Customer Terminals

Small, compact customer terminals allow customers to connect to the network and enjoy fast, reliable service at an affordable price.

Type: Single aperture phased array antenna

Frequency: Ka-band

Compact: 7 in. sq., 1 in. thick, 100 Mbps

Standard: 11 in. sq., 1 in. thick, 400 Mbps

Enterprise: 19 x 30 in surface, 1 Gbps

Prototype Missions

Kuiper is preparing to launch two prototype satellites – KuiperSat-1 and KuiperSat-2.

Mission objectives

- Missions will allow us to test communications and networking technology used in our final satellite design, and validate launch and mission management procedures.
- Prototypes include production-ready technology and sub-systems, including phased array and parabolic antennas, power and propulsion systems, and custom-designed modems.

Safety and sustainability

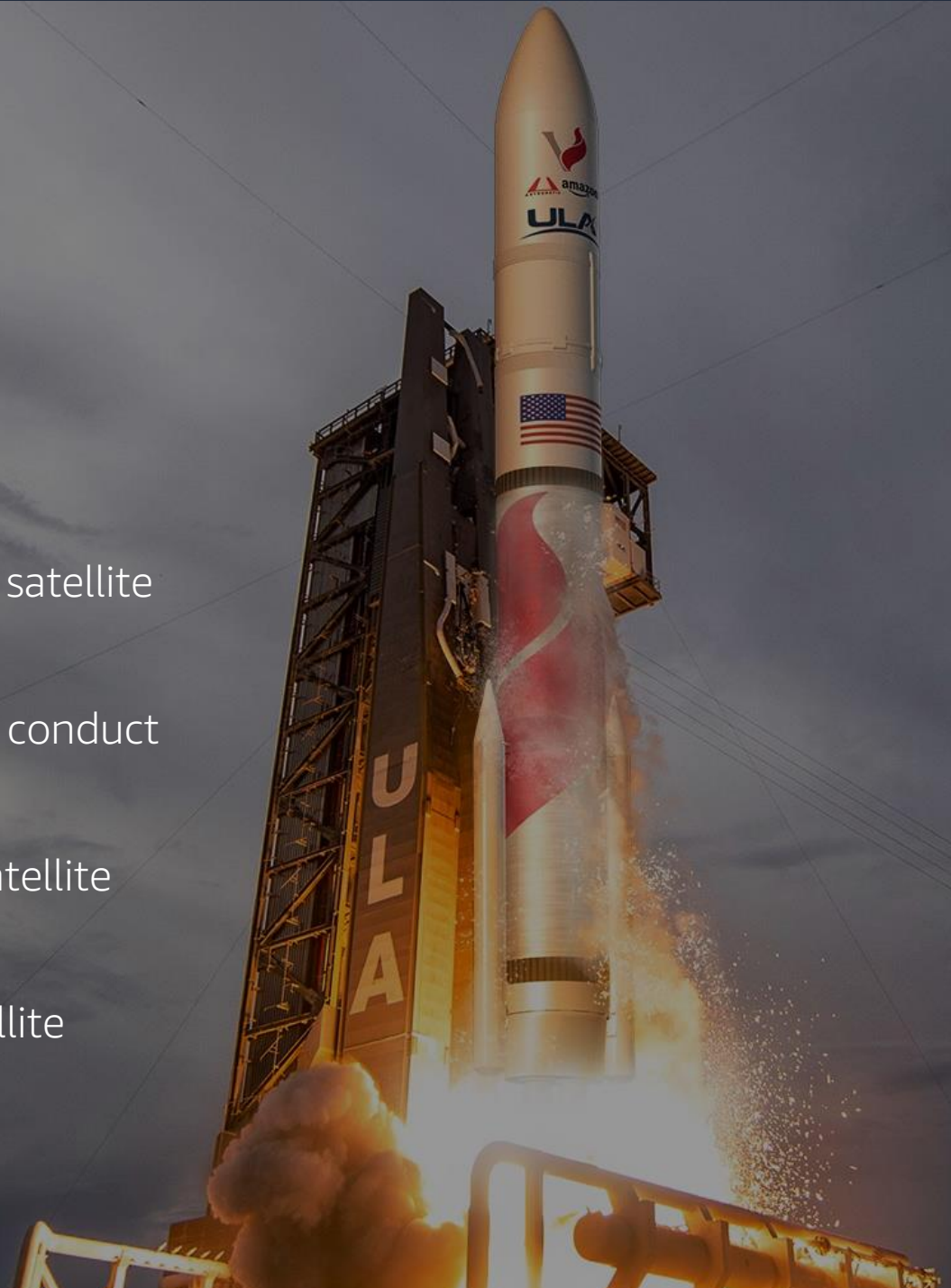
- Prototypes are designed for atmospheric demise and will be actively deorbited after the mission.
- One of two satellites will include reflectivity panels to evaluate ways to mitigate impact on optical astronomy.

Mission details

- Missions will launch from Cape Canaveral Space Force Station in Florida.

Key Milestones

- 2022 | Heavy-lift launch vehicle procurement.
  - ATLAS V
  - NEW GLENN
  - VULCAN CENTAUR
  - ARIANE 64
- 2023 | Launch two prototype satellites and begin satellite production.
- 2024 | Begin launching production satellites and conduct early customer pilot projects.
- 2026 | FCC deadline to deploy at least 50% of satellite constellation.
- 2029 | FCC deadline to deploy remainder of satellite constellation.



Space Safety

Core Kuiper features to protect against orbital debris.

