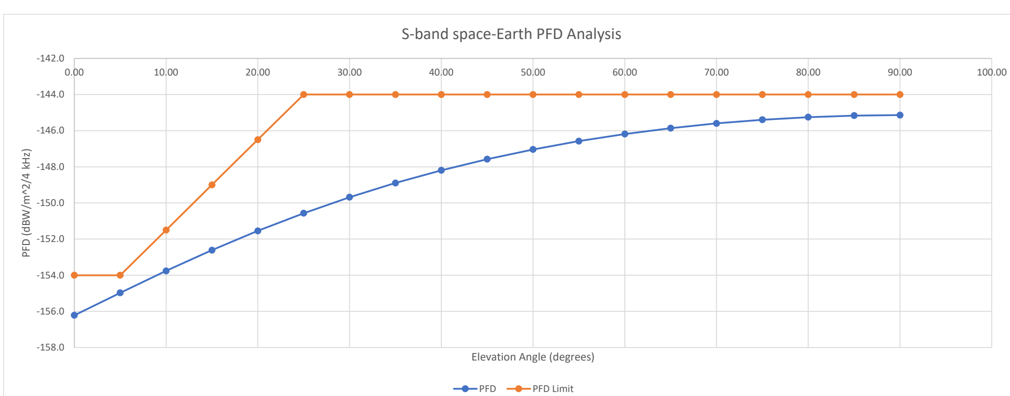
Consistent with 47 C.F.R. § 25.273(a)(3), Xona will not transmit in any manner that causes unacceptable interference to authorized transmissions of another licensee and will maintain complete and accurate technical details of current and planned transmissions to aid in the prompt correction of any potential interference should any occur.

5.2 Protection of Terrestrial Networks by NGSO Systems

The Xona System satisfies the power flux-density ("PFD") limits in ITU Radio Regulations Table 21-4 to protect terrestrial services from co-frequency space-based interference. The maximum PFD levels for the Xona System were calculated for the S-band and X-band downlinks, and these PFD values also appear in the accompanying Schedule S. Xona affirms that it will reduce RF power as necessary to maintain operations within the PFD limits at all times. Xona's PFD compliance is shown against the ITU Radio Regulations limits.

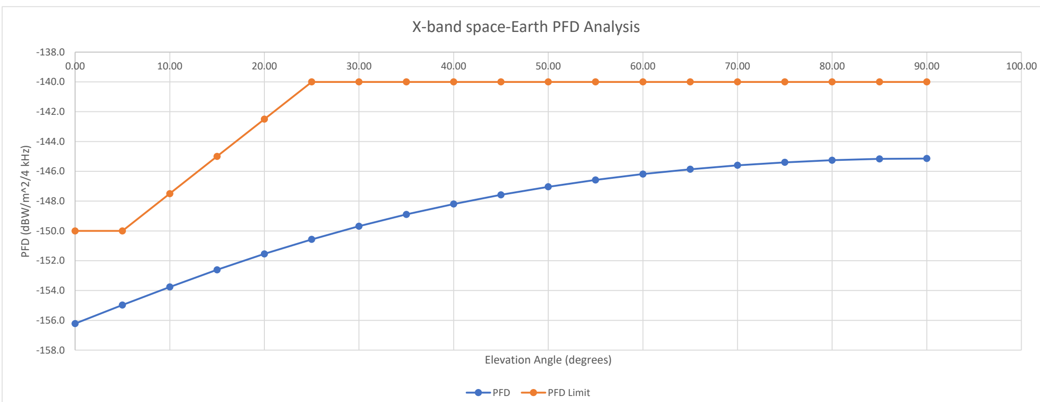
Compliance for S-band downlinks (SDL1, SDL2) is furnished in Figure 11. This S-band downlink has a maximum EIRP of 10.5 dBW and the ability to reduce the EIRP down to -9.5 dBW to assure PFD compliance at all orbit altitudes. This analysis assumes an emission bandwidth of 1 megahertz at an orbit altitude of 1080 km. This S-band downlink PFD analysis assumes the peak EIRP can be directed anywhere within the footprint. Xona reiterates that it will only operate in the S-band downlink outside of the United States.

Figure 11: PFD Compliance of Xona's S-band downlink (SDL1, SDL2) outside the United States for a 10.5 dBW EIRP Emission over 1-Megahertz Bandwidth at a 1080 km Orbit.



Compliance for X-band downlink (XDL1, XDR1) is furnished in Figure 12. The X-band downlink has a maximum EIRP of 10.5 dBW with the ability to reduce the EIRP down to -9.5 dBW to assure PFD compliance at all orbit altitudes. This analysis assumes an emission bandwidth of 1 megahertz at an orbit altitude of 1080 km. The X-band downlink PFD analysis assumes the peak EIRP can be directed anywhere within the footprint.

Figure 12: PFD Compliance of Xona's X-band Downlink (XDL1, XDR1) for a 10.5 dBW EIRP Emission over 1-Megahertz Bandwidth at a 1080 km Orbit.



5.3 Protection of GSO Networks by NGSO Systems

ITU Radio Regulations 22.5 states that in the 8025-8400 MHz band "the maximum power flux-density produced at the geostationary-satellite orbit by any Earth Exploration-Satellite Service ("EESS") space station shall not exceed -174 dB(W/m^2) in any 4 kHz band." At the maximum 1080 km altitude, assuming the spacecraft is pointed directly at GSO, the PFD would be approximately -175.2 dBW/m^2 in compliance with the limit.

5.4 Protection of EESS Systems by Non-EESS NGSO Systems

The Xona System plans to use a 1-megahertz channel in the X-band (8025-8400 MHz) EESS allocation (space-to-Earth) on an unprotected and non-interference basis primarily for space operation service. This section demonstrates how the Xona System can be operated to not cause unacceptable levels of interference to authorized satellite systems in the X-band frequencies by either selecting a set of 1-megahertz channels to reduce the interference probability into any single channel or by maintaining a 3-degree avoidance angle with other co-frequency satellite operators to ensure protection of those systems.

This analysis relies upon the protection criteria defined in ITU-R SA.1027-6.[9] This ITU recommendation defines both long-term and short-term protection criteria. The long-term protection criterion defines an interference power level, which cannot be exceeded 20% of the time. The short-term protection criterion limits the interfering signal power to -133 dBW/10 MHz for no more than 0.0025% of the time.

Figure 13: X-band EESS Protection Criteria - ITU-R SA.1027-6

Frequency band (MHz)	Interfering signal power (dBW) in the reference bandwidth to be exceeded no more than 20% of the time		Interfering signal power (dBW) in the reference bandwidth to be exceeded no more than *p*% of the time	
	Interfering signal path		Interfering signal path	
8 025-8 400	–167 dBW per 10 MHz	–150 dBW per 10 MHz	–133 dBW per 10 MHz $p = 0.0025$	–133 dBW per 10 MHz $p = 0.0050$

This simulation-based analysis' goal is to demonstrate that Xona can maintain its operations in the X-band frequencies below the ITU-specified short-term protection criterion. This analysis focuses on a U.S.-based fixed gateway earth station ("GW ES") site to which Xona may be conducting X-band downlink transmissions.[10] Further, Xona extrapolates these results, via analysis, to demonstrate that Xona can protect authorized X-band satellites operating at or near other GW ES sites Xona may use.

