28 November 2025

Radio Spectrum Management (RSM),
Ministry of Business, Innovation and Employment (MBIE),
Wellington

Dear Sir/Madam,

Space Operations New Zealand Ltd Submission Allocation of 24 - 30 GHz Spectrum

Thank you for the opportunity to provide answers to the abovementioned technical discussion document. We very much appreciate RSM's commitment to working with radio spectrum users and its commitment to engage meaningfully. In particular, we appreciate being invited to the Technical Working Group to help ensure the best outcome for everyone.

We understand that RSM is familiar with who we are and our operations, and so we do not elaborate any further here.

For completeness, our submission begins by reiterating our interests in the 24 – 30 GHz spectrum, before addressing specific matters.

SpaceOps NZ's interest in 24 – 30 GHz

We use intend to use the 24 – 30 GHz spectrum for space geodesy and space operations at our Awarua Satellite Ground Station and Warkworth Space Centre, with strong possibilities of using the spectrum also at proposed stations in the Waiau Valley north of Tuatapere and Orepuki.

We have customers already using frequencies in this spectrum for space operations at Awarua Satellite Ground Station, and we have several more customers expecting to use it in the near to medium future. Since we submitted on the Technical Questions, we have noticed growing activity in Ka-Band along with—surprisingly for us—interest in using this spectrum for deep space missions at our Awarua Satellite Ground station.

With respect to space operations, our prime interest in this spectrum is concerned with supporting spacecraft in low Earth orbit (LEO) from Awarua SGS. However, we do support Bring Into Use (BIU) manoeuvres for spacecraft in GEO, as they "drift" across the GEO arc from one GEO slot to another, for instance from Indian Ocean Region to Pacific Ocean Region, though to date we have only done this in S-Band from Warkworth SC. We intend to upgrade our 12 metre S/X-Band Warkworth SC antenna to support near space missions (out to 2 million kilometres, and so including Lunar and cis-Lunar missions) at Ka-Band within the next 5 years.

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23.75 – 24.25 GHz is the geodetic VLBI Band, which we intend to use for receiving signals from distant astronomical radio sources at Warkworth SC and the proposed Waiau Valley station.

25.5 – 27 GHz is the “near-Earth Ka-Band” or “Ka2-Band” used for supporting lunar missions. Our immediate interest is using this band to support NASA and ESA lunar missions in this band from our Warkworth Space Centre, both for transmit and receive. The frequencies are established by NASA and we have no input or ability to change the frequencies.

We are in discussions with existing and potential customers who wish to establish large aperture (15 metre diameter) antennas at our Awarua Satellite Ground Station to support Lunar missions, using X-Band uplinking and K and Ka-Band downlinking. This may be problematic as our existing customers at Awarua wish to use nearby spectrum for downloading much more powerful low Earth orbit spacecraft undertaking satellite Earth observation (see below). We think the only solution is to install such antennas at Orepuki where we have submitted a proposal to host a large aperture Military X-Band antenna to provide telecommunications to Amundsen-Scott South Pole Station.

25.5 – 27.0 GHz One of our customers at Awarua SGS, Planet Labs, has advised us that they are using 25.5 - 27.0 GHz for their Pelican and Tanager spacecraft payload downlinks with 16 carriers on each polarization for a combined total of 32 carriers and utilize nearly the entire 1.5 GHz spectrum.

27.5 – 30 GHz We host a Starlink gateway at Awarua Satellite Ground Station, transmitting in this spectrum.

We have been trying to get a grasp on future demand for this band for space operations, as is the international space community who is struggling to identify its needs and use. All we can discern is that the international space community considers that X-Band is reaching capacity and satellite operators are slowly migrating to Ka-Band. We have two customers (KSAT and RBC-Signals) who now have Ka-Band ground stations at Awarua and expressions of interest from two others. We intend to have our first Ka-Band antenna operational before May 2026, at Awarua Satellite Ground Station.