Constellation design

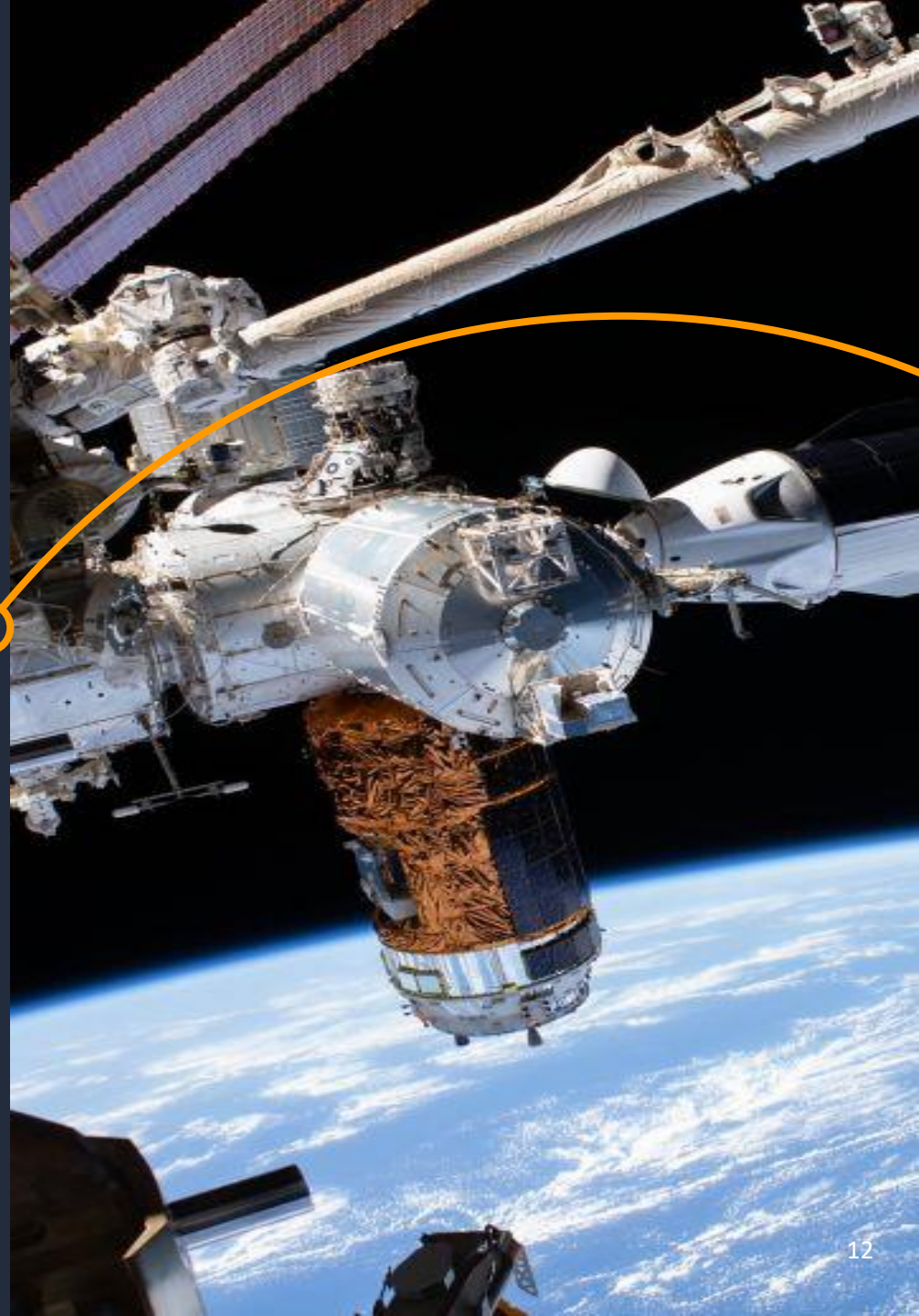
- 20 km altitude separation between shells.
- In-track separation of at least 50 km.
- No more than 9 km of cumulative altitude deviation.

Reliability

- Comprehensive subsystem and system testing, in the factory and on orbit below ISS prior to orbit raising.
- Ephemeris sharing and maneuver forecasts.

Deorbit and demise

- Designed for active deorbit within one year.
- Passive deorbit duration median duration is less than 5 years based on decay due to natural forces.



Protecting Astronomical Observations

We are taking steps to minimize our impact on astronomical observations.

System design

- Project Kuiper operates at lower altitudes and includes fewer satellites, helping reduce reflectivity compared to larger constellations or those operating at higher altitudes (over 1,000 km).
- Prototype missions will help us evaluate reflectivity and test our mitigation measures.

Deployment and operations

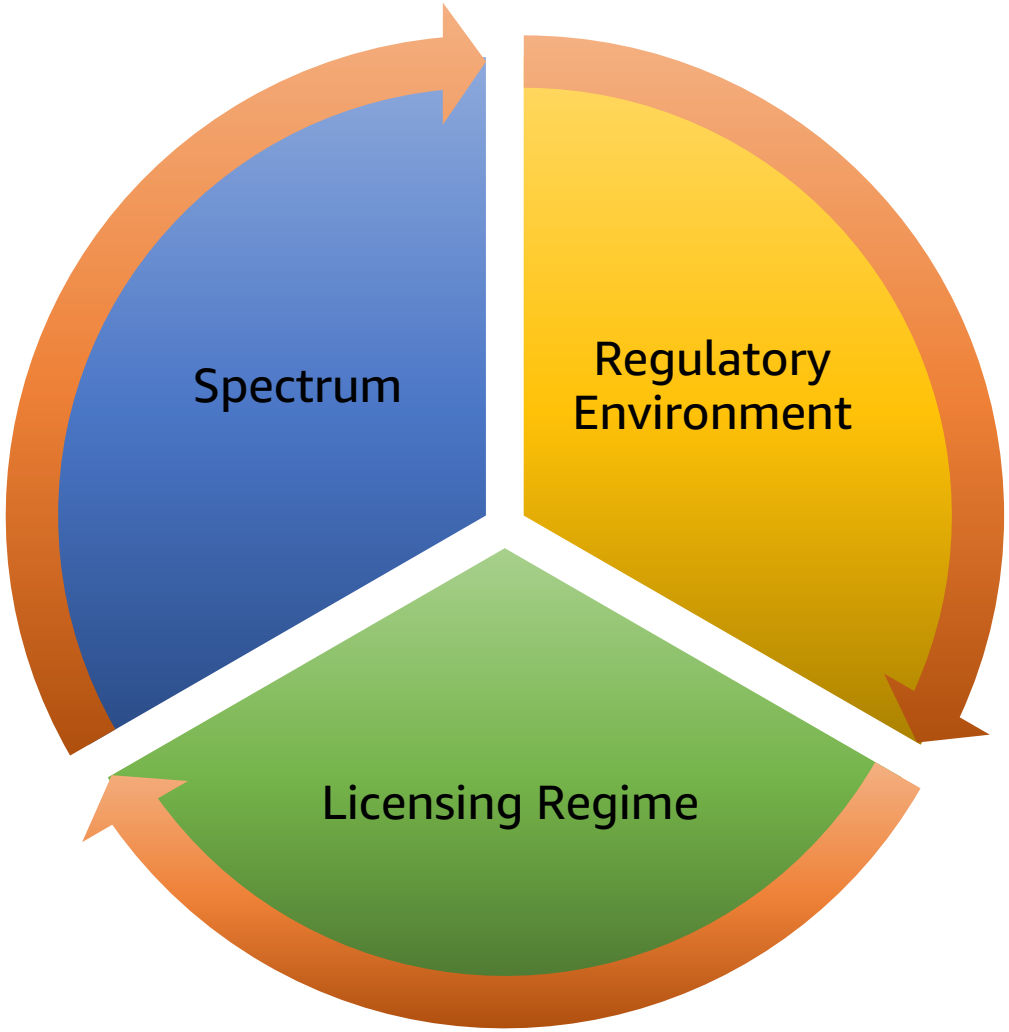
- Maneuvering capabilities reduce Earthward reflectivity during propulsive operations (orbit raise and lower).
- Stearing capabilities allow us to minimize reflections during mission operations.

