Sallye Clark
202 434 7405
sclark@mintz.com

701 Pennsylvania Avenue, NW
Suite 900
Washington, DC 20004
202 434 7300
mintz.com

MINTZ

July 6, 2020

Jose P. Albuquerque
Chief, Satellite Division, International Bureau
Federal Communications Commission
445 12th Street, SW
Washington, D.C. 20554

Re: IBFS File No. SAT-PDR-20200413-00034; Call Sign: S3065

Dear Mr. Albuquerque:

We are providing the following response to the questions posed in your letter of June 3, 2020, seeking additional information regarding the AST&Science, LLC ("AST") request for access to the U.S. market.

1. In accordance with Sections 25.102(a) and 25.114(c)(4) and (7), for AST's proposed service links, please specify the exact frequencies and directions of transmission within the 617-960 MHz, 1710-2200 MHz and 3410-3980 MHz bands on which AST intends to operate. Also, given that none of these frequencies are allocated to the Mobile Satellite Service, please provide a waiver request and justification for each of the frequencies being requested. All justifications should include a detailed technical sharing analysis, including all assumptions, with the other services allocated on those frequencies, with a particular focus on operations in the U.S. (including possessions and territories) and adjacent countries that may be impacted by transmissions by the satellite to U.S. earth stations. Also, please specify if AST will accept all interference it may receive on these frequencies from other international system(s) operating in accordance with the International Table of Frequency Allocations.

With regard to Mobile Satellite Service ("MSS") offerings, SpaceMobile can transmit (downlink) on 617-960 and 1805-2360 MHz and receive (uplink) on 663-915 and 1710-2320 MHz. Currently, based on expectations of partner agreements, AST intends to operate in the U.S. on the PCS (LTE Band 2), AWS-1 (LTE Band 4), AWS-3 (LTE Band 66) and WCS (LTE Band 30) frequency bands. These agreements would allow SpaceMobile to receive (uplink) on the portions of 1710-1780, 1850-1910, and 2305-2320 MHz and transmit (downlink) on the portions of 1930-1990, 2110-2180, and 2350-2360 MHz that correspond with a carrier's authorized channels within any particular band.

With regard to operations to mobile handsets, the Commission may waive its rules for good cause shown.[1/] In particular, waiver is appropriate when special circumstances warrant deviation from the rule, and grant of the waiver is in the public interest.[2/] Here, AST seeks waiver of the U.S. Table of Frequency Allocations[3/] to provide satellite service to mobile handsets in the mid-band frequency bands discussed above, which service would only commence upon express authorization of the relevant license holder. Granting this waiver will be squarely in line with the Commission's well-established flexible use spectrum management policies.[4/]

A technical sharing analysis is attached. This demonstrates that, as necessary, **AST could agree as a condition of authority granted by the FCC to protect other users down to a level of -20 dB I/N**, unless AST has an agreement with other users to operate at a different level of interference. The attached analysis also demonstrates how AST will successfully manage coexistence between terrestrial users and its system.

With regard to co-channel coexistence, the Commission previously has found that when there is a single operator controlling both terrestrial and satellite operations within the same frequency band so that the entity "possesses the singular ability to design, integrate and direct the operations of both terrestrial and satellite services," such a situation serves as a unique circumstance that would justify departure from the Commission's rules.[5/] While this precedent involved allowing AWS-4 operations in MSS spectrum, the same conclusion can apply to the present situation where AST seeks to provide MSS services in cellular bands. In both situations, co-existence can be managed by the spectrum holder managing use of its frequencies. Here, AST would have cooperative agreements with terrestrial operators for these purposes and would not provide MSS operations in the requested channels absent such an agreement.

Additionally, AST demonstrates in its analysis that for a given licensed market area or geographic area its transmissions can be maintained within the area and protect users operating in the adjacent areas, such as where AST's carrier partner does not hold the license for the same channels – down to an I/N level of -20 dB. In instances where there are federal users grandfathered to use portions of a frequency band (*e.g.*, 1755-1780 MHz/2155-2180 MHz), as necessary AST will coordinate through NTIA prior to using those frequencies.[6/]

[1/] 47 C.F.R. § 1.3; *Northeast Cellular Tel. Co. v. FCC*, 897 F.2d 1164 (D.C. Cir. 1990); *WAIT Radio v. FCC*, 418 F.2d 1153 (D.C. Cir. 1969).

[2/] *Northeast Cellular* at 1166.

[3/] 47 C.F.R. § 2.106.

[4/] *See DISH Network Corporation Petition for Waiver of Section 27.5(j) and 27.53(h)(2)(ii) of the Commission's Rules and Request for Extension of Time*, Memorandum Opinion and Order, DA 13-2409 at ¶ 19 (Dec. 20, 2013) ("DISH Waver").

[5/] DISH Waiver at ¶ 20.

[6/] AST recognizes that in 2120-2180 MHz, BRS licensees are grandfathered until December 2021. 47 C.F.R. § 2.106, NG 41. AST does not intend to operate on these frequencies until after that date.

Potential acceptable interference from SpaceMobile downlink (space-to-Earth) transmissions can be separated into four main scenarios:

a) Co-channel interference caused to terrestrial transmissions in areas (within the US or within other countries) adjacent to those where AST's U.S. associate operators are licensed to operate in the same frequency bands;
b) Adjacent channel interference to terrestrial transmissions licensed in areas overlapping those licensed to AST's U.S. associate operators;
c) Adjacent channel interference to terrestrial transmissions in areas (within the U.S. or in other countries) adjacent to those where AST's U.S. associate operators are licensed to operate, but where there are no operations co-frequency with SpaceMobile; and
d) Adjacent channel interference to terrestrial transmissions in areas (within the U.S. or in other countries) adjacent to those where AST's U.S. associate operators are licensed to operate and also operate co-frequency with SpaceMobile.

The protection criterion assumed by AST for co-channel interference is the worst case protection criterion used in ITU Reports addressing protection of IMT (namely Report ITU-R M.2039-3-2014 and Report ITU-R M.2292-0-2013), which correspond to an I/N level of -20 dB. The attached technical analysis demonstrates how AST could, if necessary, meet this protection criteria for all of these scenarios.