Specific matters

24.25 -27.5 GHz (26 GHz band)

EESS and SRS (space-to-Earth) users will be able to apply for receive protection licences after the conclusions of the 24 - 30 GHz process upon implementation in the form of suitable licensing frameworks and technical conditions, provided that they are for the sites in Annex 2 or identified through the consultation process. RSM may consider new EESS and SRS (space-to- Earth) sites after the 2028 – 2030 period, alongside the assignment process for mobile systems, provided that EESS and SRS (space-to-Earth) users coordinate with mobile system users as part of the licensing process. An overview of this coordination procedure is intended to be developed and described as part of the licensing process during the implementation of the outcomes of this consultation. For each EESS and SRS (space-to-Earth) site, the licencing framework will propose a suitable methodology to protect the EESS and SRS Earth station receivers with a suitable power flux density (p.f.d.) limit, which is based on the receive protection criteria of EESS and SRS receive Earth stations in 25.5 - 27.0 GHz.

We strongly agree with the proposal for EESS and SRS (space-to-Earth) users to be able to apply for receive protection licences.

We intend to use 22.500 – 27.000 GHz for downlinking spacecraft (space-to-Earth) at Warkworth SC, and potentially Awarua SGS and Waiau Valley to support NASA SCaN and ESA near space missions. Other uses at the proposed Orepuki Station are envisaged.

27.5 -28.35 GHz (a.k.a., "lower" 28 GHz band)

We are proposing that the following spectrum use will be enabled/permitted in the lower 28 GHz band:
• FSS (Earth-to-space) gateway Earth stations at fixed locations
• FSS (Earth-to-space) User Terminals/Very Small Aperture Terminals (VSAT) at fixed locations (no mobility / not in motion)
• FSS (Earth-to-space) ESIMs for aeronautical (A-ESIM) and maritime (M-ESIM) operating in accordance with the technical limits of the RR Resolution 123 (WRC-23) and Resolution 169 (WRC-19). Land ESIM (L-ESIM) will not be permitted as it cannot co-exist with Mobile in this band. After the conclusion of the 24 - 30 GHz process, RSM will set up a licensing process and regime that allows FSS Earth station users to be able to apply for licences for the above new uses for that provide long term certainty on access to spectrum (beyond 2026). RSM will also develop a licensing framework for effective sharing of 27.5 – 28.35 GHz based on the options for sharing.

We agree with this approach.

28.35 -29.5 GHz (Upper 28 GHz band)

We propose that the following new spectrum use will be permitted in the upper 28 GHz band:
• FSS Earth Station (Earth to space) gateways at specific fixed locations.
• FSS Earth station user terminals/VSAT at fixed locations (no mobility) throughout New Zealand based on area licensing (TLAs).
• FSS (Earth-to-space) ESIMs for aeronautical (A-ESIM) and maritime (M-ESIM) operating in accordance with the technical limits of the RR Resolution 123 (WRC-23) and Resolution 169 (WRC-19). Land ESIM will be permitted under a set of technical conditions with a requirement on the minimum elevation angle of the land ESIM station up to the Geostationary Satellite Orbit (GSO) or Non-Geostationary Satellite Orbit (NGSO) satellite, and a limit on the adjacent band effective isotropic radiated power (e.i.r.p.) towards the horizon.
After the conclusion of the 24 - 30 GHz process RSM will set up a licensing process and regime that allows FSS Earth station users to be able to apply for licences for the above new uses providing long term certainty on access to spectrum beyond May 2026. Licensing will be allowed at any location in New Zealand.

We will likely need to use this band to bring GEO FSS spacecraft into use, i.e. during LEOP (Launch and Early Operation Phase) where the spacecraft won't be fixed at Warkworth SC and Awarua SGS. Potentially we may wish to provide gateways and user terminals at these stations also.