[9] *See* Sharing criteria for space-to-Earth data transmission systems in the Earth exploration-satellite and meteorological-satellite services using satellites in low-Earth orbit, ITU-R SA.1027-6 (2019).

[10] Xona selected the U.S. site for this simulation effort because of the greater ease of access to the information necessary to conduct the analysis. Also, as discussed below, the U.S. ground station site is likely to be the worst-case scenario because the other ground station locations are not customarily used for EESS systems.

5.4.1 Simulation Description

The Xona U.S. GW ES sites have not yet been decided. To demonstrate worst-case interference scenarios, the analysis assumed that a Xona GW ES site is collocated with any potential victim GW ES site. The reference Xona GW earth station had the receive antenna gain listed below and a system noise temperature of 200K. The Xona space stations' emissions were simulated as 8.0 dBW of RF power spread over 1 megahertz with a peak antenna gain of 2.5 dBi.

Simulated Xona GW ES Site	**Location**	**Antenna Gain**	**Antenna Size**
Typical - collocated	Same as below	48 dBi	3.7 m
Simulated "Victim" GW ES Sites	**Location**	**Antenna Gain**	**Antenna Size**
Utqiagvik, AK	156°48'22.0"W 71°16'30.4" N	50.9 dBi	3.7 m
North Pole, AK	147°32'10.0"W 64°47'37.0" N	53.0 dBi	7.3 m
Fairbanks, AK	147°44'0.2" W 64°48'47.4" N	43.5 dBi	2.4 m
Prudhoe Bay, AK	148°23'59.2" W 70°13'13.6" N	51.0 dBi	5.4 m
Fairbanks, AK	147°31'44" W 64°53'26.0" N	51.5 dBi	7.3 m

Table 5: Simulated GW ES Sites

Based on a review of relevant GW ES and space station filings from ICFS that include space-to-Earth links to the U.S. GW ES sites, Xona identified the following satellite systems that transmit co-frequency to GW ES sites deemed most susceptible to interference from the Xona constellation (together, the "Simulated GW ES Sites").[11] To be conservative, Xona assumed all satellite systems to operate co-frequency with full spectrum overlap. Because Xona only uses 1 megahertz of bandwidth in the 375-megahertz EESS band, this assumption was very conservative

[11] As a conservative measure, Xona selected GW ES sites in Alaska for purposes of the simulation. Xona provides maximum multiple coverage over Alaska due to the combination of the sun-synchronous orbit plus 53-degree inclined orbits at 1080 km orbit altitude.

and was made only for purposes of this simulation. Furthermore, the conservative assumption that all Xona spacecraft would operate on the same 1-megahertz channel was also employed. Given the spectrum available, options exist to distribute Xona operations across 10-100 unique channels, which would reduce the probability of interference by 10-20 dB. During operations, Xona will account for spectrum overlap to avoid unnecessary operational constraints.

Satellite Constellation Name	Number of Satellites
BlackSky	18 (including 2 pathfinders)
Planet SkySat	21
Maxar WorldView	3
Maxar GeoEye	2
Ikonos	1
Quickbird-1	1
Maxar Legion	12
ICEYE XR	6

Table 6: Relevant Authorized X-band Satellite Systems

The Xona spacecraft will be operating in two sub-constellations (both at 1080 km circular orbit altitude). The orbital configuration of the two Xona sub-constellations are listed below.

Satellite Distribution per Phase				**Num Sats**
Inclination=53º (“Inclined”)		**Inclination=~97º (“Polar”)**		
N_{planes}	$N_{sats/plane}$	N_{planes}	$N_{sats/plane}$	
12	16	6	11	258

Table 7: Xona Constellation Parameters

Both constellations are Delta-Walker configurations with orbital plane right ascension of the ascending node spread evenly across 360 degrees and space station mean anomaly within planes spread evenly across 360 degrees.

5.4.2 Simulation Results

Simulations were conducted for each of the satellite systems listed in Table 6 operating with their respective Alaska GW ES sites to determine the interference power statistics caused by

Xona downlinking to collocated GW ES sites and comparing the results against the defined short-term and long-term protection criteria. The Xona spacecraft were assumed to attempt to communicate with their collocated GW ES site any time it is within line of sight and above a minimum elevation angle of 5 degrees.

Figure 14: X-band Spectrum Sharing Simulation –ICEYE at Utqiagvik, AK

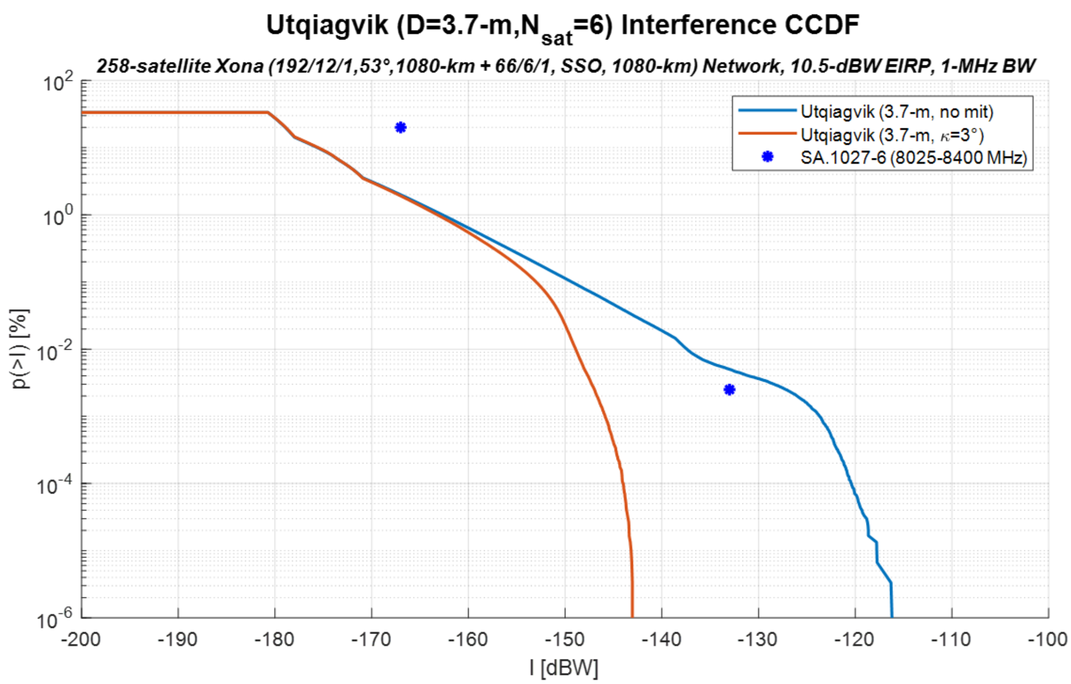


Figure 15: X-band Spectrum Sharing Simulation –Blacksky, WorldView, and GeoEye at North Pole, AK