Finally, with regard to whether AST is willing to accept interference from international systems, AST will accept all interference it may receive on these frequencies from other international terrestrial mobile system(s) operating in accordance with the International Table of Frequency Allocations.

2. **Please identify any terrestrial operators with which AST has an agreement to provide service and the frequencies covered by any such agreement.**

AST currently has a Teaming Agreement in place with AT&T and is finalizing a Memorandum of Understanding with AT&T that details and describes roles and responsibilities, commercial framework, and the frequencies that will be used by both the BlueWalker 3 test satellite and the commercial SpaceMobile constellation. Currently, AST has an experimental license that permits the use of AT&T's Band 5 spectrum for testing on its first test satellite, BlueWalker 1.

The table below details the AT&T frequencies to be used by SpaceMobile in the U.S.

No.	Uplink - Rx (MHz)		Down Link - Tx (MHz)	
1	1710.0	1780.0	2110.0	2180.0
2	1850.0	1910.0	1930.0	1990.0
3	1710.0	1755.0	2110.0	2155.0
4	2305.0	2310.0	2350.0	2355.0

5	2310.0	2315.0	2355.0	2360.0
6[7/]	2315.0	2320.0	2345.0	2350.0

3. **As part of its petition, AST provided the Papua New Guinea license for a single satellite (Blue Walker 1) in a polar orbit at 698 km with an expiration date of November 13, 2023. However, AST's petition requests access to the U.S. market for a constellation of 243 satellites in 16 orbital planes at altitudes between 725-740 km. Please indicate whether a Papua New Guinea license has been issued for the satellites for which market access is requested, and, if so, please provide a copy.**

Yes, Papua New Guinea has issued a license for the SpaceMobile constellation, a copy of which is attached.

4. Please confirm which country will register all satellites in AST's constellation with the UN, and identify any pre-conditions for registration and any supervisory activities that will be carried out by that country.

Papua New Guinea, as AST's space segment licensing authority, is expected to register the BW3 and SpaceMobile constellation with the UN. Papua New Guinea, while not a signatory to the Registration Convention, has registered satellites for other operators in accordance with the Registration Convention. AST will comply with the obligations of the Registration Convention and all conditions and requirements imposed by Papua New Guinea. In addition, AST is pleased to advise the Commission on actions and status regarding Registration Convention activities as appropriate.

5. **AST states that it will monitor TT&C operations from its system control center located in Midland, Texas, and will conduct routine TT&C from international locations distributed worldwide. Please identify the facilities outside of the United States from which AST will conduct TT&C and the owners of these facilities. Please also clarify the status of contracting with each facility. In addition, please identify any contractual provisions that guarantee the ability to transmit high-priority messages, such as commands for cessation of operations i.e. does the contract provide for something more than the lowest tier of use, preemptable by other satellites using the facility, and contain no limitations that would significantly delay the time necessary to cease operations of any of AST's satellites?**

AST is in the process of finalizing a contractual agreement with KSAT to use its global S band and UHF band services for TT&C. The locations where AST will have access to KSAT's services are: Svalbard, Norway; Troll, Antarctica; Puertollano, Spain; Athens, Greece; Los Angeles, USA; Hartebeesthoek, South Africa; Awarua, New Zealand; Punta Arenas, Chile;

[7/] Unpaired channels.

Mauritius; Tomso, Norway; Inuvik, Canada; Brostadbotn, Norway; Hawaii, USA; Panama City, Panama; Singapore; and Bangalore, India.

As part of the contract that is being negotiated with KSAT, AST will have the guarantee of sending real-time transfer of commands/telemetry to/from the spacecraft and the transfer of payload data to/from AST&Science's NOC. KSAT supports antenna scheduling via a RESTful based API. The KSAT API also can be used for retrieving antenna availability, transferring ephemeris data, monitoring passes in real time, and receiving post-pass reports. Most messages will be scheduled in advance; however, AST will have the ability in urgent situations to transmit high-priority messages. KSAT operates two 24/7 Network Operations Center to manage such urgent requests.

In terms of preemption by other satellites using the facilities and limitations in the contract, the contract does not contain any provisions that would cause significantly delay in the time necessary to cease operations of any of AST's satellites. KSAT can support passes on an urgent basis through request *via* its TNOC (or if more than 15 minutes from AOS then the API scheduler can be used). In the case of a spacecraft emergency, upon receipt of a memo from AST to KSAT declaring the spacecraft emergency, KSAT will then endeavor to provide as much contact time as possible, including requesting satellite owners who hold scheduled passes that conflict with the emergency spacecraft to cede to support the emergency.

6. What is the expected mission lifetime per satellite? How many satellites are expected to be launched over a 15-year period beginning with the deployment of the first satellite in the system?

As noted in footnote 20 of AST's Legal Narrative, the anticipated lifetime for each satellite is 7-10 years. The total number of satellites, including replacement satellites, that AST expects to launch over a 15-year period is 260.

7. **AST notes that each satellite will have an on-board electronic propulsion system that will be used for collision avoidance. Please specify if the propulsion system will be used also to maintain the orbits. If yes, please specify the orbital tolerance with which the apogee, perigee and inclination will be maintained.**

Yes, periodic orbit maintenance (re-boost, phasing) of the spacecraft will be required, using the propulsion systems. The apogee and perigee of the spacecraft within each orbital plane will be maintained within +/- 2 km of their target altitude unless tighter constraints are required. Inclination will be maintained to within +/- 1 deg of the target value.

8. Please provide additional information about the reliability of the propulsion capabilities of AST satellites, including any information concerning flight heritage. In additional, using the NASA Debris Assessment Software or a higher fidelity model, please provide the in-orbit collision risk for satellites that lose propulsion capability at the operational altitude,

assuming a 10% failure of the on-board propulsion system. Please also provide the orbital lifetime for a satellite that fails and has no propulsive capability at the operational altitude.