Other issues

29.5 - 30 GHz will continue to be available only for FSS (Earth-to-space) use only. In particular, FSS gateway licensing will on the same basis and rules as 28 GHz band. User terminals and ESIMs would require satellite operators to obtain an all-New Zealand licence and consequently, the 29.5 -30 GHz will be removed from the Aeronautical, Maritime, and Satellite Services General User Radio Licence (GURL).
The complimentary 17.7 - 20.2 GHz FSS (space-to-Earth) frequency band will be opened for receive protection licences for stations at specific locations under an individual receive protection licence under the existing FSS Earth station licensing regime. All other use (e.g., wide area user terminals / ESIM use) will be on an opportunistic basis. No changes are proposed for existing fixed links

We agree with this approach.

1. Do you agree with RSM's proposed new spectrum uses outlined in Section 1.1? If not, provide details on the modifications you wish to propose with appropriate reasoning.

We agree with RSM's proposed spectrum uses. We believe that they will work for us.

2. Do you agree with RSM's assessment of the impact on existing users within 23.6 – 24 GHz, 24 – 24.25 GHz and 24.25 – 27.5 GHz, including the proposed technical and operational considerations, as well as technical conditions for the protection of EESS (passive) and potential RAS use in 23.6 – 24 GHz from future Mobile Service emissions in the adjacent 24.25 – 27.5 GHz band? If not, please provide further specific technical details and rationale, including technical studies.

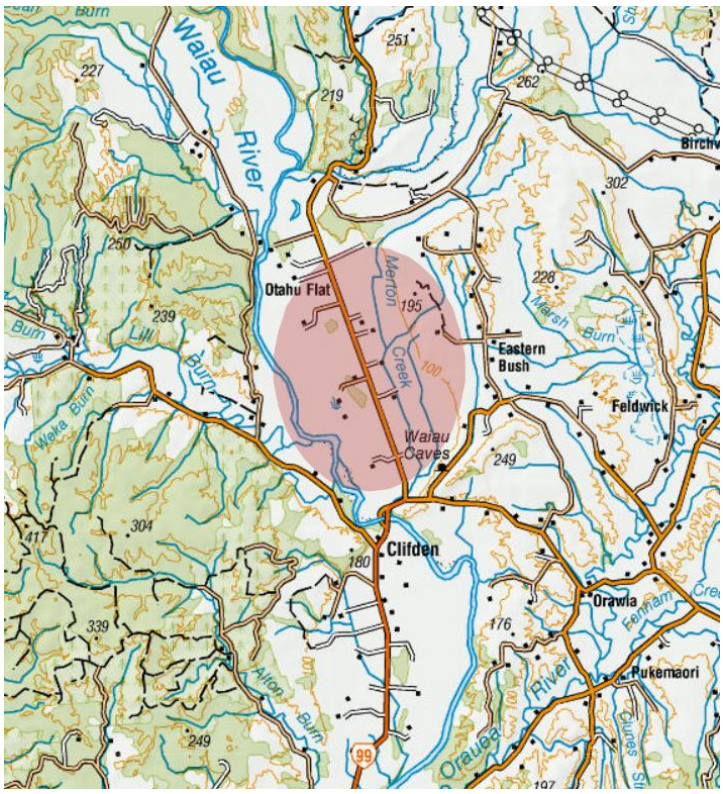
SpaceOps NZ commends RSM's thoughtful and thorough discussion of the uses of this band and especially for noting that "…RR No 5.340 (WRC-03), where "all emissions are prohibited" within 23.6 – 24 GHz". We are appreciative that the importance of RAS is well described, and the importance of protecting our present and future RAS stations is welcomed. Tables 1 – 3 are sound.

We have no concerns that the Homer radar or amateur use of the 24 GHz Band would materially affect us.

We are not entirely confident that ultra-wide broadband devices would be compatible with RAS as we have had no experience with these devices and we are not in a position to undertake studies.

3. Are you aware of other locations apart from those listed in Table 3 which would be likely be used for RAS within New Zealand? If so, please provide details of these locations including the technical and operational parameters of the RAS receiver along with supporting material showing firm plans to establish a site at these locations.