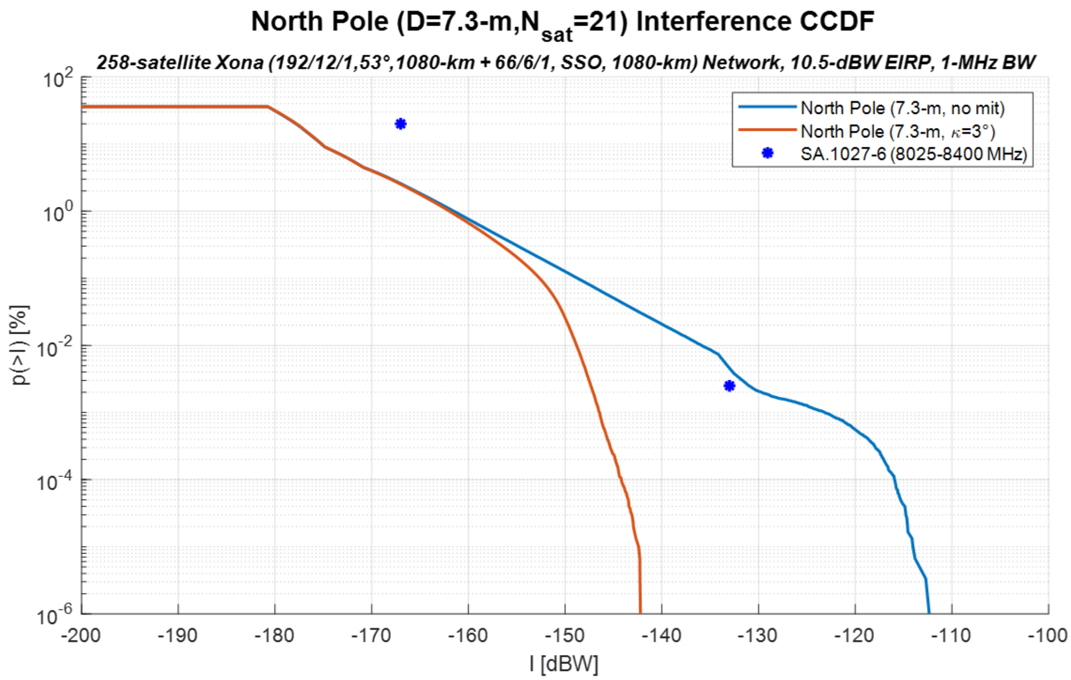


Figure 16: X-band Spectrum Sharing Simulation –Planet SkySat at Fairbanks, AK

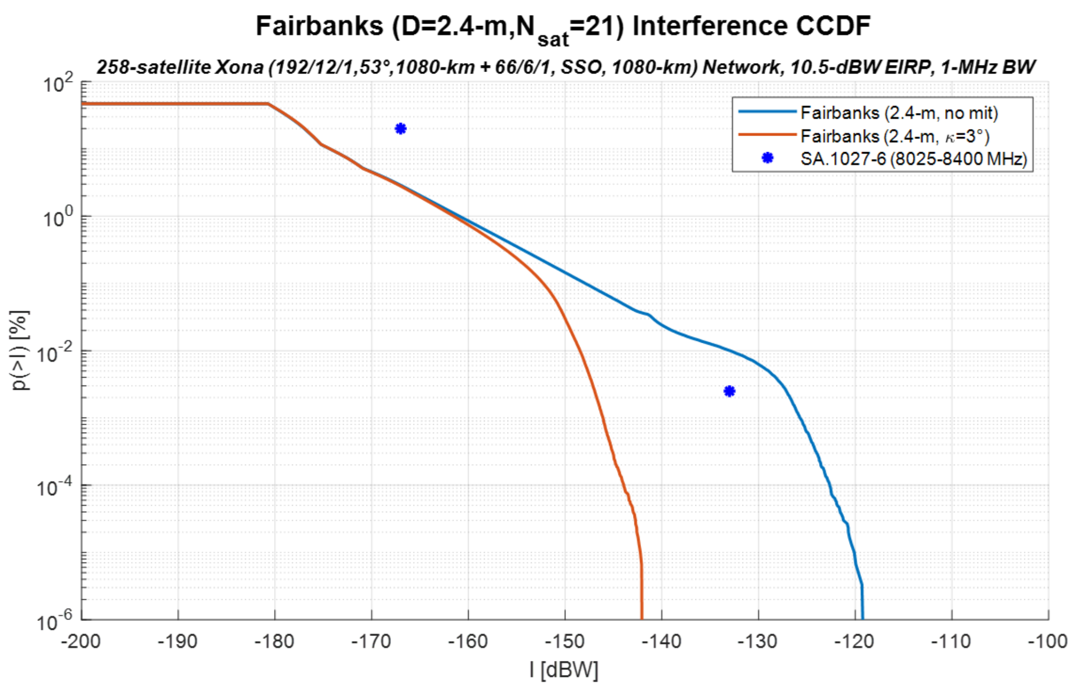


Figure 17: X-band Spectrum Sharing Simulation –WorldView, GeoEye, and Legion at Fairbanks, AK

