SpaceX Annex to non-geostationary earth station (“Gateway”) applications

Starlink Internet Services UK Limited (“Starlink”), a subsidiary of SpaceX, is seeking to enhance its connectivity capabilities and capacity in the UK.

To that end, Starlink is planning to establish additional sites in Mulberry Wharf and Harlow over the course of late 2025 and early 2026 and is applying for non-geostationary earth station (“Gateway”) licences to support these sites.

Starlink currently utilizes (and is licensed for) six gateway sites in the British Isles, located at Morn Hill, Goonhilly, Chalfont, Fawley, Woodwalton, and Wherstead. These sites currently each make use of Ka-band parabolic antennas and serve customers in the UK and the broader region. The addition of these two gateway sites will further improve and expand the coverage and availability of the satellite based broadband services provided to thousands of customers in the UK. The proposed gateways will communicate with satellites operating under the USASAT-NGSO-3X network filing, as published by the International Telecommunication Union (ITU) and coordinated in accordance with the ITU Radio Regulations.

The following information supports Starlink’s application for each of these new sites:

D1 Coexistence with existing systems

Explain how your non-geostationary earth station(s) (“Gateways”) will be able to coexist with the following:

- **Existing non-geostationary satellite systems that are licensed in the UK**
- **Non-geostationary satellite systems for which an application has been made and which has been published for comment on Ofcom’s website**
- **Other specific co-frequency earth stations registered with the ITU** **Starlink Response**

Starlink’s commercial broadband service is live in over 150 markets and is providing consumers around the world with reliable, high-speed, low-latency broadband Internet access. Starlink connects people and businesses wherever they may be, including in unserved, underserved areas and coverage “not-spots”- traditionally left on the wrong side of the digital divide. Since launching in the UK, Starlink has experienced significant subscriber growth in the UK, [redacted] indicating strong demand for increased capacity. However, as Starlink’s existing infrastructure has quickly approached capacity, Starlink has been forced to restrict access for consumers in the UK (e.g., by ending promotions and other growth activities and introducing a one-time congestion fee in lieu of putting people on a waitlist).

In order to create a fully resilient and reliable system, Starlink needs multiple gateway sites to ensure that its satellites can always establish a reliable connection with a gateway. Moreover, because the satellites use a low orbit to achieve improved space sustainability and better network performance, SpaceX’s constellation requires sufficient gateway sites on the ground to ensure connection.

Starlink’s system can coexist with other non-geostationary satellite gateways in close proximity by leveraging several important design and operational techniques. These techniques, which Starlink views as fundamental to responsible non-geostationary operations, include:

- directional antennas designed to maximize transmissions towards the SpaceX satellite system and minimize power directed elsewhere;

- multiple beams with very narrow transmit and receive beam widths;
- steerable beams on satellites, which can point in a different direction in advance of an in-line event to avoid interference;
- multiple satellites in view to provide options to serve users while avoiding in-line events;
- the ability to dynamically split spectrum (cease transmitting on certain channels) in the case of in-line events;
- low gateway height above ground level (less than two meters above ground level), to make use of shielding fences and other physical obstructions ("ground clutter") to protect adjacent users from interference

Starlink has also reviewed the list of existing NGSO system licensees on the OFCOM website to determine which systems may require a coexistence assessment (as of the date of this application). Starlink's coordination discussions are ongoing and affirm the benefits of the responsible spectrum sharing techniques described above. Starlink is committed to its good faith coordination with NGSO network earth station licensees such as Amazon Project Kuiper. Based on our understanding, these systems will operate user terminals in the Ka band, so our discussions for this spectrum have focused on the relevant gateway earth stations.

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In the case of Amazon Kuiper which operates in the Ka-band (27.5-27.8185 GHz, 28.4545-28.8265 GHz and 29.5-30 GHz), Starlink is confident that both systems will be able to co-exist with a negligible impact on each other's throughput and availability. Starlink has carried out a detailed analysis provided in the Technical Annex, which shows that even when collocated, the long-term and short-term interference between SpaceX's 40 V4 antenna and Amazon's 8 antenna sites will still be within limits. Starlink considers that this analysis is likely representative to address potential co-existence between any future Kuiper gateways.