AST will launch a test satellite, the Blue Walker 3 ("BW3") prior to the launch of the constellation. This will provide AST with information concerning flight heritage because the propulsion unit for the BW3 is the same as the units used for the constellation. In addition to the electric propulsion system, AST has incorporated an attitude and orbital control system ("AOCS") with full redundancy and flight heritage that can be used to orient the spacecraft into a high-drag configuration. The orbital lifetime for a satellite that fails and has no propulsive capability at the operational altitude can be varied depending on the orientation of the spacecraft using the AOCS components. With a failed propulsion system, it will take less than 25 years to deorbit by using the high-drag orientation of the spacecraft.

Using the NASA ORDEM 3.1 software, the surface area flux of objects greater than 1 cm at an altitude of 700 km is 1.5E-5 /m^2/yr. The area of the array is 900 m^2, so the probability of an impact occurring in less than 10 years is 13.5% if no propulsion were available. Assuming 10% failure probability of the propulsion, the probability of a collision is then 1.35%. However, if a sufficiently high collision probability with a larger object existed, the end-of-life pitch-up maneuver would allow for the satellite to be moved in-track by as much as 740 m within a 2-day period during a solar minimum, and by as much as 7.4 km within a 2-day period during a solar maximum.

9. AST notes that sufficient propellant will be maintained throughout the mission in order to provide the deorbit maneuver at end-of-life. This maneuver will be used to lower the satellite to an altitude of approximately 400 km, at which point the array can be pitched with magnet torquers that can control the exposed surface array, effectively throttling the drag. Please provide greater detail concerning the measures AST will take to avoid collisions with large objects. Please include within this discussion any specific measures with respect to crewed space stations, including the ISS and visiting vehicles, as the satellites pass through the region in which such spacecraft operate.

The constellation satellites position(s) will be known to <10 m using onboard GPS and batched least squares orbit determination methods; thus any uncertainty in the time or distance of closest approach with a secondary object will be driven by its state uncertainty. Above 400 km, the onboard thruster is capable of moving the satellite in-track by 15-25 km within a 24 hr period if the probability of a collision exceeds an acceptable threshold. This same control authority exists using drag control starting at an altitude of around 450 km during a solar minimum (600 km during a solar maximum), and increases by a factor of 2 for every 30 km reduction in altitude. The state vectors of crewed space stations (*e.g.*, the ISS) and visiting vehicles are known very accurately, so the collision probability will drop off very rapidly outside of a predicted close approach distance of about 50 m. Given a collision probability that exceeds the acceptable threshold, the time required to put sufficient distance between the objects at the time of closest approach will be relatively short, and certainly less than a day.

10. Regarding the semi-controlled re-entry of AST's satellites, please provide information on any approach to altering the ground track of the satellite, including any criteria used in deciding whether to alter the satellite's trajectory to minimize casualty risk.

Using an atmospheric density model with uncertainty (the NRLMSISE-00 model), the impact location of any surviving parts of the spacecraft at re-entry will be continuously evaluated with an uncertainty ellipse. As the satellite falls farther into the atmosphere, the uncertainty in the density will decrease, as will the uncertainty ellipse for re-entry. If the center of the re-entry ellipse shifts too far from the desired location, the rotation of the array so that it is edge-on to the velocity vector will effectively halt the de-orbit process (reducing the drag force by a factor of 900 for the constellation), allowing the center of the re-entry ellipse to shift along the ground track to the desired location. When the desired projected re-entry location is reached, the array is again rotated back to the high-drag configuration and the de-orbit continues.

11. AST states that "of the debris that does not demise before reaching the surface, those substantially contributing to the total casualty area are well below the 15 Joule kinetic energy requirement. Those components above the 15 Joule requirement contribute a total debris casualty area characterized by the 1:19,700 casualty risk assessment." Please provide a complete list of components (size, mass, and material type) expected to survive re-entry, along with the impact energy for each component. Please provide information concerning any steps taken to design the spacecraft to demise completely upon re-entry. Please also provide information on any indemnification arrangements concerning re-entry casualty risk with Papua New Guinea, with the country registering the satellites with the United Nations, or with any other country exercising a supervisory role concerning re-entry.

The attached Orbital Debris Response provides a table of components that will survive re-entry, as requested. AST has revised the casualty risk assessment as a result of design changes that have occurred since the analysis was last run, and that is included in the table. In terms of steps to ensure demise on re-entry, the spacecraft materials were selected in order to reduce mass. By reducing the mass, the likelihood of demise increases. This can be done through manufacturing structural elements in a honeycomb lattice as opposed to solid aluminum, something that is currently in the design iteration process.

The incorporation of the electric propulsion system and redundant AOCS components ensures the means of controlling the re-entry procedure. With this capability, the spacecraft can be deorbited to a remote location, eliminating the risk of human casualty. This analysis further affirms that in the event the spacecraft deorbit cannot be controlled, that the casualty risk assessment meets all requirements for debris that does not demise on re-entry.

AST is required by Papua New Guinea, under the terms of its space segment license, to obtain and maintain liability insurance in an amount not less than that required by the insurer and Launching State for the SpaceMobile network. Such insurance will name Papua New

Guinea as an additional insured. AST is also required to indemnify and hold Papua New Guinea harmless from any claims by a third party for any amount in excess of the third party liability insurance procured by AST.

Please let us know if you have any additional questions.

Sincerely,

/s/ Sallye Clark
Sallye Clark
Laura A. Stefani
Attorneys for AST&Science, LLC

Attachments:

Technical Sharing Analysis
PNG License
Orbital Debris Response

Appendix: Technical Sharing Analysis

This document was prepared to respond to the FCC's request for additional information regarding the ability of AST's SpaceMobile system to share with other services. AST has prepared a sharing study of AST's SpaceMobile system, using LTE Band 4 as an example, with the other services allocated on those frequencies. This study, and the other approaches to spectrum sharing and interference management discussed herein, demonstrate that SpaceMobile has sufficient means to manage potential interference, both co-channel and adjacent channel, with authorized users operating within the U.S. (including possessions and territories) and in adjacent countries that may be impacted by transmissions by the SpaceMobile.