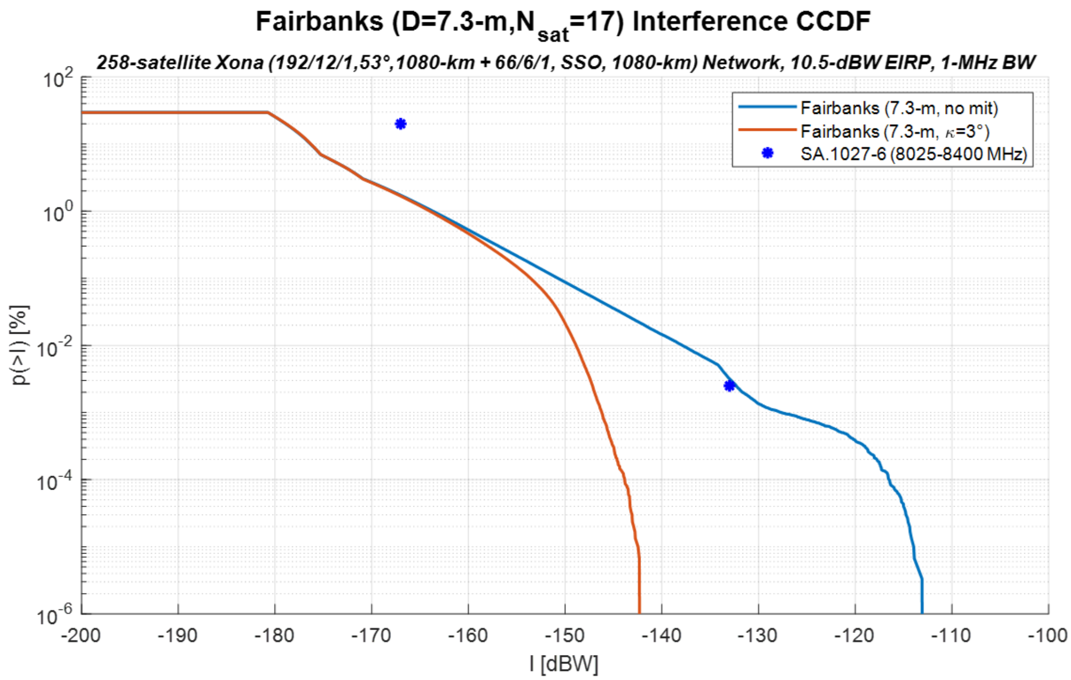
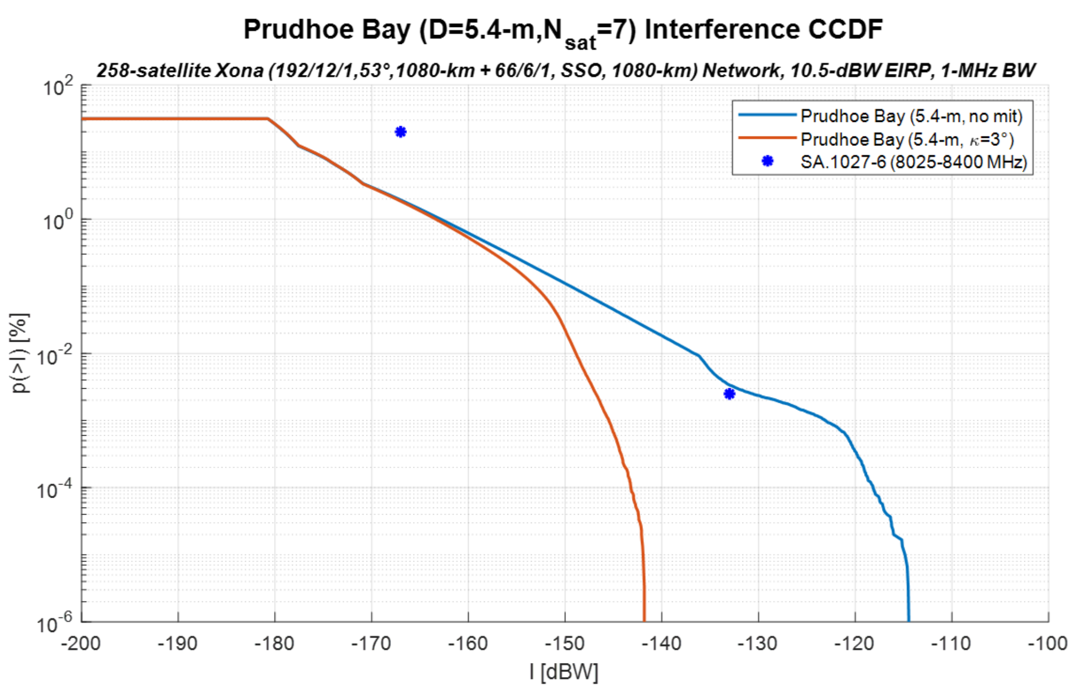


Figure 18: X-band Spectrum Sharing Simulation –WorldView, GeoEye, and QuickBird at Prudhoe Bay, AK



5.4.3 Conclusions

The X-band spectrum sharing simulations show that Xona would need to either distribute X-band space-Earth operations across ~10 unique channels or employ inline interference event avoidance of no more than 3 degrees to meet the protection criteria specified by ITU-R SA.1027-6. Every aspect of these spectrum sharing simulations was selected to capture worst-case interference statistics, including:

- selecting northernmost GW ES sites that offer maximum coverage from the Xona constellation;
- assuming spectrum overlap with all potential victim NGSO systems;
- assuming collocated GW ES sites;
- assuming all Xona space stations transmit when within line of sight and above 5 degrees elevation of the serving GW ES; and
- assuming all Xona space stations operate on the same channel.

Therefore, the simulation results should, in fact, reflect the worst-case interference scenario into other X-band downlinks. Even if an authorized user of the X-band spectrum is not properly identified and included in the batch analysis process to modify the contact plan to avoid inline interference events, the resultant interference CDF caused by the Xona space stations would most likely not exceed the protection criteria.

Nevertheless, Xona will engage in coordination with affected co-frequency systems to understand which satellites each system has in operation, collect TLE information for all applicable satellites that must be avoided, and establish relationships to receive notifications when new satellites are added to the constellations. In an abundance of caution, Xona will ensure that it is capable of avoiding authorized EESS satellites in the X-band spectrum, whenever such satellites are within 3 degrees of an inline interference event, by modifying the satellite contact plan to temporarily cease X-band emissions (space-to-Earth) during inline events. This further mitigation measure will be used, as necessary, to address valid coordination requests of co-frequency operators.

As can be seen from the simulations results, when a 3-degree avoidance angle is applied, the maximum interference power stays ~10 dB below the maximum interference level allowed by the short-term protection criterion. Because the maximum interference power remains safely below the maximum allowed interference level, any location changes of the victim GW ES would only affect the time-percentage statistics of the interference CDF (effectively only shifting the curve in the y-axis on each of the graphs). Therefore, by maintaining a 3-degree avoidance angle during operations, one can extrapolate these simulation results to any GW ES location supporting any number of authorized X-band satellites and never exceed the protection criteria.

5.5 Compatibility with Existing L-Band RNSS Systems

5.5.1 Compatibility Showings for 1593.3225 MHz and other RNSS

An overview of the methodology used is provided in this section. Additional details can be found in the provided references.[12] The post-correlator C/N_0, denoted C/N_0', is given by:

$$\frac{C}{N_0'} = \frac{C}{\rho N_0 + I_{ref} + I_{alt} + I_{rem} + I_{ext}}$$

where the terms are defined as:

C: Post-correlator received desired-signal power (W) from the satellite in the reference constellation including any relevant processing losses.

[12] A coordination methodology for radionavigation-satellite service inter-system interference estimation, Recommendation ITU-R M.1831-1 (2015); John W. Betz et al., *Intersystem and intrasystem interference with signal imperfections*, Position Locat. Navig. Symp. (2004).

N_0: Receiver pre-correlator thermal noise power spectral density (W/Hz).

N_0': Post-correlator effective receiver thermal noise power spectral density (W/Hz).

I_{ref}: Post-correlator effective white-noise power spectral-density (W/Hz) due to the aggregate interference from all the signals, except the desired signal, transmitted by all the in-view satellites in the reference constellation including any relevant processing losses.

