BEFORE THE INDEPENDENT HEARINGS COMMISSIONER
APPOINTED BY THE INVERCARGILL CITY COUNCIL

UNDER	the Resource Management Act 1991
IN THE MATTER	of Part 8 of the Act
BY	**SPACE OPERATIONS NEW ZEALAND LIMITED**
	Requestor

STATEMENT OF EVIDENCE OF ROBIN MCNEILL

Dated: 14 September 2026

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Statement of evidence of Robin McNeill

Introduction

[1] My name is Robin Gustav McNeill.

[2] I hold an honours degree in Electrical and Electronic Engineering from the University of Canterbury. I am a Chartered Professional Engineer (CPEng) and Professional International Engineer (PEInt).

[3] I am a Senior Life Member of the Institute of Electrical and Electronics Engineering (SMIEEE) and a Fellow of Engineering New Zealand (FEngNZ). I am an Approved Radio Engineer (ARE) under the *Radiocommunications Act 1989* and I am an Expert on the International Astronautics Federation (IAF) Space Operations Committee.

[4] In 2024, I was the inaugural winner of the Prime Minister's Space Prize for Professional Excellence.

[5] I have been active as a professional engineer working in radio telecommunications since 1981 and satellite ground stations since 1991, when I assisted with the establishment of Telecom New Zealand's ground station at Scott Base, Antarctica. Subsequently, I was a Senior Expert in the International Telecommunications Union (ITU), an executing agency in the United Nations, leading a project to provide telecommunications to Tokelau that included, amongst other things, establishing a satellite ground station on each of the three atolls.

[6] I am currently the Chief Executive Officer (CEO) of Space Operations New Zealand Limited (**SpaceOps NZ / Requestor**) having been appointed to the position when the company commenced operating in October 2021. Prior to that I had been responsible for most of SpaceOps NZ's functions since 2004, when they were being undertaken by a business unit within Southland Regional Development Agency Limited (**Great South**) and its predecessor, Venture Southland, a Combined Committee of Councils.

[7] As CEO, I lead SpaceOps NZ's technical and business development. In this capacity, I have been involved in securing and protecting the unique attributes of Awarua Satellite Ground Station (**Awarua SGS**), including

working with Radio Spectrum Management (**RSM**) to formulate radio spectrum policy. From time to time, I provide legislative and regulatory advice to the New Zealand Space Agency.

Scope of evidence

[8] My statement of evidence provides corporate evidence on SpaceOps NZ's notice of requirement for a designation in respect of airspace and land surrounding the Awarua SGS. The land and airspace surround Lot 1 Deposited Plan 483454 and Lot 1 DP 524692 held in Record of Title 837915, located at 781 Colyer Road, and Lot 2 DP 524692 held in Record of Title 1134415, located at 721 Colyer Road (together, the **Site**).

[9] My evidence will address:

(a) How and why Awarua SGS became important to the international space community since it became operational in 2008. A brief history of the station is included to assist understanding.

(b) How space operations are undertaken. This includes a discussion on how Awarua SGS supports spacecraft in Low Earth Orbit (**LEO**) and Geosynchronous Earth Orbit (**GEO**) during operational phase of spacecraft missions, and for supporting rocket (hereafter called a launcher) launch campaigns and the early support of spacecraft once they have been launched (known as Launch & Early Operation Phase, **LEOP**).

(c) Why Awarua SGS is of international significance.

(d) How terrestrial structures can interfere with the reception of radio signals from spacecraft.

(e) The objectives of SpaceOps NZ.

Space Operations New Zealand

[10] Space Operations New Zealand Limited (trading as SpaceOps NZ) is a wholly owned subsidiary of Southland Regional Development Agency

Limited (trading as Great South), operating with an independent board of directors and its own balance sheet.

[11] SpaceOps NZ is a Council Controlled Trading Organisation (CCTO) under the *Local Government Act 2002*.

[12] SpaceOps NZ owns and operates the Awarua SGS, and leases land for Lochiel Ground Station and Warkworth Space Centre, where it owns and operates equipment.

SpaceOps NZ's objectives

[13] The approval of SpaceOps NZ to become a Requiring Authority reads:

Space Operations New Zealand Limited is approved as a requiring authority under section 167 of the Resource Management Act 1991 for its network utility operation of constructing, upgrading, maintaining and operating the Awarua Satellite Ground Station based in Awarua, Southland to the extent that this station undertakes radiocommunication activities as defined in section 2(1) of the Radiocommunications Act 1989.