1 Overview of SpaceMobile Approaches for Sharing and Interference Management

SpaceMobile's use of the selected LTE frequencies for satellite connectivity to mobile handsets will only occur with permission of its partner spectrum holders and will follow the terms of the agreements with those partner spectrum holders. AST will use frequencies that are either national wide or that cover a wide geographic area. As such, much of the co-channel interference within the coverage area(s) will be a matter of self-interference and will be managed within the SpaceMobile system; such techniques could include using frequency selection (reuse),Inter-Cell Interference Coordination (ICIC), beam control, power control, and other methods, when and if necessary depending on the operational case. Beyond the self-interference management, AST has considered the following sharing/interference scenarios:

a) Adjacent channel interference Case 1: Sharing the same coverage/market area with other users operating on adjacent channel frequencies; and
b) Adjacent channel interference Case 2: Potential interference to users operating in neighboring market areas or countries which are operating on different channels from SpaceMobile.

   In both of these cases, the sharing approach is the same, and interference to other systems can be limited to acceptable levels (with the ability to meet ITU protection criteria discussed below) because:
   - SpaceMoible's phased array power amplifier (PA) and the associated Digital Pre-Distortion (DPD) will ensure at least 45 dB Adjacent Channel Leakage Ratio (ACLR) from any SpaceMobile beam
   - Given the beam peak maximum in-band channel C/N around 19 dB, as shown in Table 2, the downlink link budget, the satellite total adjacent channel (out of band) interference within an active beam coverage area will produce I/N < -20 dB. This means that SpaceMobile will cause no unacceptable interference to systems using adjacent frequencies within the SpaceMobile service area
   - The satellite adjacent channel (out of band) interference outside an active beam coverage could be even lower (i.e. lower than -20 dB I/N) due to lower sidelobe gain levels

c) Operations on the same frequency as users located in adjacent/neighboring market areas and/or adjacent countries:

- Cross-border interference potential varies with satellite position and therefore management of interference is a matter of system operations.
- In case there is a coordination agreement with the neighboring country or region, potential interference can be managed via
    - Using different frequencies between cross border countries/regions so that interference management becomes a matter of adjacent channel interference, *i.e.* Scenario B discussed above.
    - Using ICIC through eNodeB coordination among SpaceMoble and any potentially affected cross border terrestrial system
    - Beam and beam power controls
- In situations where there is no coordination agreement with the neighboring country/region, any combination of the following strategies will be used to ensure that the potential interference to other users will be down to I/N < - 20 dB:
    - Turning off beams covering the cells immediately next to the border
    - Reducing the active beam power level of the beams transmitting near the border and at low elevation angle (with capacity reduction)
    - Shifting the beam boresight slightly inward from the cell center only for the beams transmitting near the border.

The following section will focus on the sharing study for Scenario c, assuming there is no agreement with the neighboring country/region regarding the sharing, as the sharing in scenarios a and b are straightforward.

2 Co-Channel Cross Border Interference Analysis

2.1 System Characteristics Assumptions

The following assumptions are used in the analysis

Table 1 Assumptions for Example Sharing Analysis

Satellites	
Frequency Band	Middle Band: 1710 to 2200 MHz
Satellite Orbit	LEO with 730 km altitude
Number of active beams	560 per satellite, each with 10 MHz channel
Nominal Total Radiated Power (TRP) to an active beam	~11.5 dBW
TRP control range per beam	At least 25 dB
Minimum service elevation angle	30° when the constellation is used in SISO over a given region 20° in general
Cell diameter covered by each beam	24 km
Beam tracking	Each active beam tracks a given cell on ground when passing the coverage area
Nominal beam C/N	~19 dB at beam peak (with 11.5 dBW/10MHz TRP), Table 2
UE	
Noise figure	9 dB
Antenna gain	0 dBi

Cross border interference level for sharing [1][2]	*See* footnotes below
I/N	< -6 dB, -10 dB, -15 dB, or -20 dB

[1] *See* Report ITU-R M.2039-3-2014: Characteristics of terrestrial IMT-2000 systems for frequency sharing/ interference analyses
[2] *See* Report ITU-R M.2292-0-2013: Characteristics of terrestrial IMT-Advanced systems for frequency sharing/interference analyses

An illustration of the cross-border interference management conducted by turning off the beams near the border and an example of the geographic areas for the analysis are provided in the following figures.

AST will commit to maintaining a minimum geographic separation between its authorized service area and adjacent service areas, whether in the U.S. or in adjacent countries or regions, referred to herein as the "minimum gap", where the service beams will be turned off to ensure no unacceptable interference to the adjacent countries, regions or market areas beyond the required or agreed upon protection criteria.

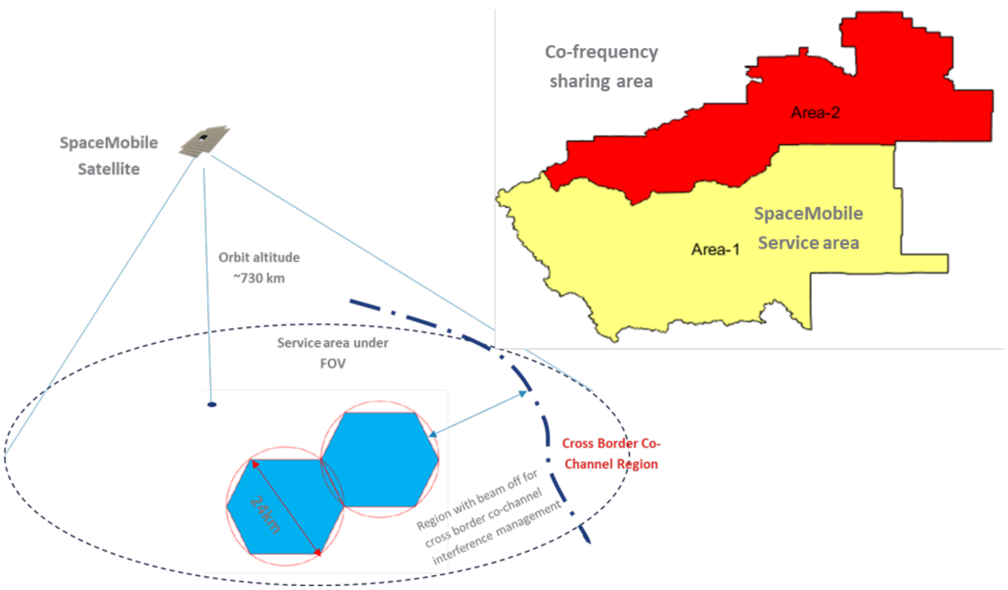


Figure 1 Cross border interference management and an example adjacent market area used for analysis