I_{alt}: Post-correlator effective noise power spectral-density (W/Hz) due to the aggregate interference from all the signals transmitted in the frequency band of interest by all the in-view satellites of a specific "alternate" constellation.

I_{rem}: Post-correlator effective noise power spectral-density (W/Hz) due to the aggregate interference from all the signals transmitted in the frequency band of interest by all the in-view "remaining" RNSS satellites, *i.e.*, those that are not in either the reference constellation or the alternate constellation.

I_{ext}: Post-correlator effective white-noise power spectral-density (W/Hz) due to the aggregate interference from all radio signals other than those of the RNSS, including any relevant processing losses.

ρ: Dimensionless effective thermal noise factor.

In the analysis of interference caused by the proposed X1 waveform, the Xona satellite constellation is the "alternate" constellation, and I_{alt} is the interference from the Xona signal which can affect other RNSS signals. The reference signal interference I_{ref} is interference from the same RNSS constellation, from all signals, except the one being evaluated for interference effects (the desired signal). For example, if GPS is the reference GNSS system being analyzed for its interference susceptibility, interference from C/A, P(Y), L1C, and M signals from all satellites in view to a C/A signal from one GPS Space Vehicle ("SV") would constitute the interference I_{ref} when analyzing C/A interference. Finally, interference from all signals in remaining RNSS constellations, other than the reference or alternate constellations, is combined into the term I_{rem}.

Interference from external, non-RNSS systems operating in the vicinity of the RNSS signals and potentially interfering with the desired operation, including any interference from ground systems, is captured in the interference term I_{ext}. I_{ext} is typically modelled as a noise source with a constant equivalent noise power spectral density.[13] A value of $I_{ext} =$ -206.5 dBW/Hz is assumed, with a level 5 dB below the thermal noise floor level,[14] which is assumed to be -201.5 dBW/Hz for a typical receiver.[15]

Using the X1 transmission properties submitted, Xona assesses the C/N_0 degradations shown in Table 8. As previously stated, Xona considers all signals described in Recommendation ITU-R M.1787.3 but reduces the number of results reported by ignoring the victim signals that have a spectral separation coefficient ("SSC") < -120 dB(1/Hz) because the resultant degradation would be effectively 0 dB. Xona further reduces the number of signals reported by ignoring those that show less than 0.2 dB degradation. The worst-case degradation of 0.9 dB occurs for the GLONASS-FKL1(-02)-HA signal centered at 1598.0625 MHz, which remains below the GPS Innovation Alliance ("GPSIA") internationally and domestically recognized threshold of 1 dB for assessing interference between GNSS devices.

[13] A coordination methodology for radionavigation-satellite service inter-system interference estimation, Recommendation ITU-R M.1831-1 (2015).

[14] A coordination methodology for radionavigation-satellite service inter-system interference estimation, Recommendation ITU-R M.1831-1 (2015); John W. Betz et al., *Intersystem and intrasystem interference with signal imperfections*, Position Locat. Navig. Symp. (2004).

[15] A coordination methodology for radionavigation-satellite service inter-system interference estimation, Recommendation ITU-R M.1831-1 (2015).

Table 8: X1 C/N0 Degradation Results.

Interfering Signal	Reference Signal	C/N0 Degradation (dB)
Xona X1 Signal	BeiDou-B1-A	0.23
	GLONASS-FKL1(-01)-HA	0.75
	GLONASS-FKL1(-02)-HA	0.90
	GLONASS-FKL1(-03)-HA	0.88
	GLONASS-FKL1(-04)-HA	0.68
	GLONASS-FKL1(-05)-HA	0.35
	GLONASS-FKL1(-07)-HA	0.26
	GLONASS-FKL1(00)-HA	0.50
	GLONASS-FKL1(01)-HA	0.24
	GLONASS-FKL1(05)-HA	0.22
	GLONASS-FKL1(06)-HA	0.30
	GLONASS-L1OC-P	0.30
	Galileo-E1-A	0.32

5.5.2 Compatibility Showings for 1190.51625 MHz and other RNSS

Assuming the X5 transmission properties submitted, and the same methodology described in section 5.5.1, Xona assesses C/N_0 degradations shown in Table 9. As previously stated, Xona considers all signals described in Recommendation ITU-R M.1787.3 but reduces the number of results reported by ignoring the victim signals which have < -120 dB(1/Hz) SSC because the resultant degradation would be effectively 0 dB. Xona further reduces the number of signals reported by ignoring those that produce more than 0.20 dB degradation. The worst-case degradation of 0.98 dB occurs for the GLONASS-L3OC-P and GLONASS-L3OC-D signal, which remains below the GPSIA internationally and domestically recognized threshold of 1dB for assessing interference between GNSS devices.

Table 9: X5 C/N0 Degradation Results.

Interfering Signal	Reference Signal	C/N0 Degradation (dB)
Xona X5 Signal	BeiDou-B2A-D	0.52
	BeiDou-B2A-P	0.52
	BeiDou-B2B-I	0.44
	BeiDou-B2B-Q	0.44
	GAGAN-L5	0.52
	GLONASS-FKL3(MAX)	0.50
	GLONASS-L3OC-D	0.98
	GLONASS-L3OC-P	0.98
	GPS-L5I	0.52
	GPS-L5Q	0.52
	Galileo-E5	0.45
	IRNSS-L5-RS	0.93
	QZSS-L5-I	0.52
	QZSS-L5-Q	0.52
	QZSS-L5-S	0.52
	SBAS-L5	0.52

5.5.3 Compatibility Showings for 1190.51625 MHz and ARNS

PFD is the amount of power per unit area within a unit bandwidth. It is equivalent to a signal's power spectral density (power per unit bandwidth) per unit area. Equivalent PFD ("EPFD") is the aggregate PFD that is summed together as caused by various satellites transmitting at adjacent frequencies from various incident angles, distances, and various incident PFDs. Xona adopts and describes the EPFD definition specified by Recommendation ITU-R M.1639-1 and Recommendation ITU-R M.1642-2 as shown in the following equations and definitions.

$$\mathrm{EPFD} = 10\left[\sum_{i=1}^{N_a} \frac{10^{\frac{P_i}{10}} * G_t(\theta_i) * G_r(\varphi_i)}{4\pi d_i^2 * \ G_{r,max}}\right]$$

where:

N_a is the number of satellites that are visible from the receiver,

i is the index of each individual satellite whose incident PFDs are summed,

P_i is RF power per reference bandwidth at the input of the transmit antenna on the i’th transmitting satellite (dB(W/MHz)),

θ_i is the off-NADIR angle (degrees) that describes the direction toward the receiver from the i’th transmitting satellite,

$G_t(\theta_i)$ is the linear transmit antenna gain of the satellite in the direction of the receiver,

d_i is the distance (meters) between the i’th transmitting satellite and the receiver,

φ_i is the elevation angle (degrees) that describes the direction toward the i’th transmitting satellite from the receiver,

$G_r(\varphi_i)$ is the linear receive antenna gain of the receiver in the direction of the i’th transmitting satellite,

$G_{r,max}$ is the maximum linear gain of the receiver, and

EPFD is the instantaneous Equivalent Power Flux Density (dB(W/(m^2 · MHz))).