Starlink can also confirm that we have coordination agreements with OneWeb, Kepler Communications, Inmarsat and Space Norway, as well as Telesat for both their GSO and NGSO operations. All parties remain engaged on keeping these agreements up to date, hereby ensuring system co-existence with a negligible impact on each other's throughput and availability.

D2 Coexistence with future systems

State what flexibility your Gateways have to coexist with future non-geostationary satellite systems. You should include measures you would be able to put in place if another non- geostationary satellite system were to enter the market in the future, and the expected benefits of such measures. Also state what measures future non-geostationary satellite systems could reasonably be expected to put in place to coexist with your Gateways.

Starlink Response

Starlink's system is designed in anticipation of a vibrant, competitive space landscape and implements important threshold technologies and techniques to promote coexistence. SpaceX selects low altitude orbits for Starlink satellites, driving down transmission power requirements and promoting coexistence with other systems. In NGSO systems like ours, where there are multiple satellites in view and transmitter beams are dynamic and finite, the duration and extent of interference to other operators is minimized. This is supported by the following measures:

- Starlink employs established coordination practices that align with regulatory standards. Consistent with ITU guidance and regulatory consensus, Starlink engages in operator-to-operator coordination for spectrum management, which ensures efficient spectrum use. This methodology has been successfully implemented across global markets.
- Starlink's technical approach supports effective industry coexistence through proven interference mitigation technologies including directional antennas, narrow beamwidths, steerable satellite beams, dynamic spectrum management, and low-profile installations. These capabilities provide the foundation for effective coexistence, and Starlink welcomes collaboration with other operators to support coordinated spectrum use across the NGSO sector.
- The system design incorporates flexibility and risk mitigation measures through multiple redundancy layers and adaptive capabilities that maintain service quality in various interference scenarios.

Combined with established practices, these gateways present minimal interference risk while delivering clear consumer benefits and enhancing competition without affecting existing operations.

The additional gateway capacity will enable Starlink to serve customers in areas where terrestrial broadband options remain limited, directly increasing competitive choice for consumers in underserved communities. These gateways support the UK Government's commitment to nationwide gigabit-capable coverage and digital inclusion objectives, particularly in rural and remote areas. The gateway expansion represents infrastructure investment in the UK, creating local employment and supporting the domestic supply chain.

Starlink carried out a detailed analysis (see Technical Annex) which shows that even with forty antennas, the long-term and short-term interference with the Kuiper satellite network still be within limits.

Starlink has also made effort to coordinate with other OFCOM NGSO licensees. The effort concluded in there being no other operational systems to coordinate with, and no responses to communications were received in outreach to some of the other licensees. Nonetheless, Starlink foresees no challenges with easily coordinating technical co-existence with service providers that launch commercial satellites and services in the future.

D4 Competitive Impact

Explain the impact of issuing you a licence (combined with other non-geostationary satellite system licences held or applied for by you) in terms of:

- **Any risks to competition in the UK. This may refer to the ability to coexist with other nongeostationary satellite systems.**
- **Benefits for UK customers, end consumers and/or citizens.**

Starlink Response

The gateway sites further both the interests of consumers and competition.

- **Promoting broadband access and choice for existing and new consumers:** As more satellites are launched and more users are added, Starlink ground systems require more gateway antennas and fiber bandwidth than currently available at existing sites. By expanding network capacity, the sites aim to safeguard service delivery and enhance system resilience for existing customers while enabling Starlink to serve additional consumers currently without adequate broadband options. This expansion also promotes competition by providing greater consumer choice alongside services from Network Access Associates, Kepler Communications, Amazon Project Kuiper, and other satellite and terrestrial providers, fostering a competitive market that benefits all consumers.