[14] SpaceOps' primary objective, as stated in its request to become a Requiring Authority, is to deliver modern, efficient and reliable antenna infrastructure to the space community. To achieve this ultimate objective, SpaceOps' objectives for this designation are as follows:

(a) Ensure that the satellite Ground Station can continue to run in an efficient manner by sending and receiving radiotelecommunications as defined in the Radiocommunications Act 1989;

(b) Ensure that activities on surrounding land do not interfere with the already established protection zone for space research, space operation and Earth exploration-satellite services; and

(c) Ensure that the District Plan is aligned with the RSM protection zone.

[15] SpaceOps NZ wishes to achieve through the designation the ability to continue to operate as a world-class satellite ground station in a unique location that is important to the international space community.

[16] The background for seeking these objectives are now discussed.

[17] Over the last 22 years, Awarua SGS has grown hand-in-hand with the "new space" revolutions brought about by commercial launch companies such as Rocket Lab. Through prudent and cautious investment, SpaceOps NZ has evolved over time to meet the increasingly demanding requirements of a maturing market. SpaceOps NZ has been able to meet all the ensuing requirements, except for being able to guarantee to customers that the radio path for their ground station at Awarua to their spacecraft is always unobstructed.

[18] At the same time, customers demand that their elevation horizon agreed to at contract signing remains unobstructed and that EMI is dealt with satisfactorily. A typical example of a contract demonstrating customer concern is shown in [*L Service Contract 20210113.pdf*].[1] In short, customers demand and expect that their operations will remain unaffected.

[19] SpaceOps NZ first learnt of the importance of protecting its horizon mask and the need for low EMI during its early work with the French Space Agency, CNES in 2004 [*Ariane 5 site report 20102004.pdf*].

[20] Aware that Invercargill City Council was contemplating developments of some sort in the Awarua area, I wrote to the Chief Executive of ICC, Richard King, on 1 August 2007 to advise him that the area was of significance for radio science and radio astronomy, and to register our interest in the area [*Letter to ICC re Awarua Industrial Development 070801.pdf*[2]].

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[1] Attachments are referred to throughout my evidence in square brackets and italics, for example: [*Document title*]. These attachments have been filed alongside my evidence.

[2] The letter appended was printed on Venture Southland letterhead paper and physically signed, to be delivered by the internal mail system. This means that the signed, paper version is likely lost to time.

[21] Subsequent meetings over time with Richard King confirmed in our minds that we had no grounds for concern at Awarua with respect to Council activities and we expected that we would be consulted on any developments that could affect us.

[22] A consolidated summary of efforts by SpaceOps NZ and its precursors, Venture Southland and Great South, to use and protect the land and radio spectrum at Awarua SGS is presented in [*Summary of Land use, Consenting and Radio Spectrum protection efforts.pdf*].

Horizon Mask

[23] Until recently, SpaceOps NZ had not seen an urgent need to protect its exceptionally low horizon mask that is an important feature for customers, confident that the height limit of 35 metres in the Awarua Quadrant would not be a problem—SpaceOps NZ had seen the original ICC development plans for the Awarua Quadrant and had inferred from it that the south-eastern corner was not considered to be suitable for serious development. SpaceOps NZ has sufficient flexibility in locating customers' antennas at Awarua SGS so that it was confident that any object 35 metres high in the Awarau Quadrant could at any rate be accommodated. At no stage was it envisaged that any object greater than 35 metres would be contemplated.

[24] In light of the above and confident that ICC would advise us of any impacts their land developments may have on our operations, we did not make protecting Awarua SGS a high priority until recently when we had grown to sufficient size that our finances and resources could stretch sufficiently to afford to do so.

[25] In my opinion, based on my experience in satellite ground station operations, a 5° horizon mask would provide a substantial level of protection for the operational horizon mask while remaining practicable. Indeed, seeking a 5° elevation mask protection is a major concession by SpaceOps NZ.

[26] A 3km radius was deemed to be appropriate to ensure large structures and buildings, such as wind turbines, that have the potential to impact the operation of the Ground Station are captured.

EMI protection

[27] SpaceOps NZ is also seeking EMI protection of its important S-Band radio spectrum through the District Plan. What is sought is no more than that set out in RSM's current rules.