Reference ARNS system modeling characteristics are provided in Recommendation ITU-R M.1642-2 at annex 2, including the reference antenna pattern (dB below maximum gain with some polarization mismatch loss), as well as a reference aircraft height of 40,000 ft (or 12,192 m), which provides the maximum interference scenario where the ARNS receiver gain is roughly 3 dB below peak and has visibility of RNSS satellites between elevation angles -4 deg and +4 deg.

The analysis is simplified given that Xona assumes worst case destructive interference (10log10(number of SV planes)); however, it is overly pessimistic. Future interference analysis for coordination with the Resolution 609 committee may adopt the simulation methodology prescribed in Recommendation ITU-R M.1642-2 as desired.

For aggregate EPFD data for existing and operating RNSS systems, Xona uses the most recent data published in the Resolution 609 19th Consultation Meeting ("CM"). The Resolution 609 data is reported on a spacing of 1-megahertz center frequencies, and for the due diligence in Xona's analysis, Xona performs interpolation between those data points since X5 is centered at a non-integer megahertz frequency and thus has peak PFD at non-integer megahertz center frequency.

Considering the limit of -121.5 dB(W/(m^2 · MHz)) aggregate EPFD,[16] and assuming the X5 transmission properties submitted, Xona assesses the result depicted in Figure 19 (Initial Phase) and Figure 20 (Final Phase). Whereas the 19th CM reported an EPFD margin of 0.02 dB and 0.07 dB for the two cases, the addition of the Xona X5 signal does not degrade the EPFD margin in a significant way (much less than 0.01 dB). By design, the X5 signal occupies a highly efficient portion of the spectrum between existing RNSS signals and thus does not introduce significant new interference. Importantly, the X5 signal does not preclude future RNSS systems from introducing new signals in the 1164-1215 MHz band.

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[16] Protection of aeronautical radionavigation service systems from the equivalent power flux-density produced by radionavigation-satellite service networks and systems in the 1 164-1 215 MHz frequency band, ITU-R Resolution 609 (WRC-07).

Figure 19: Aggregate EPFD – Initial Phase.

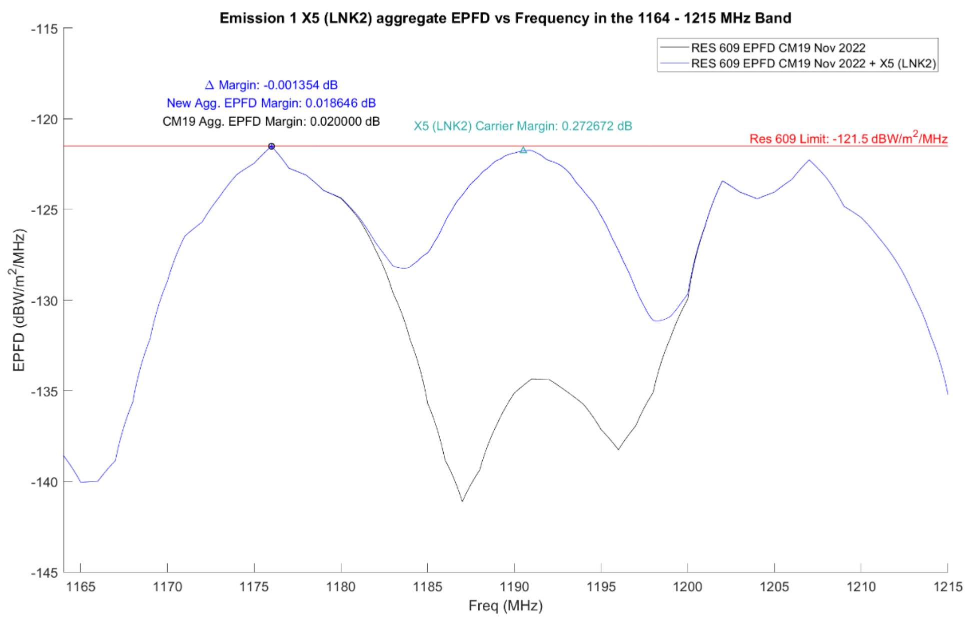
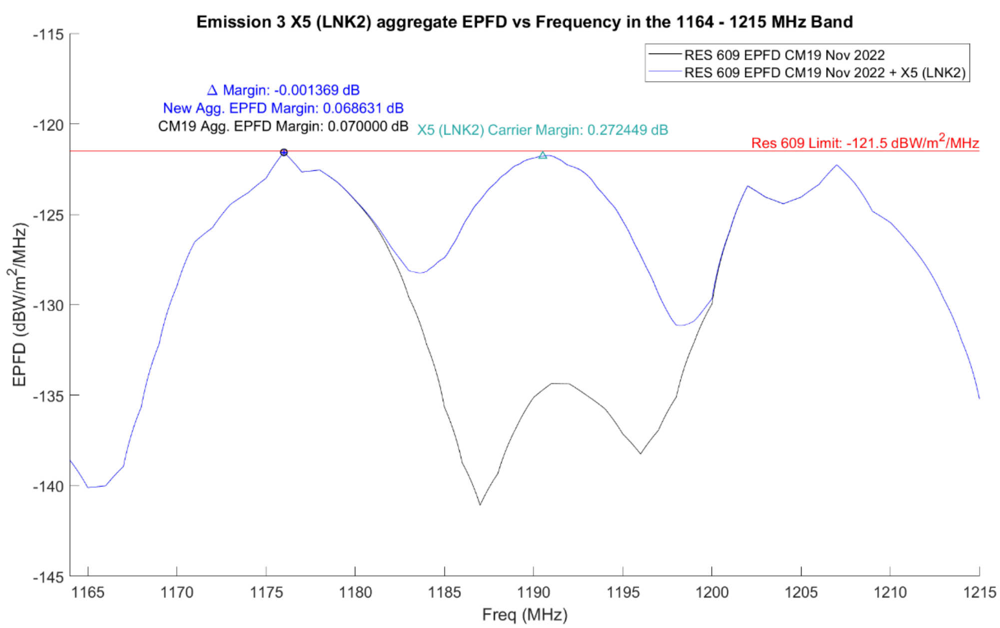


Figure 20: Aggregate EPFD – Final Phase.