We have no plans for establishing RAS stations beyond those described in Table 3. Please be aware that the Otahu Flat/Waiau Valley spatial coordinates are indicative, and are subject site surveys and securing the land. Our area of interest is approximately shown below:



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4. Are there any further application/system details you wish to provide which qualifies as an existing user?

We have recently entered into discussions with one customer who intend to use Ka-Band to support deep space missions in the 31.8 – 32.3 GHz Band at Awarua SGS. This is unexpected and while outside of the scope of this consultation, does give a flavour of the dynamic nature of space companies.

In the last year we have been made aware that at least one USA company has ambitions and funding to provide "satellite 4G" service to the Moon within the next few years through and following on from the NASA Commercial Lunar Payload Services (CLPS) initiative www.nasa.gov/commercial-lunar-payload-services/programme and www.nasa.gov/reference/commercial-lunar-payload-services/. Their initial backhaul to Earth is likely to be in X-Band, with a move to Ka-Band in the future. None of the details are clear to us, except that they are very interested in having a station in New Zealand, most likely Warkworth, Awarua, or Orepuki.

5. Do you agree with RSM's understanding of the spectrum requirements and key usage scenarios for enabling different services and applications (e.g., Mobile Service, EESS and SRS) in 24.25 – 27.5 GHz?

We believe RSM's understanding of our requirements for SRS is sound.

6. What are your spectrum estimates for the use of Mobile Services, EESS and SRS in 24.25 – 27.5 GHz which you wish to implement or use? Present a technical analysis with appropriate justification.

We are in discussions with NASA Goddard Spaceflight Center's Space Communications and Navigation (SCaN) directorate regarding operating a ground station complying with their Lunar Exploration Ground Sites (LEGS) specification, which is presented in Appendix 1. The specification calls for an 18m class antenna, but industry is debating with SCaN the necessity of this size, arguing that a 12 metre class antenna should be adequate at Ka-Band.

Our current thinking is to add a Ka-Band feed to our Warkworth 12 metre antenna to operate in this band to support SCaN missions.

7. Can you provide a link budget of a system which you plan to operate in 24.25 – 27.5 GHz, which will assist RSM to better plan, allocate and assign this frequency range?

See Appendix 2.

8. Do you plan on operating mobile systems that are not standardised by 3GPP? If so, what type of equipment do you plan to operate and what are its technical characteristics? Where possible, please provide the relevant supporting technical documentation.

No.

9. Does the mobile BS and UE you wish to operate within 24.25 – 27.5 GHz have unwanted emissions falling within 23.6 – 24 GHz of −39 dBW/200 MHz for BSs and − 35 dBW/200 MHz for UEs? If so, could you provide details of the unwanted emission mask as a function of frequency? If not, could you provide the unwanted emissions limits of the equipment you wish to operate with the necessary technical justification?

n/a

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10. Does the mobile BS you wish to operate meet the −60 dBW/MHz Category B spurious emissions limit from Recommendation ITU-R SM.329? If not, what do you propose for the necessary protect EESS (passive) receivers in 50.2 – 50.4 GHz and 52.6 – 54.25 GHz from the second harmonic of mobile BS emissions within 24.25 – 27.5 GHz?

n/a

11. Do you agree with our 5% quantification for the use of the terms "very limited" number of BSs operating in 24.25 – 27.5 GHz that are expected to communicate with a positive elevation angle towards indoor mobile UEs? If not, what technical modifications would you suggest to this quantification?

n/a

12. For mobile system deployments envisaged in 24.25 – 27.5 GHz, what are the typical range of values for electrical and mechanical tilts which you intend to use? Do these parameters relate to the deployment environment (i.e., urban, sub-urban, etc)? If so, provide details of the relationship.

n/a

13. How would you mathematically characterise the term "normally" pointing the BS below the horizon, as quoted in "resolves 2.1" of Resolution 242 (WRC-19)?