- **Seamless co-existence with other systems:** As noted in the response to question D2, Starlink does not require any specific geographic separation between its gateway earth stations and those of other co-frequency systems, but rather undertakes coordination assessments based on the proposed locations and operating parameters of each system. Given our excellent experience in seamlessly coordinating with other co-frequency systems around the globe, Starlink does not consider that the proposed additional gateway earth stations will have an exclusionary effect on other NGSO systems.

- **Improving quality of experience:** As of today, SpaceX is operating more than 8000 satellites in its first-and second-generation constellations. The 53-degree inclination orbit occupied by most Starlink satellites means that there are a larger number of satellites above the UK in comparison to other latitude bands. In order to provide a broadband service, these satellites must connect with gateway earth stations that are connected to the Internet. Locating the sites in close proximity to an Internet Exchange Point (IXP) and data centre significantly improves end-to-end network performance by minimising terrestrial transmission distances, reducing the number of network hops, and enabling direct peering with major content and cloud service providers. This results in lower latency, reduced jitter and packet loss, improved service resilience, and more efficient traffic routing, while also lowering transit costs and supporting local traffic exchange. For all users across the UK, this results in higher user throughput, reduced congestion, and improved quality of experience for bandwidth-intensive and latency-dependent applications in video conferencing and real-time voice platforms, online and cloud-based gaming, on-demand and live entertainment content, enterprise and other cloud-based applications, distance learning, telemedicine, emergency and public safety communications, etc.
- **Enabling Network Resilience:** Additionally, Starlink plans its gateway earth stations for weather diversity and resilience. This means that Starlink requires a sufficient variety of locations such that if one site is experiencing connection problems due to weather, other sites can provide back-up. For example, during Storm Eunice, Starlink was able to provide service throughout the UK despite record-breaking adverse weather conditions. We attribute Starlink's resiliency during the storm to the geographic diversity Starlink has at other gateway sites in the region. This ensured that whenever the weather was the worst in one area, there was another site that was available. Additionally, in the rare event that a gateway site is taken down due a power or fiber outage, multiple gateway sites are able to serve as a redundancy to ensure

that Starlink can continue to provide quality service to customers in the UK and throughout Europe. Geographic coverage optimisation, load balancing, and future-proofing anticipated growth are additional factors which would benefit the network with these and sites.

In summary, Starlink estimates that with additional gateway sites, it will be able to meet demand, and make available the weather diversity and network resiliency needed to provide high-speed, low-latency Starlink services to consumers in the UK. The latency benefits, to all UK consumers, will be possible from a reduction in the absolute latency and the variation in jitter associated with improvements in backhaul capacity and the positive impact on congestion and transmission of backhaul content.

Technical Annex

Preamble:

SpaceX ran two dynamic simulations - downlink and uplink – to assess the worst-case aggregated interference incurred upon Kuiper system due to the Starlink gateway (GW) site with 40 antennas, conservatively assuming both Kuiper and Starlink GW sites were collocated.

The gateway earth station planned for Harlow is currently anticipated to host a combination of Eight (8) V3 and Thirty-two (32) V4 antennas. The gateway earth station planned for Mulberry Wharf is expected to host Forty (40) V4 antennas and the station will operate within the bounds of the license, with *N_CO* 8+32 in the Ka Band as covered in this analysis. As such, this analysis applies to Mulberry Wharf as well.

Orbital Configurations:

SpaceX simulated co-frequency aggregated interference to the Kuiper system (Table A-1) from the Starlink Generation 1 (Table-A2) and Generation 2 system (Table A-3) assuming collocated GW sites of both systems at Bude, England (51.5080°N, -0.0952°E). The satellite orbital configuration of Kuiper is the same as Kuiper used in its submission to Ofcom. For Starlink, 4408 satellites and an example of the current FCC-approved 7500-satellites orbital configuration is used for Generation 1 and 2, respectively. Generation 1 and 2 satellites will communicate simultaneously with 8 and 32 Starlink GW antennas, respectively.