5.6 Compatibility for C-band RNSS Service

The Xona XC signal will operate at a center frequency of 5020.3725 MHz and occupy a reference bandwidth of 18 megahertz extending from 5011.3725-5029.3725 MHz, where 5010-

5030 MHz is allocated by the ITU for space-to-ground transmission from RNSS. To operate in this band, systems must meet PFD requirements in two frequency bands adjacent to the allocated 5000-5030 MHz band for RNSS operation, which are as follows:

1. The 4990-5000 MHz band reserved for Radio Astronomy applications[17]
   a. -171 dB(W/m^2) in a 10-megahertz bandwidth for GSO satellite networks in the 4990-5000 MHz band (not applicable)
   b. -245 dB(W/m^2) in a 10-megahertz bandwidth for NGSO satellite networks in the 4990-5000 MHz band more than 2% of the time
2. The 5030-5091 MHz band allocated to International Civil Aviation Organization ("ICAO") Microwave Landing Systems ("MLS")[18]
   a. -124.5 dB(W/m^2) in any 150-kilohertz band within the 5030-5091 MHz MLS band

Analysis presented in this section shows that Radio Astronomy and the MLS requirements are met with acceptable margin. The XC PFD margins are shown in Table 10.

Table 10: C-Band PFD Margins Summary.

Band	Frequency Range (MHz)	PFD Limit	Max Aggregate PFD	Margin (dB)
Radio Astronomy	4990-5000	-245 dB(W/m^2/10 MHz)	-248.0 (W/m^2/10 MHz)	3.0
MLS	5030-5091	-124.5 dB(W/m^2/150 KHz)	-144.5 (W/m^2/150 KHz)	20.0

[17] Protection of the radio astronomy service in the frequency band 4990-5000 MHz from unwanted emissions of the radionavigation-satellite service (space-to-Earth) operating in the band 5 010-5 030 MHz, ITU-R Resolution 741 (WRC-15).

[18] Potential interference between the ICAO standard microwave landing system (MLS) operating above 5 030 MHz and radionavigation-satellite service (RNSS) systems in the band 5 000-5 030 MHz, Report ITU-R M.2262.

5.6.1 Methodology

Here, the PFD is derived as a function of elevation angle. The SV slant range d_i at an elevation angle θ_{el} is given by:

$$d_i = -r_E \sin\theta_i + \sqrt{r_E^2(\sin^2\theta_i - 1) + (r_E + h)^2}$$

where h is the altitude of the SV (1080 km), r_E is the Earth's radius, and θ_i^a is the SV antenna off-boresight angle in the direction of the receiver on the ground (which sees the SV at elevation angle θ_{el}). This angle is given by:

$$\theta_i^a = \sin^{-1}\left(\frac{r_E}{r_E + h}\cos\theta_{el}\right)$$

The antenna gain in the direction of the receiver on Earth is then:

$$G'(\theta_{el}) = G\left(\sin^{-1}\left(\frac{r_E}{r_E + h}\cos\theta_{el}\right)\right)$$

Figure 10 shows the SV antenna gain $G'(\theta_{el})$ in the direction of a receiver which sees an SV at elevation angle θ_{el}. The received power from an SV at elevation θ_{el} is given by:

$$P_R(\theta_{el}) = \left(\frac{\mathrm{EIRP}(\theta_{el})}{4\pi d_{el}^2}\right)\left(\frac{\lambda^2}{4\pi}\right) = \mathrm{PFD}(\theta_{el}) \cdot A_E$$

In the above, $A_E = \lambda^2/(4\pi)$ is the effective aperture of the antenna which relates the PFD to the received power on the ground. To derive the formula for determining the PFD in bandwidth B, Xona uses the normalized PSD of the signal XC, which is defined as $\bar{S}_{XC}(f) = S_{XC}(f)/\gamma$, with:

$$\gamma = \int_{-\infty}^{+\infty} S_{XC}(f)\, df$$

Then the PFD in a bandwidth B from an SV at elevation θ_{el} is:

$$P_R(\theta_{el}) \int_{-\infty}^{+\infty} \bar{S}(f) df = \mathrm{PFD}(\theta_{el}) \cdot A_E$$

$$P_R(\theta_{el}) \int_{f_1}^{f_2} \bar{S}(f) df = \mathrm{PFD}(\theta_{el}; B) \cdot A_E$$

$$\int_{f_1}^{f_2} \bar{S}(f)df = PFD(\theta_{el}; B) \frac{A_E}{P_R(\theta_i)} = \frac{PFD(\theta_{el}; B)}{PFD(\theta_{el})}$$

$$\therefore PFD(\theta_{el}; B) = PFD(\theta_{el}) \cdot \int_{f_1}^{f_2} \bar{S}(f)\, df = \rho \cdot PFD(\theta_{el})$$

In the above, $\rho = \int_{f_1}^{f_2} \bar{S}(f)\, df$ is the fraction of the total power in the XC waveform that is in any band B from f_1 to f_2. For the Radio Astronomy requirement, $\rho = \rho_{RA}$ is the fraction of the XC signal power in the band from 4990-5000 MHz. For the MLS requirement, $\rho = \rho_{MLS}$ is the maximum fraction of the total power that occurs in any (overlapping) 150-kilohertz band beginning at 5030 MHz and ending at 5091 MHz. For the MLS band, the maximum PFD level was determined by computing the PFD in overlapping 150-kilohertz band segments, in 5-kilohertz steps from 5030 MHz to 5091 MHz, for approximately 12,000 different 150-kilohertz bandwidth segments. For the XC signal, the value of ρ_{RA} and ρ_{MLS} are listed in Table 11.

Table 11: Values of ρ_{RA} and ρ_{MLS} for the XC Waveform.

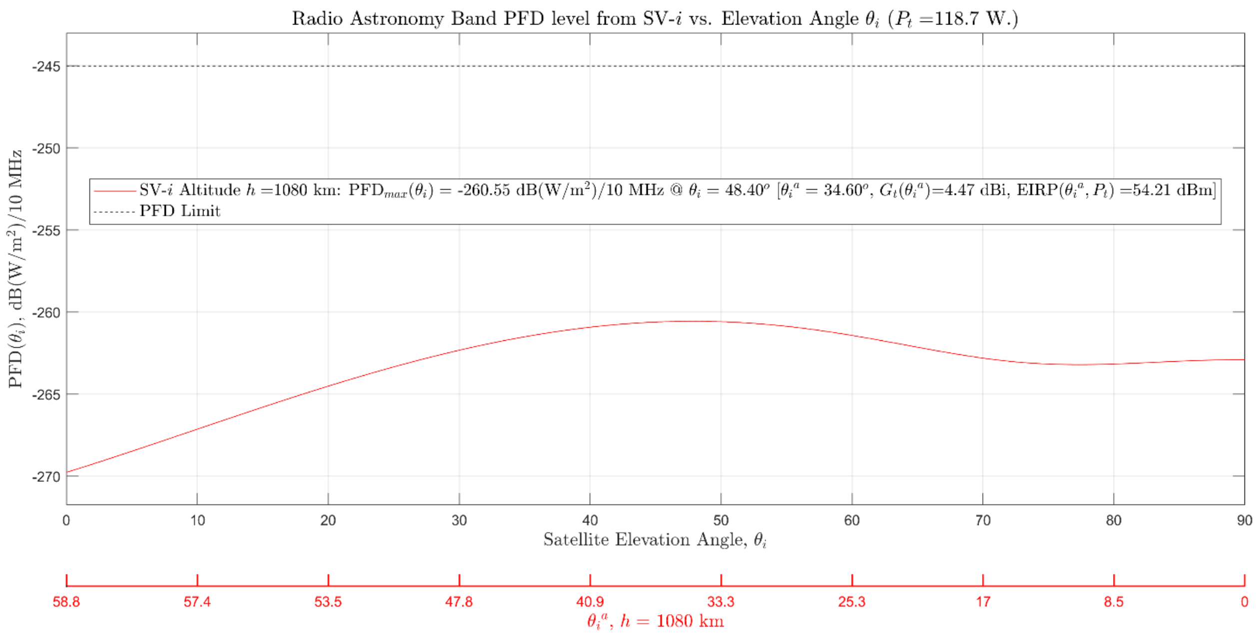
Parameter	**Band**	**Frequency Range (MHz)**	**Parameter Value (Magnitude and dB)**	
ρ_{RA}	Radio Astronomy (RA)	4990 – 5000	1.9793E-08	-77.04 dB
ρ_{MLS}	Microwave Landing System (MLS)	5030 – 5091	1.7641E-05	-47.53 dB