2.2 Interference Variation with Cell Elevation Angle

Since SpaceMobile is a LEO satellite system with satellite beams tracking specific ground cells in the satellite Field of View (FoV), the elevation angle of a given cell viewing the satellite will vary as the satellite is flying over the service area. The elevation angle range will be from the minimum service elevation angle (20^o or 30^o depending on the service) up to 90^o when the cell is directly under the satellite.

The digital beam former on a SpaceMobile satellite selects different section of the satellite phased array antenna aperture to form the beam that tracks a cell at different elevation angles. The lower the cell elevation angle, the larger the selected aperture size (until it reaches the limit of the phased array antenna maximum aperture size). Examples of the antenna aperture selections based on the cell elevation angles and the corresponding beam patterns formed through the Chebyshev algorithm that track the cell are provided in Figure 2.

As can be seen, the beam-width narrows as the elevation angle decreases. The narrowed beam-width results in a higher antenna beam gain that compensates the increased path loss at the low elevation angle. This approach produces a near consistent C/N at the beam peak regardless the cell elevation angle as long as the cell is within the satellite service field of view. This is demonstrated in the downlink link budgets shown in Table 2.

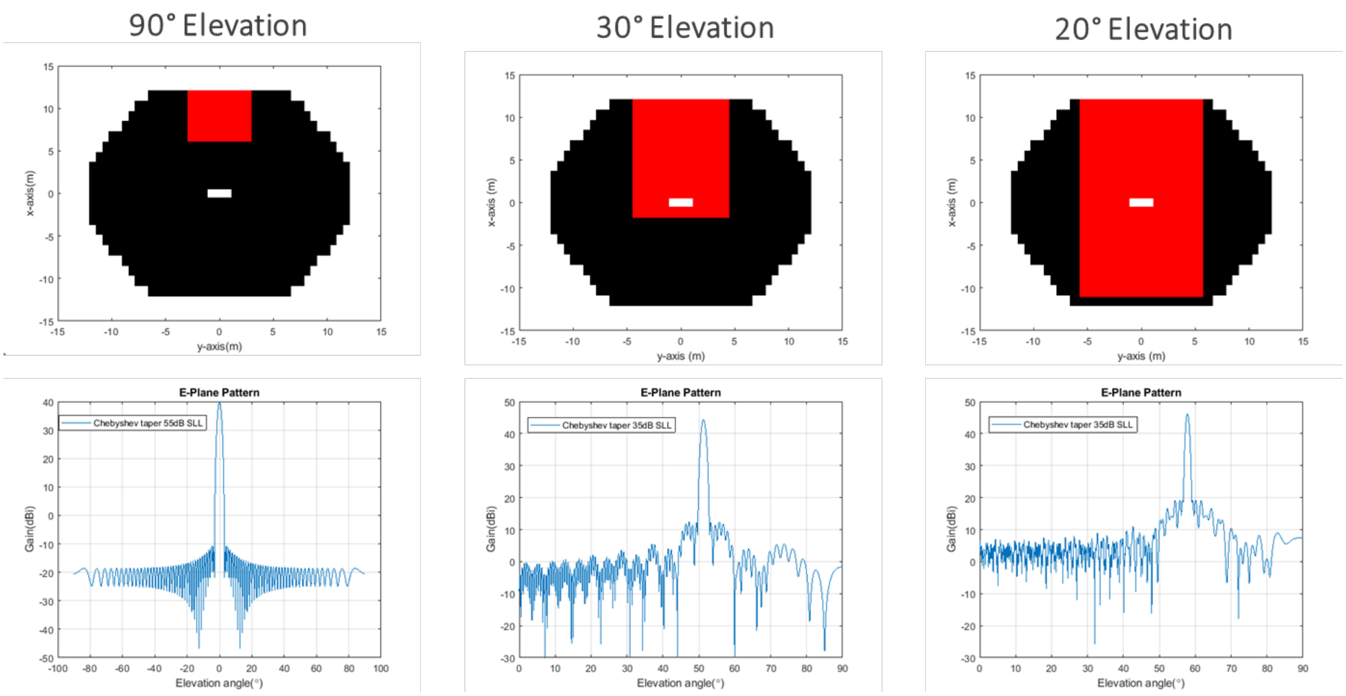


Figure 2 Satellite Phased Array antenna aperture selection for forming a beam tracking a cell at different elevation angle and the corresponding beam pattern

Table 2: SpaceMobile Downlink Beam Peak C/N Budget

Downlink	**Satellite to UE**			
Parameters	**90° Elevation**	**30° Elevation**	**20° Elevation**	**Unit**
Total Channel Bandwidth	10000	10000	10000	kHz
Carrier bandwidth	9000	9000	9000	kHz
Number of Carriers per Beam	1	1	1	
Downlink Power per Carrier	13.0	13.0	13.0	dBW
Output loss	1.50	1.50	1.50	dB
Total Radiated Power per Beam	11.50	11.50	11.50	dBW

Space Station Transmit Antenna Peak Directivity	39.9	44.4	46.3	dBi
Antenna Total Loss	1.00	1.00	1.00	dB
Space Station Transmit Antenna Peak Gain	38.9	43.4	45.3	dBi
Downlink Peak e.i.r.p./Carrier	50.4	54.9	56.8	dBW
Elevation angle	90	30	20	°
Transponder Frequency	2115.0	2115.0	2115.0	MHz
Path length	730.0	1284.6	1639.7	km
Downlink path loss	156.2	161.1	163.2	dB
Atmospheric Loss	0	0	0	dB
UE Rx Antenna Gain	0.0	0.0	0.0	dBi
UE Rx Noise Figure	9.0	9.0	9.0	dB
UE Antenna Noise Temperature	200	200	200	K
UE Ambient Temperature	290	290	290	K
UE Rx System Noise Temperature	2213.6	2213.6	2213.6	K
UE Receive G/T	-33.5	-33.5	-33.5	dB/K
Down Link Beam Peak C/N	19.8	19.3	19.2	dB

Due to the beam scanning distortion and the projection on the curved earth surface, the beam coverage area varies with the elevation angle. The lowest elevation angle beam drives the cross-border interference.