Collaboration

- Kuiper is committed to working with the astronomical community to find shared solutions. We will share ephemeris data throughout operations to help protect and preserve scientific research.

Regulatory Framework

- Achieving universal access to broadband will require bringing over 3.7 billion people online.
- More capacity will be needed as technology evolves and demand grows.
- A predictable and enabling regulatory environment is essential to attracting long-term investment and building the digital economy.
- Regulatory certainty and harmonized spectrum requirements are essential.
- Reducing administrative/regulatory burdens enables the delivery of affordable services.



Regulatory Environment

- Regulations are different in each country, and complex global networks require various regulatory approvals.
- Differences in licensing burdens between countries impacts the ability of NGSO operators to adopt a uniform approach to provide services.
- Different rules and requirements impacts decisions on type of service to be provided and whether or not to cover a particular country.
- Spectrum use is highly regulated due to sharing requirements with other services.
- NGSO systems require regulatory certainty, and their spectrum requirements must be taken into account.
- Harmonized spectrum allocations lead to predictability and facilitates deployment of new technologies.
- For satellite to play its role in the communications ecosystem, including the future 5G ecosystem, it must continue to have access to the spectrum in use today and to new spectrum to meet future demand.

Regulatory Environment (continued)

- Regulatory decisions need to foster competition, innovation and certainty.
    - “Open Skies” policies allow customers to choose among competing options and reduce costs of connectivity to customers.
- Agile regulations can help regulators meet their connectivity objectives.
    - Technology neutrality.
    - Blanket licensing for exemption from individual licensing for customer earth stations and Earth Stations in Motion (ESIM).
    - Regulations must provide a stable operating environment to which all services can be designed.
    - Space is a shared natural resource, and all stakeholders must the duty to design and operate satellite systems responsibly to ensure the long-term preservation of space.

Enabling Regulatory Regime

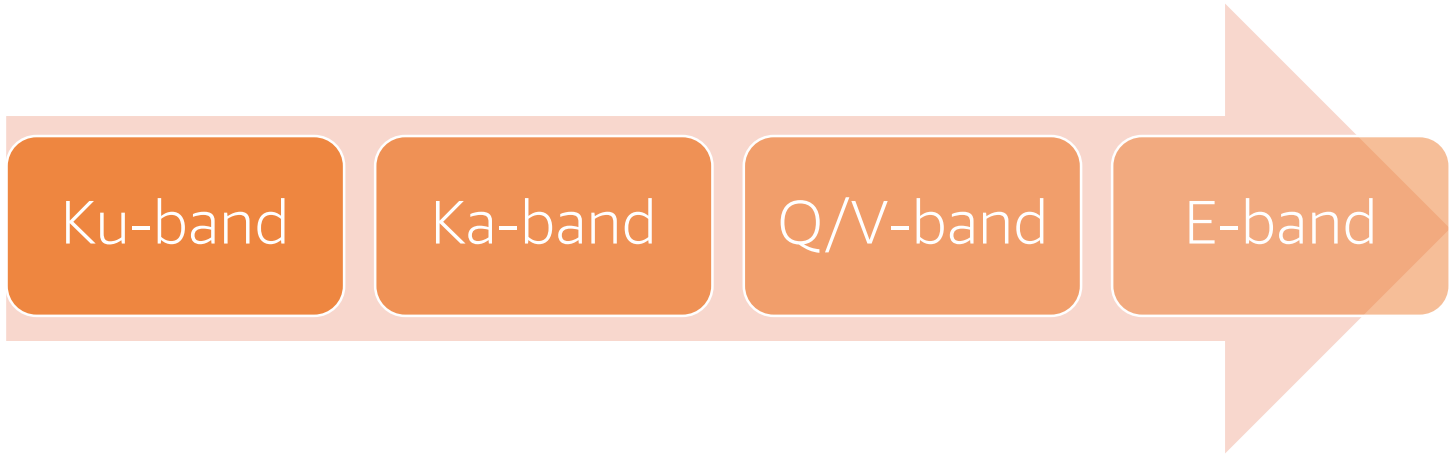
- Ensure flexible and streamlined licensing procedures for domestic internet service providers and satellite broadband providers.
- Allow for satellite provision of international internet capacity without a requirement for domestic ground stations to route traffic to and from satellites.
- Regulatory transparency is key for licensing processes.
- Availability of licensing and spectrum planning information allows operators to plan and undertake processes in a timely manner.
- Online licensing processes facilitate entry and reduces costs.
- Spectrum use and allocation information facilitates spectrum management and coordination.
- Reduced license and spectrum costs/fees (administrative cost recovery) help reduce costs of connectivity to end users.
- Mutual recognition of equipment certification/homologation reduces time and complexities of introducing new services.