14. What would be your mobile BS's typical elevation beam steering range and would the composition of the BS antenna array cause grating lobes to occur? If so, would you be able to quantify the direction and magnitude of these grating lobes?

n/a

15. What type of TDD synchronisation options would you prefer and why? Do you prefer to have a default frame structure? What do you consider the underlaying technical conditions to manage the any potential interference should be?

n/a

16. Do you agree with RSM's assessment on the need to design exclusion areas around the proposed EESS and SRS (space-to-Earth) sites in 25.5 – 27.0 GHz to protect them from aggregate Mobile Service emissions in 24.25 – 27.5 GHz? If not, what other technical alternative(s) would you suggest?

Yes. We are anxious to receive such protection. However, the list of planned locations should include Warkworth Space Centre, where we expect early work to commence. Table 6 should be amended to include Warkworth SC.

17. Do you agree with RSM's assessment of the licencing framework for EESS (space-to-Earth) and SRS (space-to-Earth) anticipated to operate in 25.5 – 27 GHz? If yes, provide your reasoning. If no, which other alternative would you suggest to licence these services and why?

We agree with RMS's assessment up to a point.

We agree an exclusion zone with a radius on the order of approximately 10 km within which mobile BSs and UEs would not be permitted to operate is pragmatic and, allowing our limited resources to conduct detailed modelling, we believe it is likely to work for us.

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We suggest that a blanket receive protection licence regime for the EESS and SRS ground stations be adopted for this band as it is not possible to predict what exact frequencies may be used for these purposes in the future, noting that we have no control over what actual "channels" within this spectrum may be used as they are dependent on the mission being supported; it would be unfortunate if a channel to be used by a future SRS mission were to suffer permanent interference from a terrestrial user licenced in the short term.

18. Do you agree with RSM's assessment of the licencing framework for RAS operating in 23.6 – 24 GHz? If yes, provide your reasoning. If no, which other alternative would you suggest to licence these services and why?

We agree. Obviously, we would sooner there be no administrative fees. The radio astronomers would likely wish to use the full bandwidth available to them and so the administrative burden of creating a single site licence for the full spectrum should be minimal. It is not clear what the situation would be when we were still to establish a K-Band radio astronomy station at Warkworth or Waiau Valley and so would not hold a receive protection licence.

19. Do you agree with RSM's proposed new spectrum uses within 27.5 – 28.35 GHz, noting the growing demand for FSS (Earth-to-space) GSO and NGSO gateways and user terminals?

Yes

20. Do you agree with RSM's assessment of the impact on existing users, including the sharing and compatibility scenarios, considerations and overall conclusions in the form of conditions to be met for the protection of existing users such as individually licenced FSS GSO and NGSO Earth stations, as well as FSS satellite receivers operating within 27.5 – 28.35 GHz? If not, please provide further specific technical details and rationale.

Yes

21. Is there any further application/system details you wish to provide which qualifies as an existing user? If so, please provide the details, including any relevant technical information.

No

22. Do you agree with RSM's understanding of the spectrum requirements for enabling different services and applications, e.g., FSS (Earth-to-space) and Mobile Service in 27.5 – 28.35 GHz?

Yes

23. What are your spectrum estimates for FSS (Earth-to-space) and Mobile Services (including their applications) which you wish to implement or use in the 27.5 – 28.35 GHz range?

We have no immediate use.

24. Can you provide a link budget of systems which you plan to operate in 27.5 – 28.35 GHz, which will assist RSM to better plan, allocate and assign this frequency range?

No

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25. Can you provide further insights into the typical metrics and calculation methodologies often used for GSO to GSO, GSO to NGSO and NGSO to NGSO FSS coordination? In doing so, given an application, how can we ultimately determine the amount of spectrum an FSS operator can ultimately use relative to another, while respecting the provisions contained in Article 9 of the ITU RR? RSM encourages you to share as much detail as possible.