Figure 1Figure 3 (a), (b), and (c) show the S/N and I/N variations in terms of the distance from the cell center covered by a beam with 90^{o} elevation angle, 30^{o} elevation angle, and 20^{o} elevation angle, respectively. The minimum required distance between the edge of the SpaceMobile service area and the border of an adjacent country/region varies with the minimum service elevation angle and maximum sidelobe gain level.

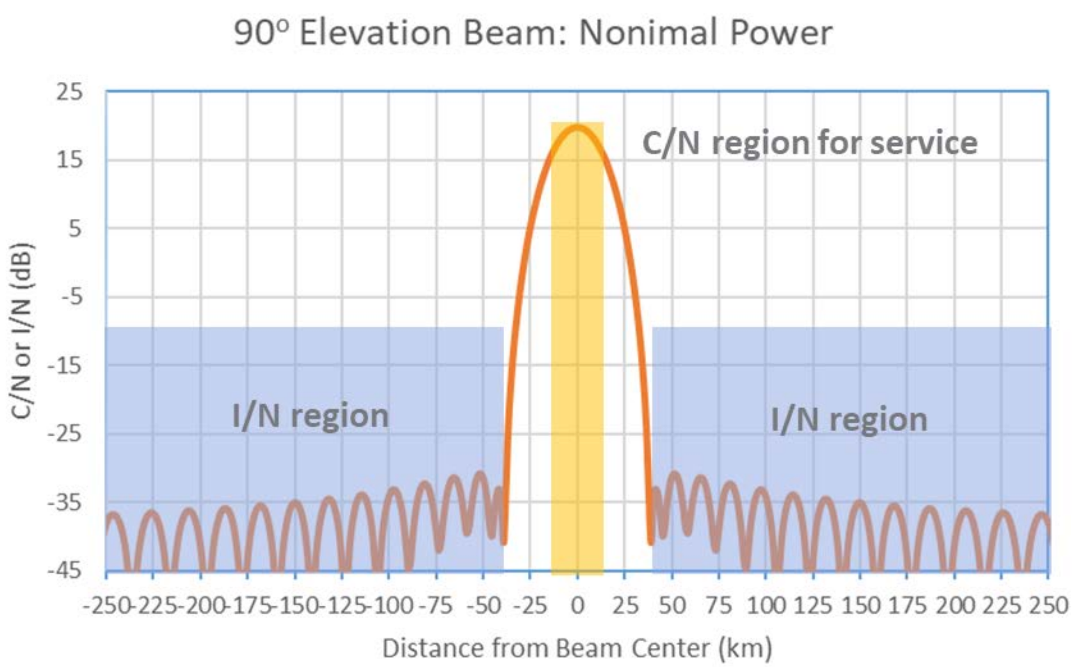
For example, for 30^{o} minimum service elevation angle, by reducing the nominal power by 7 dB and keeping the edge of the SpaceMobile service area up to 63 km away from the border of the area to be protected, an I/N value of up to -20 dB could be assured.

For 20^{o} elevation angle, the nominal power needs to be reduced by 12 dB and the edge of the SpaceMobile service area needs to be kept up to 95 km away from the border of the area to be protected, in order to ensure the same I/N value.

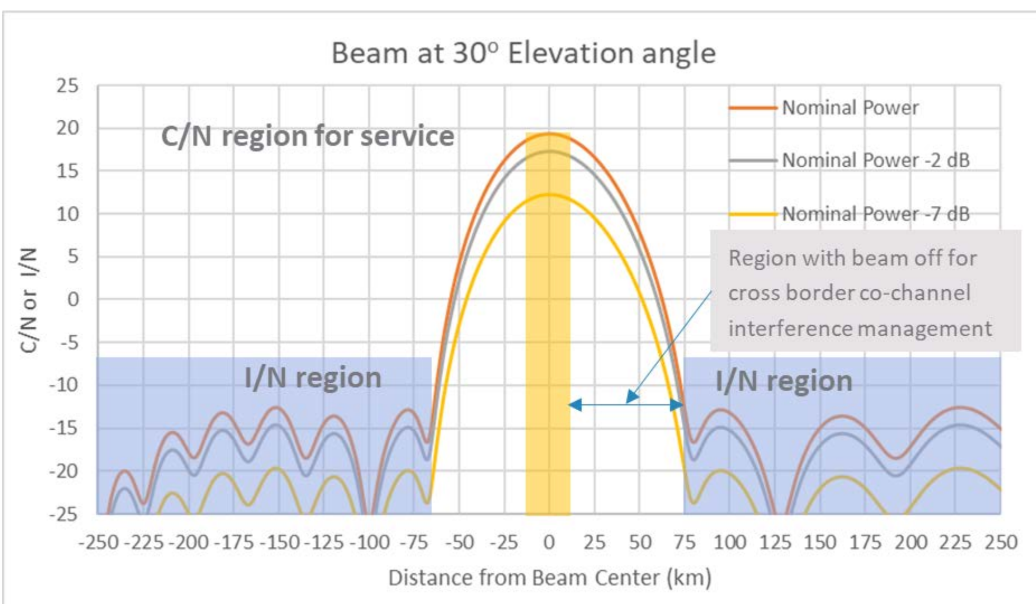
For other elevation angles, the same procedure will be followed to ensure consistent protection to the required level.