Orbital Altitude (km)	590	590	610	630
Inclination (deg)	33°	30°	42°	51.9°
Orbital Planes	782	1	1292	289
Satellites per Plane	1	2	1	4

Table A-1. Kuiper Orbital Parameters

Orbital Altitude (km)	540	550	560	560	570
Inclination (deg)	53.2°	53°	97.6°	97.6°	70°
Orbital Planes	72	72	6	4	36
Satellites per Plane	22	22	58	43	20

Table A-2. Starlink Generation 1 Orbital Parameters

Orbital Altitude (km)	525	530	535	535
Inclination (deg)	53°	43°	33°	33°
Orbital Planes	28	28	24	4
Satellites per Plane	120	120	28	27

Table A-3. Starlink Generation 2 Orbital Parameters

Simulation Setup:

To demonstrate the interference that Starlink GW system could cause, SpaceX designed its simulation steps to allow use of dual interference metrics as suggested by OFCOM non-GSO satellite earth stations licensing guideline 2.10—increase in unavailability for short-term interference and degradation of time-averaged spectral efficiency for long-term interference.

Regarding the simulation methodology, SpaceX performed each of the time-domain simulations at one second time steps over 1-million-time steps. At each time step of a simulation, both the C/N and carrier-to-noise plus interference ("C/(N+I)") values are calculated, for both Kuiper downlink and uplink, where the Starlink's GW system is the interference source. For the C/N and C/(N+I) values calculated at a time step, SpaceX incorporates all atmospheric attenuation characteristics (see Recommendation ITU-R P.618 and references therein) that both systems may experience, including degradation due to atmospheric gases, rain, cloud cover, and scintillation. Each calculated C/N and C/(N+I) value at a time step is recorded in an array, where these paired values are accumulated over the simulation duration. These arrays for Kuiper downlink and uplink operations were then sorted and processed into cumulative distribution functions ("CDFs"), which allow for calculation of short-term and long-term interference of the four cases described further below.

For each case, four figures of merit are provided to show the impact of interference from Starlink's proposed GW expansion system into Kuiper's service. The first two are the baseline availability percentages and availability percentages with Starlink's GW in operations at objective C/N of 0 dB as well as the graphical figure from which these values were derived, which demonstrate how interference impacts Kuiper's C/N. The third is the reduction in availability due to Starlink's GW, which is the difference between Kuiper's baseline availability percentages and availability percentages with Starlink's GW at this objective C/N. Finally, the fourth is the degradation of Kuiper's time-averaged spectral efficiency, showing Kuiper's throughput loss due to Starlink's GW.

Assumptions:

SpaceX assumes that both the Starlink and Kuiper systems maintain constant power flux density and Effective Isotropic Radiated Power ("EIRP") for downlink and uplink transmissions, respectively. SpaceX also assumes complete bandwidth overlap and a single receive polarization to enable analysis on a per-Hertz basis without the potential for discrimination. The interference simulations use a random pointing strategy as a proxy for simulating satellite selection for Kuiper systems. For Starlink, a topology-based empirical distribution is used for satellite selection simulation.

Parameters and Results:

Table A-3 to A-7 and Figure 1 and Figure 2 specify the parameters, provide the analysis summaries, and display the analysis graphically for each direction. The parameters for each case are specified just before that case summary and graphical analysis are presented.

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[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]

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Baseline Availability (%)	**Availability with STARLINK (%)**	**Difference in Availability (due to STARLINK GW) (%)**	**Avg. Throughput Degradation (due to STARLINK GW) (%)**
99.9942	99.9936	0.0005	1.752