5.6.2 Compatibility Showings for Radio Astronomy

This analysis focuses on the NGSO PFD requirements in the 4990-5000 MHz band reserved for Radio Astronomy, as they are the most applicable. Figure 21 shows the PFD in dB(W/m^2/10 MHz) in the Radio Astronomy band versus elevation angle for one satellite. This is achieved in part with filtering on this band with a result in an additional -74 dB of suppression. The maximum value is -260.55 dB(W/m^2/10 MHz) per satellite, which occurs at an elevation of 48.4 degrees. The maximum aggregate PFD levels assume the worst-case destructive interference (10log10(number of SV planes) = 12.55 dB) and conservatively that these are all in view at the same elevation (48.4 degrees) so that the value in Table 10 is 12.55 dB higher than the maximum PSD from a single SV shown in Figure 21 at -248.00 dB(W/m^2/10 MHz).

For the Radio Astronomy band requirement, a minimum margin of 3.0 dB is achieved. This is the lower bound on what is likely a wider PFD margin because the result assumes SVs are at the elevation (48.4 degrees) that produces the highest PFD level.

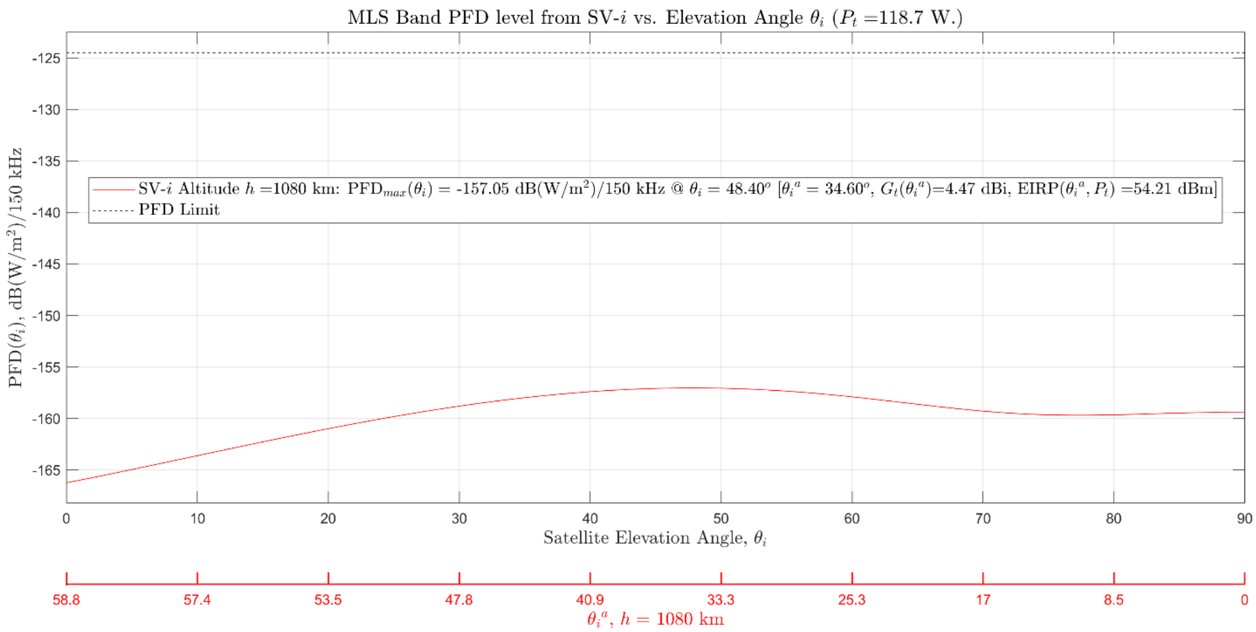
Figure 21: Worst-Case PFD Level into the Radio Astronomy Band from 4990-5000 MHz versus SV Elevation Angle for a Single SV.



5.6.3 Compatibility Showings for ICAO MLS

Figure 22 shows the maximum PFD in any 150-kilohertz band within the MLS band based on the power from an SV between elevations of 0 degrees and 90 degrees. The maximum PFD was found to be -157.05 dB(W/m^2/150 kHz) per SV at an elevation of 48.4 degrees. The maximum aggregate PFD levels assumes the worst-case destructive interference (10log10(number of SV planes) = 12.55 dB) and conservatively that these are all in view at the same elevation (48.4 degrees) so that the value in Table 10 is 12.55 dB higher than the maximum PSD from a single SV shown in Figure 22 at -144.50 dB(W/m^2/150 kHz). From Table 10, the PFD margin relative to the requirement in Report ITU-R M.2262 of -124.5 dB(W/m^2/150 kHz) is 20.00 dB. As with the margin computation for the 4990-5000 MHz Radio Astronomy band, the 20.00 dB MLS band margin is the lower bound on what is likely a wider PFD margin because the result assumes SVs are at the elevation (48.4 degrees) that produces the highest PFD level.

Figure 22: Worst-Case PFD Level into Any 150-Kilohertz Segment within the MLS 5030-5091 Band from a Single SV vs. SV Elevation Angle θ_{el}.



6. Orbital Debris Mitigation Plan

Consistent with 47 C.F.R. § 25.114(d)(14), this application contains a high-level overview of the design and operational strategies Xona will use to mitigate orbital debris. In the forthcoming ODAR, Xona will use the latest NASA Debris Assessment Software to validate that the Xona System satisfies the latest FCC and NASA STD-8719.14 requirements. Xona is committed to safe operation of its constellation and collaboratively working with third parties to develop sustainable space safety practices and policies.

ENGINEERING CERTIFICATION

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

/s/ Adrien Perkins

Adrien Perkins
VP, Engineering
Xona Space Systems, Inc.