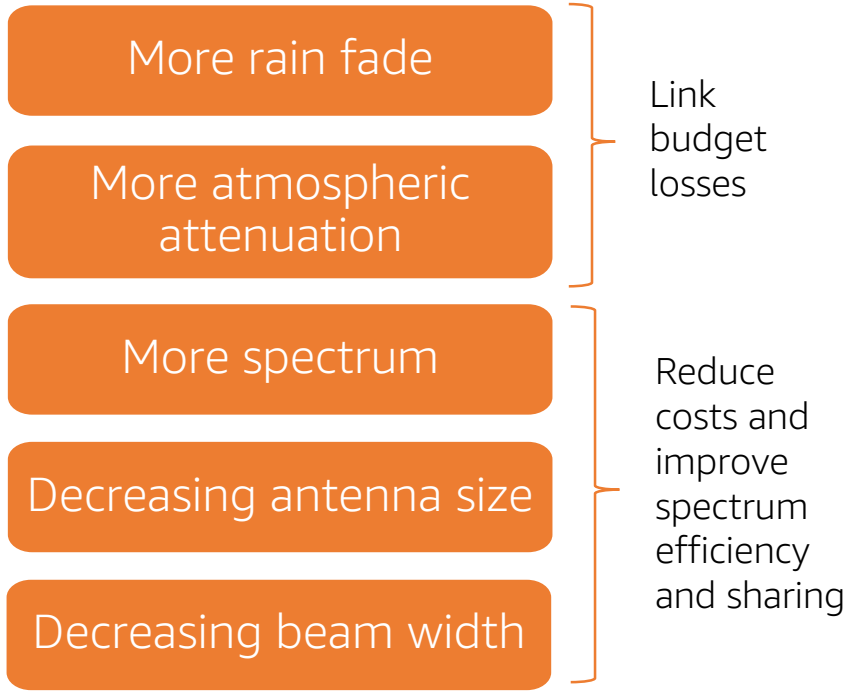
Most Important Radio Regulations for NGSO Systems

Volume 1: Articles	Volume 2: Appendices	Volume 3: Resolutions	Volume 4: ITU-R Recommendations incorporated by reference
• Article 5: frequency allocations • Article 9: Coordination procedures • Article 11: Notifying and recording frequency assignments • Article 21: terrestrial/space sharing. • Article 22: space service sharing – equivalent power flux-density limits (EPFD).	• Appendix 4: characteristics of satellite networks and earth stations for filings. • Appendix 5: identification of administrations for coordination. • Appendix 7: determining the coordination area around an earth station. • Appendix 8: includes earth station antenna patterns.	• Resolution 35: NGSO milestones. • Resolution 49: administrative due diligence. • Resolution 76: aggregate EPFD limits. • Resolution 85: application of Article 22 (EPFD).	• Resolution 27 (Rev. WRC-19) explains the use of incorporation by reference in the Radio Regulations. • Incorporation by reference changes a Recommendation from voluntary to mandatory.

Radio Frequency Spectrum

- Modern LEO broadband systems are licensed in the following frequency bands:
  - Ku-band: 10.7-12.7 GHz (↓), 13.75-14.5 GHz (↑)
  - Ka-band: 17.7-20.2 GHz (↓), 27.5-30 GHz (↑)
  - Q/V band: 37.5-42 GHz (↓), 47.2-50.2 GHz (↑), 50.4-51.4 GHz (↑)
  - Potential next frontier in E-band: 71-76 GHz (↓), 81-86 GHz (↑)





Opportunities to improve spectral efficiency for NGSO systems being addressed by the ITU

- Promote and develop ITU-R Recommendations and sharing studies that accurately reflect planned NGSO systems (many ITU-R Recommendations are based on work from 1997-2003).
- Develop regulations to allow NGSO systems such as Kuiper to deliver their stated goals and share effectively with incumbent systems.
- Enable the operation of ESIM with NGSO systems (WRC-23 Agenda Item 1.16).
- Harmonize worldwide spectrum available for NGSO systems (WRC-23 Agenda Item 1.19).

WRC-23 Agenda Item 1.16 (NGSO ESIM)

- In accordance with WRC-23 Agenda Item 1.16, ITU-R WP4A has studied the operation of NGSO ESIM in the Ka band.
- ESIM are an important component in the operation of NGSO systems, and the ability to serve moving platforms such as aircraft present a valuable operational aspect for these next generation systems.
- Regulatory provisions for the operation of GSO ESIM were approved by WRC-19 and regional approvals for both GSO ESIM and NGSO ESIM have been adopted by both Europe and the FCC.
- Studies at WP4A have confirmed and CPM text (Method B) has been developed to support a solution that allows NGSO ESIM to operate.
- Regional groups around the world have adopted the solution contained in Method B as their positions heading into WRC-23
- Another component of these studies is the protection of EESS in 18.6-18.8 GHz, where a solution has been developed and is also reflected in the CPM text.

WRC-23 Agenda Item 1.19 (17.3-17.7 GHz FSS allocation in Region 2)

- WRC-23 AI 1.19 - to consider a new primary allocation to the FSS in the space-to-Earth direction in the frequency band 17.3-17.7 GHz in Region 2.
- There is already a FSS allocation for this frequency band in Region 1 and an allocation for this frequency band in Region 2 for the broadcasting-satellite service (BSS).
- This allocation would support harmonization with other regions and additional contiguous bandwidth for FSS operations to support growth.
- Studies at WP4A have confirmed the ability for FSS NGSO systems to operate in these bands and protect existing services.
- Studies at WP4A have confirmed and CPM text has been developed (method B, option 1) to allow for the ability for FSS NGSO to operate in these bands and protect existing services.
- Regional groups around the world have adopted this position (method B, option 1) as part of their preparations.