The back off to reach different cross-border I/N values is summarized in Table 3. As can be seen, SpaceMobile is capable to control the potential for the cross-border interference down to a level of -20 dB I/N. These controls can be performed in orbit by the on-board digital beamformer continuously based on the elevation angle change of the service area and the coordinated cross-border interference level.

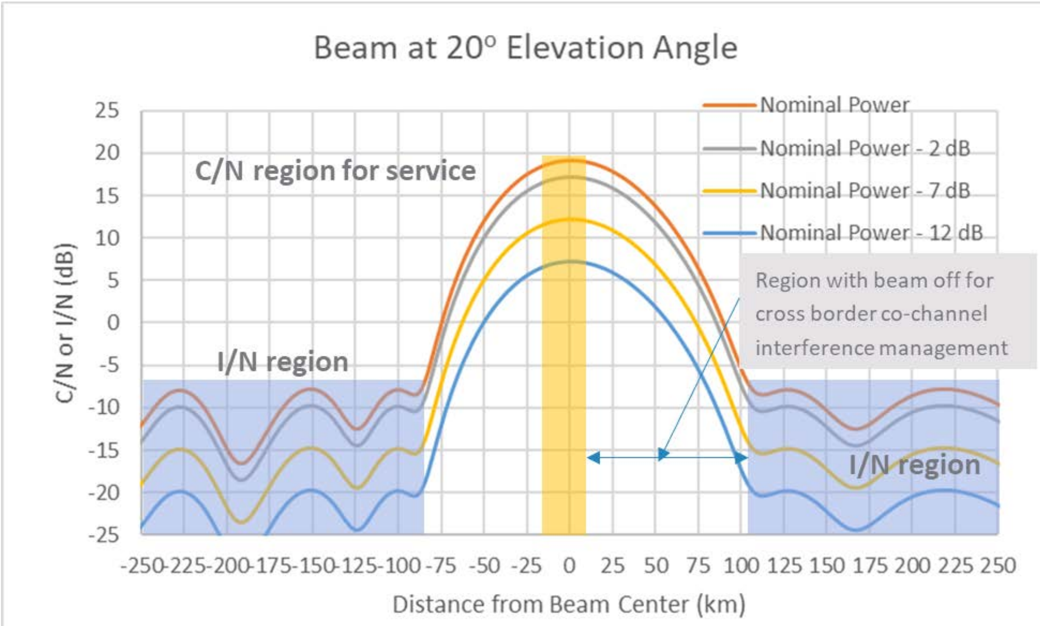
The back-off of the beam power will mean that the SpaceMobile beam capacity varies with elevation angle when the cross-border interference control is implemented. This will be handled and managed within the SpaceMobile system.



(a)



(b)



(c)

Figure 3 Channel Interference control by creating a gap between the SpaceMobile service area and the adjacent country/region/market area border (a) Beam at 90° elevation angle; (b) Beam at 30° elevation angle; and (c) Beam at 20° elevation angle

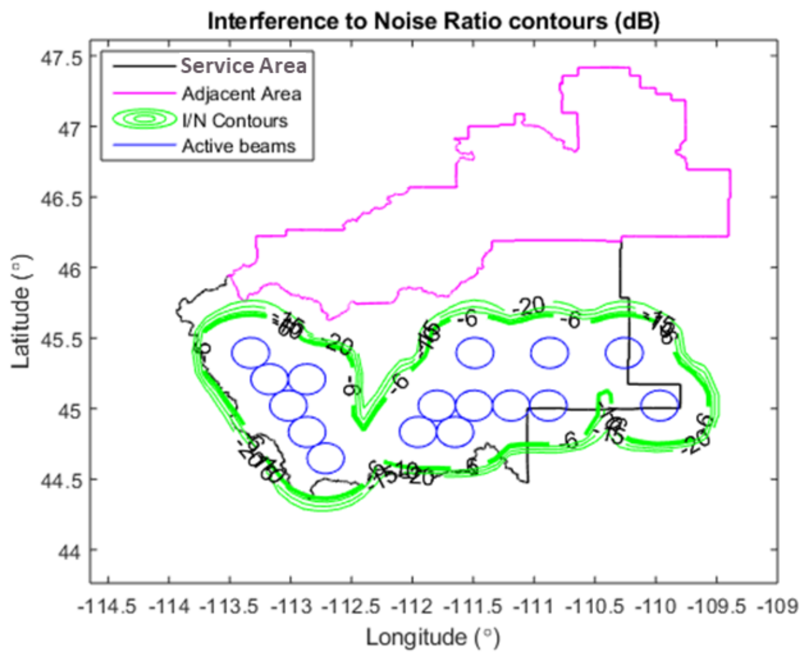
Table 3 Cross-Border Interference by Controlling Beam Power

Beam/S/N or I/N	90° Elevation	30° Elevation	20° Elevation
Nominal power	Peak C/N: 19.8 dB I/N: < -30 dB	Peak C/N: 19.3 dB I/N: < -13 dB	Peak C/N: 19.2 dB I/N: < -8 dB
Nominal power – 2 dB	Not needed	Peak C/N: 17.3 dB I/N: < -15 dB	Peak C/N: 17.2 dB I/N: < -10 dB
Nominal power – 7 dB	Not needed	Peak C/N: 12.3 dB I/N: < -20 dB	Peak C/N: 12.2 dB I/N: < -15 dB
Nominal power – 12 dB	Not needed	Not needed	Peak C/N: 7.2 dB I/N: < -20 dB