Table A-5. Downlink Analysis Summary

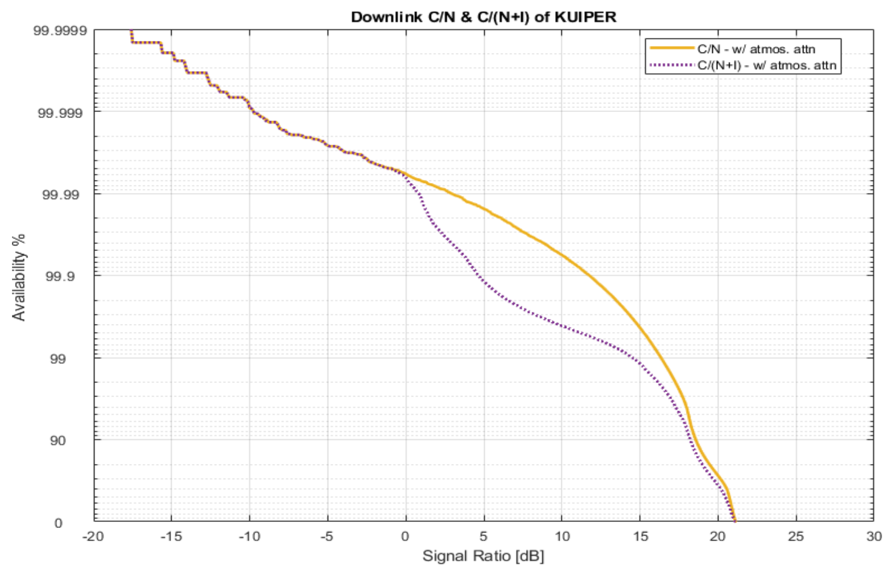

Figure 1. Downlink: C/N & C/(N+I) of Kuiper System

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Baseline Availability (%)	Availability with STARLINK (%)	Difference in Availability (due to STARLINK GW) (%)	Avg. Throughput Degradation (due to STARLINK GW) (%)
99.9844	99.9729	0.0113	0.7156

Table A-7. Uplink Analysis Summary

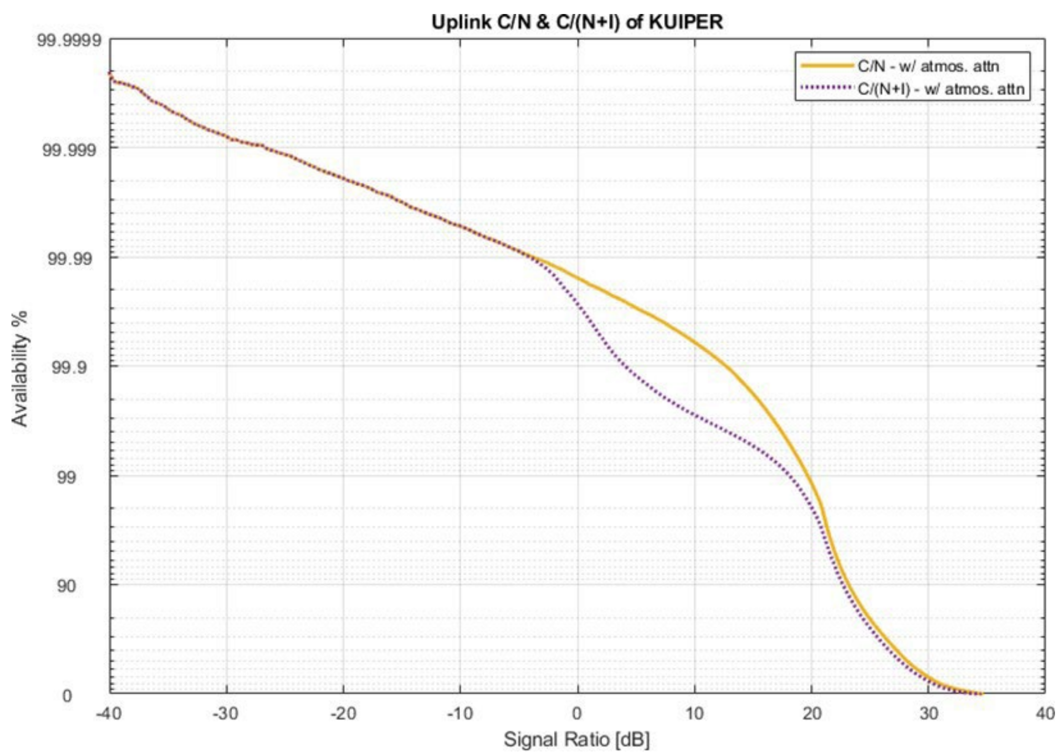

Figure 2. Uplink: C/N & C/(N+I) of Kuiper System