Article 21 RR No. 21.16.6 (PFD scaling factor for NGSO systems)

- WRC-19 invited the ITU-R to initiate studies on the appropriateness of the Article 21 equations in RR No. 21.16.6 for large scale NGSO systems, which scale the PFD limit based on the number of satellites in the NGSO constellation.
- Studies at WP4A have confirmed that the equations in No. 21.16.6 are inappropriate for NGSO systems and leads to the scaling for each NGSO satellite in gross excess of the number of satellites that are visible or are even in the constellation.
- WP4A has performed studies in consultation with WP5A/5C and found that the modification of the equations as follows will ensure protection to terrestrial services:

$X = 0$ dB for $N \leq 50$

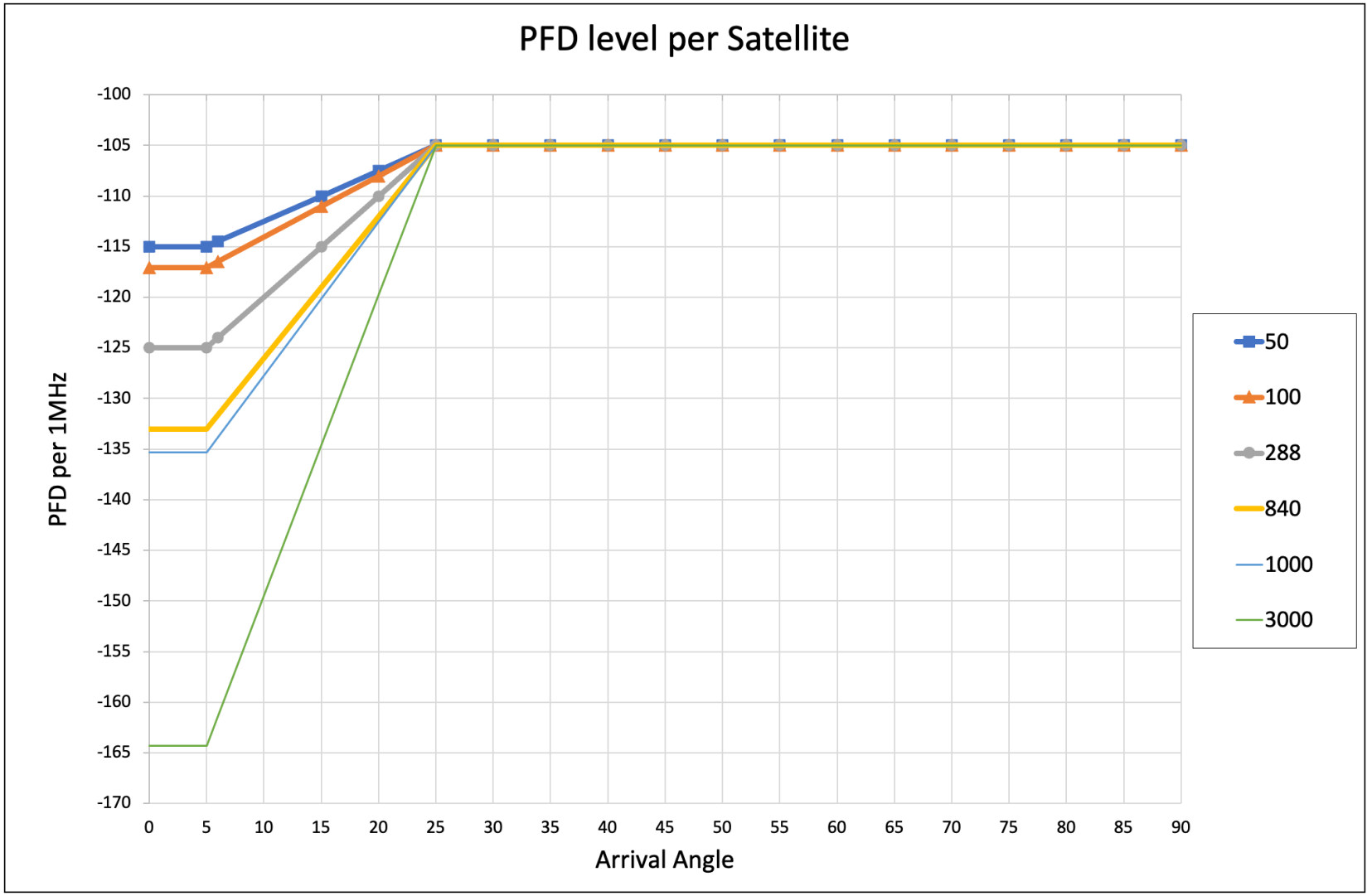
$X = \frac{5}{119}(N - 50)$ dB for $50 < N \leq 288$

$X = \frac{1}{69}(N + 402)$ dB for $288 < N \leq 1000$

$X = \text{Max}[20.3, 10 \times \log10(Nv)]$ dB for $1\,000 < N$

- The issue will be discussed at WRC-23 under AI 9.2 – Director's Report.

Article 21 RR No. 21.16.6 (PFD scaling factor for NGSO systems) - continued



WRC-23 Agenda Item 7 – Issue A (Orbital Tolerance) and Issue J (Resolution 76)

Issue A

- WRC-23 Agenda Item 7 Issue A seeks to define an acceptable orbital tolerance from the filed parameters of a NGSO system.
- The four parameters being discussed are perigee altitude, apogee altitude, inclination, and argument of perigee.
- Amazon supports the development of a 20 km and 1° tolerance trigger for NGSO systems (CPM text Method A4).
- If the trigger is exceeded, showings must be provided to BR to ensure interference environment has not changed.
- Some proponents are proposing a tolerance as large as 100 Km.
    - We do not support this due to rise in interference levels as well as orbital safety concerns.

WRC-23 Agenda Item 7 – Issue A (Orbital Tolerance) and Issue J (Resolution 76)

Issue J

- Resolution 76 seeks to establish a consultation process for NGSO systems to evaluate aggregate interference into GSO networks.
- Resolution 76 also identifies the need to establish a Recommendation that accurately models aggregate interference.
- Work to establish the Recommendation on modeling techniques is on-going but not yet complete.
- We support a WRC-23 work item to study this issue and develop appropriate methodologies during the next study cycle WRC-27 (Method J5).
- A consultation process should not be established until a proper Recommendation to model interference from NGSO systems is developed by WP4A.