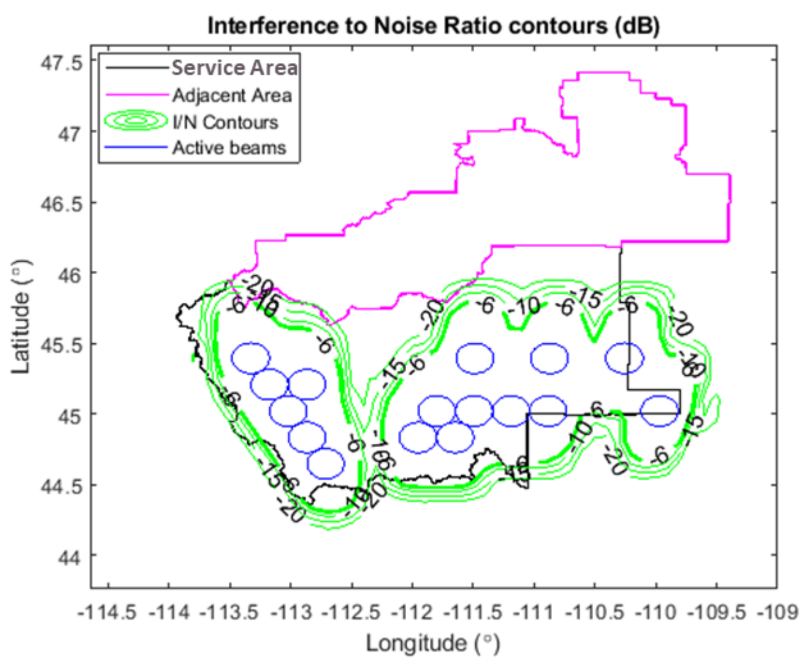
2.3 Combined Co-Channel Cross-Border Interference Analysis

SpaceMobile will provide coverage to areas not currently covered by terrestrial systems. As such, the active beams most likely will be sparse over a given region.

Using the example in Figure 1 for the cross-border co-channel sharing analysis, a typical combined cross-border potential interference scenario is shown in Figure 4. As can be seen, the cross-border I/N can be controlled to a level down to -20 dB, as necessary.



(a) Service area near 90° elevation angle with beams at Nominal Power (Beam Peak C/N = 19.5 dB)



(b) Service area near 30° elevation angle with beams at ~12 dB back-off (Beam Peak C/N = 7.3 dB)

Figure 4 Cross-border Co-channel interference analysis example

2.4 Cross-Border Adjacent Channel Interference

As discussed in Section 1, the ACLR from SpaceMobile will be better than -45 dB which is controlled by the SSPA DPD and operating point. Therefore, the cross-border adjacent channel potential for interference will be 45 dB below the co-channel potential for interference. The I/N can be down to -65 dB since the co-channel interference to noise level can be controlled to a level down to -20 dB.

3 Conclusions

The flexibility of the SpaceMobile system provides it with excellent ability to deal with co-channel sharing and adjacent channel sharing. The cross-border potential for interference can be maintained down to -20 dB I/N in the scenario of the co-channel sharing, in situations where necessary. The cross-border adjacent channel interference can be maintained to a lower level, as necessary.

For these reasons, SpaceMobile has the ability to comply with various sharing requirements, as necessary.

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CERTIFICATION OF PERSON RESPONSIBLE FOR PREPARING ENGINEERING INFORMATION

I hereby certify that I am the technically qualified person responsible for preparation of the engineering information contained in this application, that I am familiar with the Commission's rules, that I 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.

____
Huiwen Yao, PhD
Chief Technology Officer
AST&Science
5825 University Research Ct. Suite 2300
College Park, MD 20740
240-650-0054

PAPUA NEW GUINEA
NATIONAL INFORMATION AND COMMUNICATIONS TECHNOLOGY AUTHORITY

NATIONAL INFORMATION AND COMMUNICATIONS TECHNOLOGY ACT 2009
National Information and Communications Technology (Radio Spectrum) Regulation 2010

Radiocommunications Apparatus Licence

Licence Type: Space Station License

Licence No: RCAP-SS-0000-004

Issued by NICTA

NATIONAL INFORMATION & COMMUNICATIONS TECHNOLOGY AUTHORITY
The Common Seal of

SCHEDULE 1 – GENERAL PARTICULARS

Date of Issue: 06 June 2020

Date of Expiry: 06 June 2025 (may be extended in accordance with Satellite Filing Agreement 2017)

Name: AST&Science, LLC

Postal Address: 2901 Enterprise Lane, Midland, TX, USA

SCHEDULE 2 - TECHNICAL CHARACTERISTICS

In accordance with: **Information registered with ITU**

Satellite Name: SpaceMobile Constellation

Orbital Location: 725-745 km LEO

Station Type: LEO

Service Type: Mobile Satellite

Uplink/ Downlink Frequencies

Uplink Frequencies	Downlink Frequencies	Starting Frequencies Uplink/Downlink	Ending Frequencies Uplink/Downlink
617-960 MHz 1710-2200 MHz (and other LTE Bands as needed)	617-960 MHz 1710-2200 MHz (and other LTE Bands as needed)	617 MHz 1710 MHz (and other LTE Bands as needed)	960 MHz 2200 MHz (and other LTE Bands as needed)

SCHEDULE 3 - LICENCE CONDITIONS

This Licence is subject to compliance with:

Condition Number	Condition Description
605	i. the National Information and Communications Technology Act 2009; ii. the National Information and Communications Technology (Radio Spectrum) Regulation 2010; iii. the Satellite Filing Agreement 2017; iv. Provisions of the ITU Radio Regulations

Objects That Do Not Demise	Dimensions	Material	Mass (kg)	Total Debris Casualty Area (m^2)	Kinetic Energy (J)
Control Satellite	1.288 m x 1.288 m x 0.37 m	Aluminum	131	2.67	148,669
Micron Magnetorquers	5 mm Diameter x 44 cm Length	Iron	0.05	1004.36	12.65
LMDS High Displacement Joint (Short)	0.172 m x 0.644 m x 0.004 m	Aluminum	0.26	5.62	13.56
LMDS High Displacement Joint (Long)	0.172 m x 1.288 m x 0.004 m	Aluminum	0.756	1.75	57.7
LMDS Low Displacement Joint (Short)	0.1 m x 0.644 m x 0.004 m	Aluminum	0.092	6.13	2.92
LMDS Low Displacement Joint (Long)	0.1 m x 1.288m x 0.004 m	Aluminum	0.192	118.01	6.39
Total Debris Casualty Area ($m^{2)}$					**4.42**
Risk of Human Casualty					**1:15,100**