No

26. Do you agree with the geography-based by area type option of sharing the 27.5 – 28.35 GHz frequency range between FSS (Earth-to-space) and Mobile Services, as detailed in Option 1? If not, please propose alternatives with the required details for RSM's consideration.

We have no particular preference, but we note that NGSO user terminals are favoured ways to obtain internet by students and others who lead somewhat transient lifestyles and change flats somewhat frequently as by so doing they overcome the real or perceived difficulties of ordering and getting a fibre-optic cable Internet connection that may involve a long term commitment.

27. Do you agree to divide Option 1 by Part A and Part B by using the Statistics New Zealand defined area accessibility criteria? If not, please suggest an alternative criterion which RSM could use?

We have held some scepticism of Stats NZ's rural/urban categorisation for some time and I harbour doubts as to the suitability of the Stats NZ urban-rural continuum for the purpose proposed. I suggest that population density may give a better picture of the situation. I note that this is not at all straightforward.

28. In accordance with Part A of Option 1, do you agree that L-ESIMs should not be permitted inside major, large, medium, small urban areas and high urban accessibility areas? If not, please provide an alternative with a detailed explanation.

We have no view.

29. To facilitate the use of the Mobile Service in accordance with Option 1, do you have any suggestions on how RSM could implement coordination of mobile BSs with FSS (Earth-to-space) GSO and NGSO gateways and user terminals? In particular, which coordination trigger and methodology should RSM use (including any relevant reasons)?

We have no suggestions.

30. In accordance with Part B of Option 1, do you agree that Mobile Service (and its applications) should not be allowed to operate inside medium and low urban accessibility areas, as well as remote and very remote areas? If not, please provide an alternative with a detailed explanation.

We have no view.

31. Would you like to propose any modifications for Option 1? If so, please provide modifications with relevant associated details.

No.

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32. Do you agree with the geography-based by priority of service type option of sharing the 27.5 – 28.35 GHz frequency range between FSS (Earth-to-space) and Mobile Services, as detailed in Option 2? If not, please propose alternatives with the required details for RSM's consideration.

We have no view.

33. Which areas would you like FSS to have priority over Mobile Services, and vice versa, and why?

We have no view.

34. How would you recommend RSM to calculate the coordination zones described in Part A and Part B of Option 2?

We have no view.

35. Are there any other suggestions for licencing conditions which you wish to see included as part of Option 2? RSM encourages details of specific conditions for different types of FSS user terminals, e.g., fixed terminals vs. A-ESIMs and M-ESIMs.

No

36. Would you like to see any additional technical conditions which facilitate sharing for Parts A and B of Option 2? Describe in detail, the changes you would want to make to this proposal.

No

37. Do you agree with our approach of ESIM use in 27.5 – 28.35 GHz?

We have no view.

38. Do you wish to offer, implement or use pier-to-pier or gate-to-gate M-ESIM and A-ESIM applications in 27.5 – 28.35 GHz?

no

39. Is there any other change which you wish to see in our approach for using A-ESIM and M-ESIM? If so, provide the relevant details.

No

40. Do you agree with RSM's proposed new spectrum uses outlined in Section 3.1? If not, provide details on the modifications you wish to seek with appropriate reasoning.

Yes

41. What is the likelihood of interference from land ESIM terminals operating in 28.35 – 29.5 GHz to Mobile Service receivers (BSs and UEs) operating in 27.5 – 28.35 GHz under possible shared use of FSS (Earth-to-space) and Mobile Services in 27.5 – 28.35 GHz?

We are not able to comment

42. What technical conditions may be required to ensure that future L-ESIM use is not constrained in 28.35 – 29.5 GHz while protecting possible Mobile Service receivers in 27.5 – 28.35 GHz. Provide necessary technical justification to support your answer.