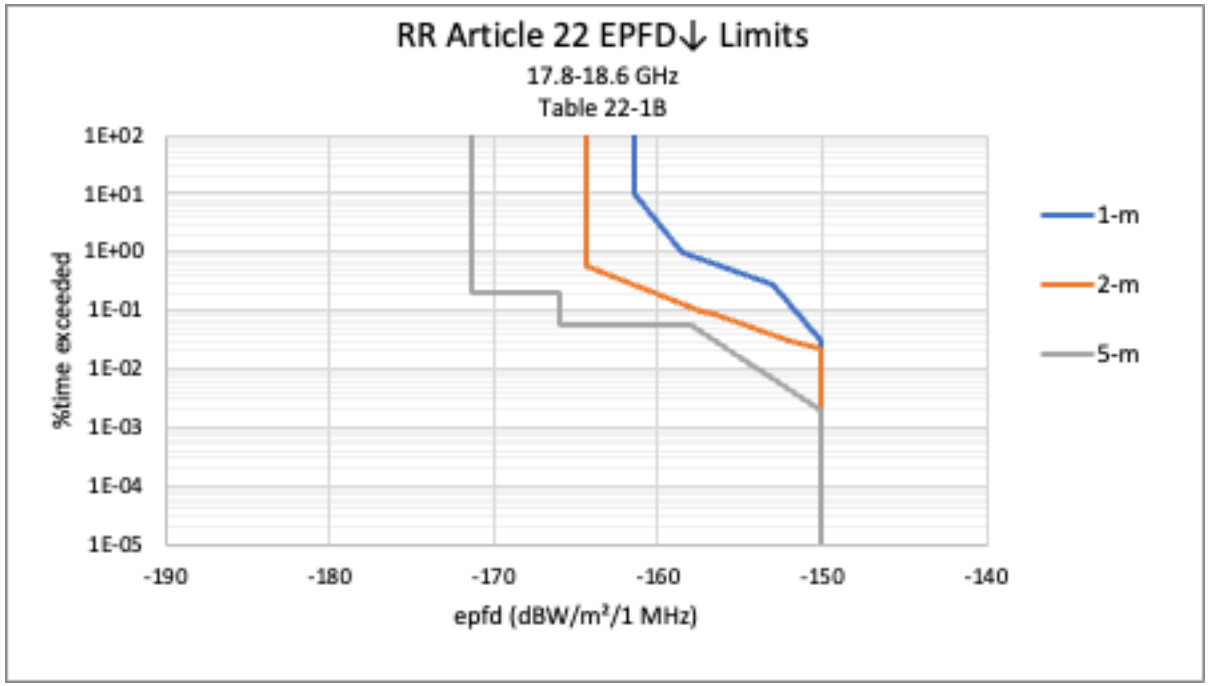
WRC-27 Future Agenda Items (FAIs)

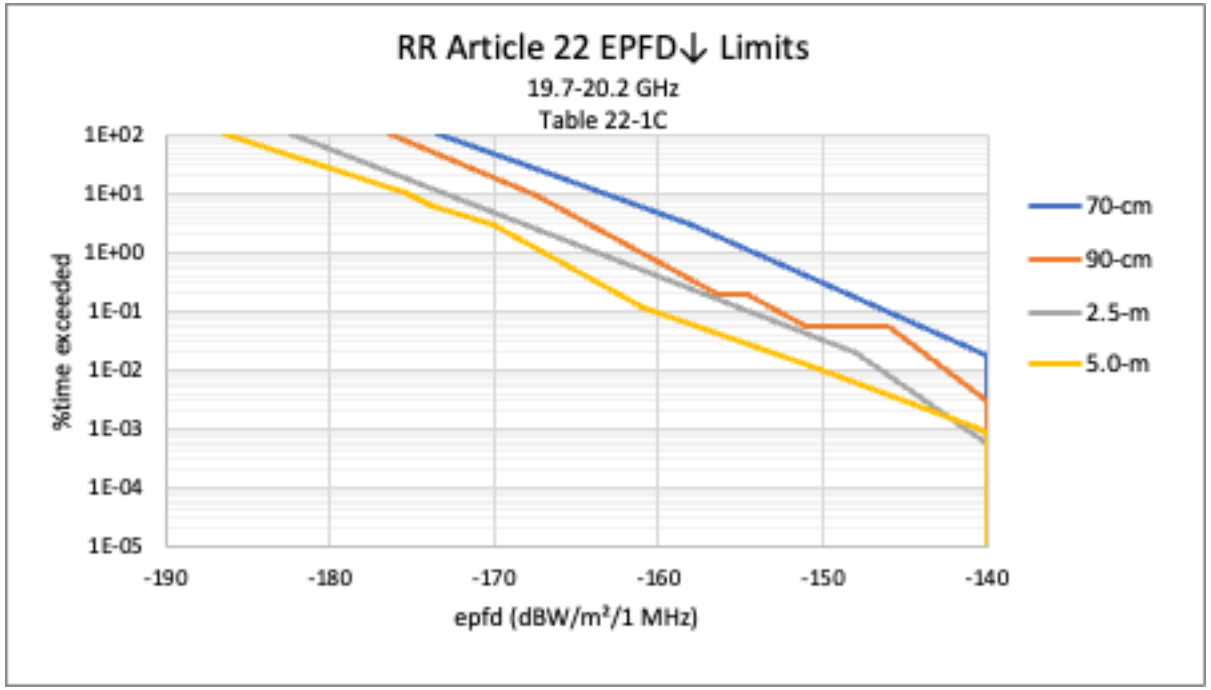
- Part of the work of WRC-23 will be to decide on the Agenda Items for the next conference (WRC-27) and other future WRCs.
- Project Kuiper supports the following FAIs:
  - Use of the 51.4–52.4 GHz band for NGSO.
  - Use of the 17.3-17.7 GHz band in Region 3.
  - EPFD relaxation related Agenda Item.

Article 22 EPFD limits revision – Future Agenda Item overview

- Amazon is supportive of a Future Agenda Item to review the EPFD limits in Article 22.
  1. Increase the spectrum utilization by non-GSO systems in the Ku- and Ka-bands.
  2. By revising the outdated EPFD framework in Article 22.
- Current EPFD limits limit the ability of non-GSO operators to provide broadband to unserved and underserved communities around the world.
- Improvements to spectral efficiency will allow NGSO FSS systems to:
  - Bring online additional capacity for fast, affordable broadband.
  - Decrease costs of connectivity.
  - Increase innovation, competition, and investment that are needed to bridge the digital divide on the continent.
- Bridging the digital divide will take a combination of all satellite technologies GSO and NGSO - operating with upmost spectral efficiency.
- Amazon is committed to ensuring protection of the GSO.

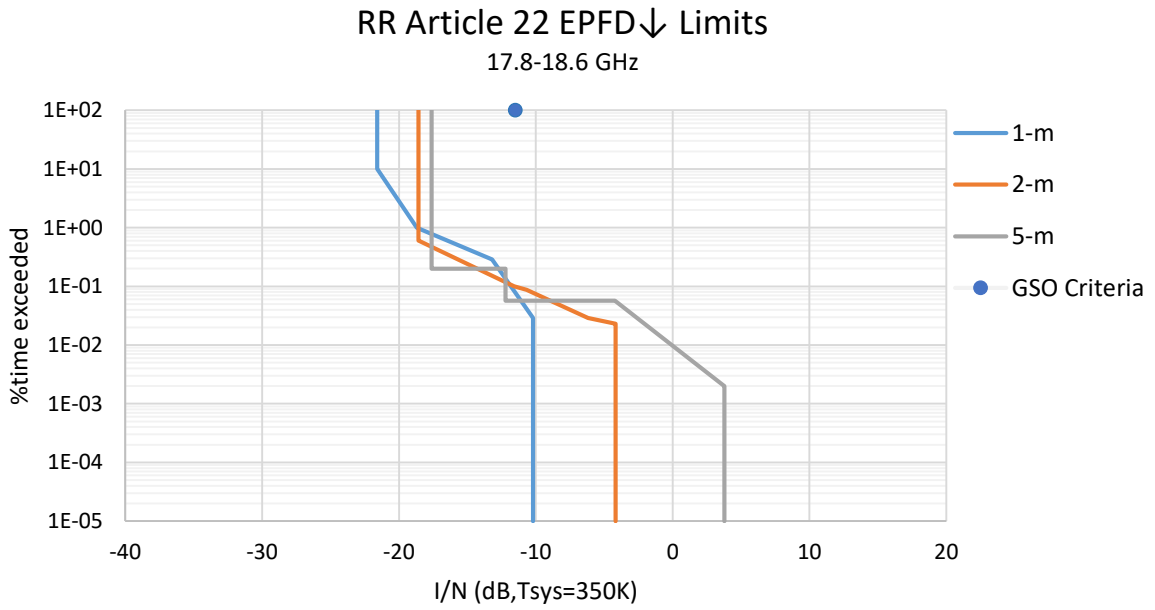
Status quo Ka-band EPFD limits

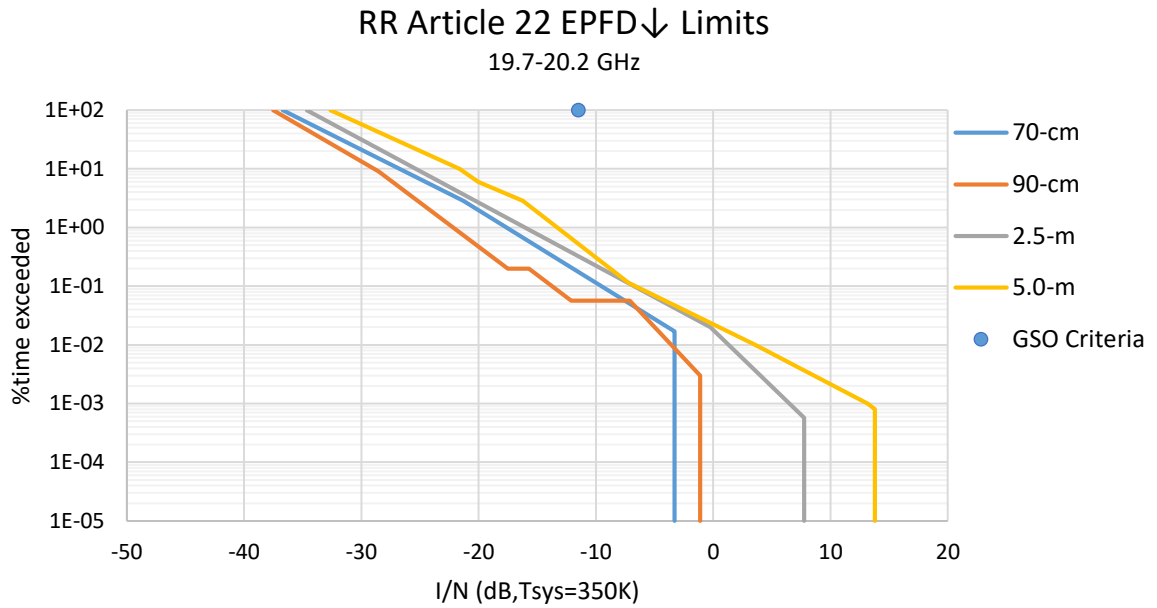




- These plots represent the applicable EPFD limits for Ka-band NGSO systems.
- Note that even though the modern GSO systems and protection criteria are similar, the limits in Table 22-1C for 19.7-20.2 GHz band are much more restrictive then the limits in Table 22-1B for 17.8-18.6 GHz.

EPFD limits converted to I/N protection criteria





- These plots represent the applicable EPFD limits converted to I/N using an assumed Tsys=350K
- The EPFD limits were derived using Recommendation ITU-R S. 1323 Methodology A
- Methodology A of Recommendation ITU-R S.1323 only considers a short-term protection
- The blue dot represents the single entry long-term FSS protection criterion, i.e. -11.5 dB (derived by an aggregate of -6.02 dB, as per Rec. S.1432)
- Note that for the long-term portions of the curve, the EPFD limits are excessively restrictive as compared to the single entry FSS protection threshold of -11.5 dB

Why an Agenda Item on this issue is critical?

Update the ITU Radio Regulations

Current EPFD limits are operational restrictions that result in spectrum inefficiencies that limit the ability of non-GSO operators to provide broadband to unserved and underserved communities around the world. The issues and spectrum inefficiencies of the EPFD limits have already been proven by ITU-R studies. Only a WRC-23 agenda item will allow changes to Regulations.