We are not able to comment

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43. To not constrain future use of A-ESIMs and L-ESIMs, do you propose any changes to the technical conditions for operating A-ESIMs and L-ESIMs within 28.35 – 29.5 GHz? If so, what would these be and what assumptions as well as processes did you use to derive these changes? RADIO SPECTRUM MANAGEMENT 55 Allocation of 24 - 30 GHz Spectrum

We are not able to comment

44. Do you agree with RSM's proposed licencing arrangement to licence FSS (Earth-to-space) GSO or NGSO gateways operating in 28.35 – 29.5 GHz? If not, what changes would you recommend?

Yes

45. Which licencing option would you prefer for licencing FSS GSO and NGSO fixed user terminals and moving user terminals (ESIMs), respectively? RSM requests for appropriate justification to support your answer.

We have no view

46. Do you agree with RSM's proposed approach to 29.5 – 30 GHz? If not, what modifications would you suggest to our proposal?

Yes

47. Do you agree with RSM's proposed approach to 17.7 – 20.2 GHz? If not, what modifications would you suggest to our proposal?

Yes

Yours faithfully,

Robin McNeill
Chief Executive Officer

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Appendix 1. Lunar Exploration Ground Sites (LEGS) Specification

Space Communications and Navigation (SCaN)

*Antenna image above is WS1 at WSC

LEGS Locations (Site, Lat., Long.)

White Sands, USA: 32.544863, -106.612504
Matjiesfontein, South Africa: -33.231224, 20.58163 (TBD)
Pacific Region TBD

Additional Information

FUNCTION	PERFORMANCE
Antenna Diameter (D)	D > 18m
Services	TT&C, CCSDS Forward and Return data, Radiometric tracking and antenna auto tracking angles
Transmit and Receive Polarizations	Tx: RHC or LHC Rcv: RHC & LHC
Antenna Travel Range	>360 deg Azimuth Continuous (TBR) 0-90 deg Elevation
Antenna axis Tracking rate	0.5 deg/s velocity (TBR)
Radiometric Tracking	Per CCSDS 414.1-B-2, Pseudo-Noise (PN) Ranging Systems
Radiometric Accuracy	Equivalent to DSN adjusted to C/No
Autotrack Accuracy	+/- 0.2 dB of beam peak (TBR)
Multiple Spacecraft Per Antenna (MSPA)	Up to 4 simultaneous return services per aperture (Max 3 Ka)
Timing Reference	short term stability better than 10^-14 (TBR)

Lunar Exploration Ground Sites (LEGS)

The LEGS mission is to provide direct-to earth communication and navigation services for missions operating from 36,000 kilometers (km) in the GEO to cis Lunar and other orbits out to 2 Million km. To fully support distant orbits there will be three LEGS sites equally spaced around the Earth. The Ground sites utilize CCSDS Modulation and coding schemes for forward and return data. Specialized/unique Mod-Cods are optional. User Local Equipment on site is optional. Ground system performance characteristics are provided below:

Antenna System Radio Frequency Operating Regimes

Radio Frequency (RF) Band	Operating Frequency	
	Lower limit	Upper limit
S-Band (Forward)	2025 MHz	2120MHz
S-Band (Return)	2200 MHz	2300 MHz
X-Band (Forward)	7145 MHz	7235 MHz
X-Band (Return)	8400 MHz	8500 MHz
Ka-Band (Forward)	22.55 GHz	23.15 GHz
Ka-Band (Return)	25.50 GHz	27.0 GHz

RF Performance Criterion	Radio Frequency Performance (Forward)		
	S-Band	X-Band	Ka-Band
EIRP (minimum) [3]	81 dBW	86 dBW	89 dBW
Approx 3 dB Beamwidth[3]	0.5°	0.1°	0.04°
Forward Distortions [2]	1 dB max	1 dB max	1 dB max
Carrier Modulation	Direct PCM/PM PCM/PM/PSK, OQPSK, BPSK[1]	Direct PCM/PM PCM/PM/PSK, OQPSK, BPSK[1]	BPSK, OQPSK Filtered OQPSK[1]
Max Data Rate	10 Msps	10 Msps	40 Msps