Embrace new technology

NGSO technology has changed and improved substantially compared to the networks planned that were used to develop the EPFD limits 25 years ago. GSO technology is also vastly different. Regulation must recognize how satellite technology and protection requirements has evolved over the past 25 years.

Enhance flexibility

The regulatory EPFD limits applicable to non-GSO systems below 30 GHz represents the single greatest operational restriction for systems like Kuiper and Starlink. This limits delay the ability of NGSO systems to commence service, leaves a substantial amount of system capacity fallow, and increases the cost of our system and service.

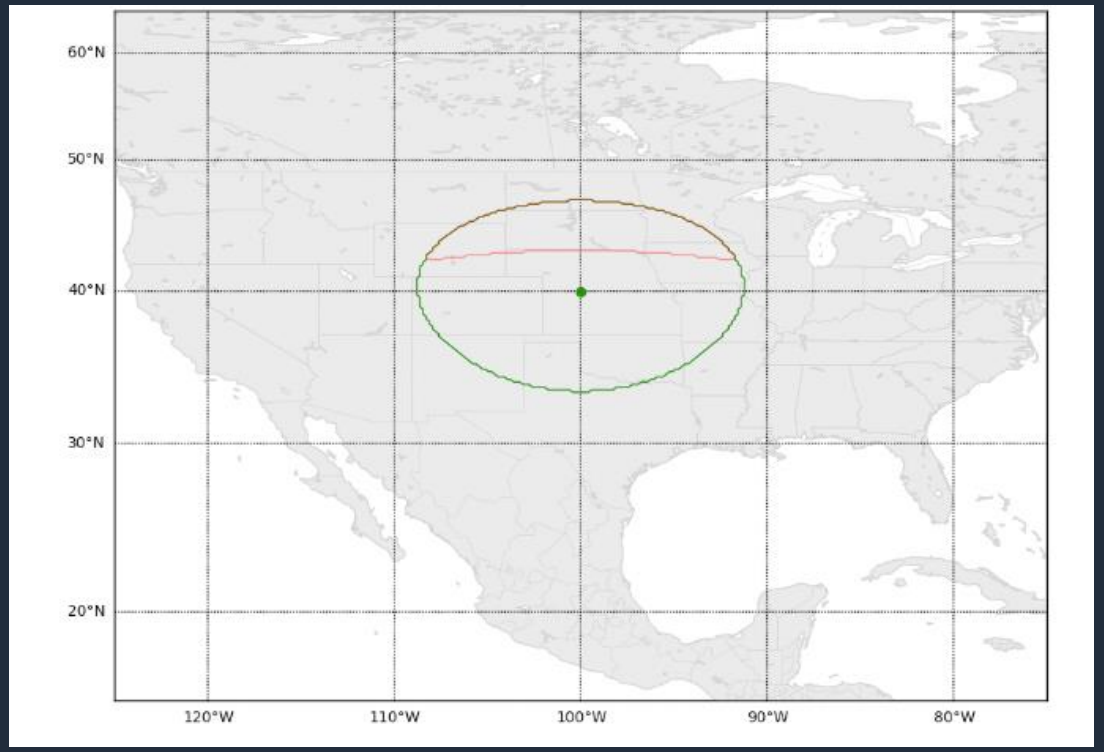
Close the digital divide

Current EPFD limits are operational restrictions that limit the ability of non-GSO operators to provide broadband to unserved and underserved communities around the world. Updating the regulations during the next study cycle will allow modern NGSO system to operate at their full potential, and according. According to some studies, updating EPFD limits could enable NGSO systems to bring online 75% additional capacity and significantly reducing costs. Only an Agenda Item leading to regulatory changes will allow this to happen.

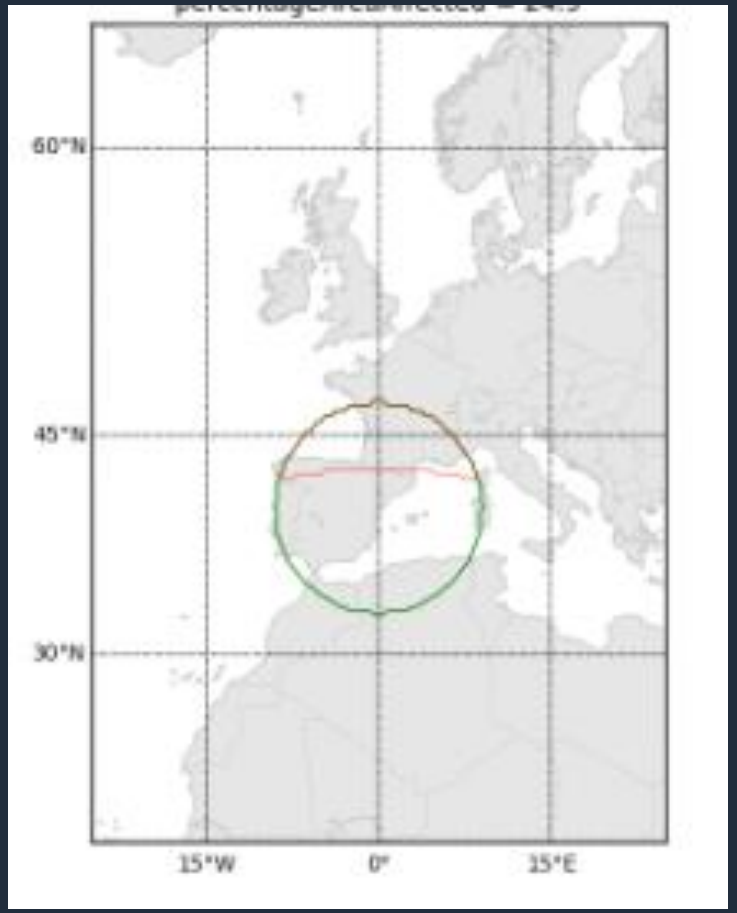
Pictorial impact of EPFD limits to Kuiper operations

Red Portions of curve represent areas where Kuiper is not allowed to turn on satellites to serve customers within the coverage area of that satellite

United States



Europe




Bringing fast, affordable broadband to unserved and underserved communities around the world
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