RF Performance Criterion	Radio Frequency Performance (Return)		
	S-Band	X-Band	Ka-Band
G/T (minimum) [3]	28 dB/K	39 dB/K	47.5 dB/K
Approx 3 dB Beamwidth[3]	0.5°	0.1°	0.04°
Implementation loss [2]	2 dB max	2 dB max	2 dB max
Demodulation	Direct PCM/PM, PCM/PM/PSK, OQPSK, BPSK[1]	Direct PCM/PM, PCM/PM/PSK, OQPSK, BPSK[1]	OQPSK, Filtered OQPSK[1]
Max Data Rate	20 Msps	150 Msps	500 Msps

[1] Additional modulation schemes or data service types are optional
[2] GSFC CLASS link calculations use a 3dB implementation loss of which, the receive system is allocated 2dB and the transmit system distortions are allocated 1dB
[3] TBR pending finalization of antenna system requirements

Appendix 2. Link budgets for future missions

The link budgets below were prepared for Morehead State University who are currently fitting their 12 metre Patriot antenna with a tri-band feed (S,X and Ka-Bands). This antenna, other than the new feed, is identical to SpaceOps NZ's 12 metre antenna at Warkworth SC.

GEO BIU Manoeuvre

Link budget for a nominal Bring Into Use GEO manoeuvre.

Parameters

Spacecraft			
Description	**Symbol**	**Value (Real)**	**Unit**
SC Transmit Power	Pt	25.00	W
Spacecraft Line Loss		-1.00	dB
Spacecraft Pointing Loss		-2.00	dB
Spacecraft Antenna Gain		20.00	dBi
Downlink Frequency		19700.00	MHz
Uplink Frequency		28350.00	MHz
LNA Data Power Threshold		-85.00	dBm
Ground Station			
Description	**Symbol**	**Value (Real)**	**Unit**
Polarization Mismatch		-0.50	dB
Pointing Loss		-1.00	dB
Downlink Aperture Efficiency		0.50	
Uplink Aperture Efficiency		0.40	
Aperture Size		12.00	m
System Noise Temperature		260.00	K
Transmit Power		100.00	W
Environment			
Description	**Symbol**	**Value (Real)**	**Unit**
Range		37000.00	km
Additional Losses		0.00	dB
Multipath Loss		0.00	dB
Additional Noise Temperature		3.00	K
Receiver			
Description	**Symbol**	**Value (Real)**	**Unit**
Required S/No		25.00	dBm-Hz

Information Rate		1000000.00	bps
Code Rate		0.50	
Modulation Order		2.00	
Implementation Loss		0.00	dB
Required Eb/No		4.75	dB

Link Budget (space-to-Earth)

Description	Value (Real)	Unit	Value (dB)	Unit
Transmit Power	100.00	W	20.00	dBW
			50.00	dBm
Polarization Mismatch			-0.50	dB
Pointing Loss			-1.00	dB
Frequency	28350.00	MHz		
Speed of Light	2.998E+08	m/s		
Wavelength	0.01057469	m		
Aperture Efficiency	0.40			
Aperture Diameter	12.00	m		
Antenna Gain	5083782.355		67.06	dBi
Effective Isotropic Radiated Power Data	**508378235.5**	**W**	**87.06**	**dBW**
			117.06	**dBm**

Range	37000.00	km		
	3.700E+07	m		
Free Space Path Loss	5.173E-22		-212.86	dB
Additional Losses			0.00	dB
Multipath Loss			0.00	dB
Data EIRP at SC Antenna	2.62966E-13	W	**-125.80**	**dBW**
			-95.80	**dBm**

Description	Value (Real)	Unit	Value (dB)	Unit
SC Antenna Gain			20.00	dBi
Line Losses			-1.00	dB
LNA Data Power Received	2.08881E-11	W	-106.80	dBW
			-76.80	dBm
LNA Data Power Sensitivity			-85.00	dBm

Data Power Margin			**8.20**	**dB**

Commercial Information

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