[28] The rationale for SpaceOps NZ seeking the determination to include EMI is, in the spirit of transparency, to make RSM's existing protection clear. We suggest that RSM's Decision on S-Band [*RSM Re-planning-decision-for-frequency-bands-within-1710-2300-mhz.pdf*] would otherwise be unlikely to be to the forefront of anyone's mind when assessing the use of land surrounding Awarua SGS.

Establishment of space operations activities at Awarua SGS

[29] A consolidated history of technical and administrative matters concerning SpaceOps NZ and Awarua SGS is presented in [*Timeline of Awarua SGS Developments 190430.docx*].

[30] Undertaking space operations at Awarua SGS began in May 2004 when Venture Southland (a Joint Committee of Invercargill City Council, Southland District Council and Gore District Council, a precursor to Great South, in turn a precursor to SpaceOps NZ) was approached by the European Space Agency (**ESA**) and the French Space Agency (**CNES**) to establish a relocatable ground station facility in the Southland region to support "Ariane 5 ATV" launch campaigns for resupplying the International Space Station.

[31] As a result, Venture Southland, led by me, was tasked to find the best site for such a ground station. The present Awarua site was selected [*Ariane 5 site report 20102004.pdf]* in October 2004 and 0.325 ha of land of land was consequently leased from the farmer to establish the station.

[32] The factors that identified Awarua as being an ideal site for a satellite ground station included its low EMI with no discernible EMI to be found in the radio frequencies of interest, low horizon in all directions with 0° elevation mask for launch support, a rural aspect and convenient access to Invercargill. Innovative solutions were adopted to provide telecommunications.

[33] Awarua SGS (then called Awarua Tracking Station) was officially opened by Hon David Parker and Chris de Cooke of ESA in March 2008. ESA transferred the infrastructure to Venture Southland shortly afterwards, with ESA's contribution exceeding €200,000. The first of the five ATV resupply launch campaigns occurred later that month.

[34] Resultant engagement with engineers and others in ESA and CNES introduced Venture Southland to wider possibilities that could exploit Awarua's unique natural advantages [*Southland Space Projects Strategy 090923.pdf]*, which was adopted by Venture Southland in October 2009. This strategy convinced Venture Southland management to continue with space activities as a part-time business unit and for the Venture Southland Charitable Trust Board to purchase the leased land and some adjacent land, amounting to 1.7 ha, in 2014.

[35] Over time, the initial microwave radio link and single-phase 11 kV power line established for the ESA launch campaigns were upgraded to dual, route-diverse fibre-optic cables to Invercargill and a three-phase power supply. Work is underway to establish a second three-phase 11 kV power line to the station to improve reliability and service growing demand.

[36] Developments at Awarua SGS have occurred continually since then. The station now occupies 32.5 ha, where there are now more than 30 antennas larger than 3 metres and another 15 smaller antennas.

[37] A $4.55 million headquarters building and facilities are being constructed at the north-west of Awarua SGS to accommodate up to 20 staff and visitors. It is expected that the building will be occupied in early 2027. The building is in part funded by a government loan through Kānoa – Regional Economic Development & Investment Unit.[3]

Adjacent activities

[38] In 2015, in order to manage a radio spectrum conflict at Awarua SGS, I spent over 6 months searching for a second site in Southland to host a customer's ground station. This led to the establishment of a very limited

[3] See: https://www.beehive.govt.nz/release/build-begins-southland-space-headquarters.

capacity site at Lochiel with a compromised field of view for the antenna. Despite its shortcomings, this site was the best that we could find in Southland that was more than 20 kilometres from Awarua SGS (a distance that was calculated to be sufficient to negate the radio spectrum conflict).

[39] In 2021, the same customer wished to erect another antenna in Southland. Rather than augment the Lochiel station, the customer chose to erect their antenna at Awarua SGS because of its superior location and facilities, noting that the customer could choose either station because it was to operate in a different radio band than the first antenna.

[40] As a strategic development, in 2020 Great South sought to establish a complementary ground station in the north of the North Island. The hilly Northland topography, limited access to high-speed fibre-optic cable and logistics established that the only site that had any chance of success was at Ruakaka, south of Whangarei.

[41] The Ruakaka site was found to be just acceptable for space operations and detailed planning and consenting effort was initiated. A public meeting established that there was no social licence for having a satellite ground station in the neighbourhood and the endeavour had to be abandoned.

[42] Searching for a site in Northland highlighted to us (1) how difficult it is to find a suitable site for a ground station, (2) how good Awarua is for a ground station, and (3) the importance of social licence.

[43] In 2023, SpaceOps NZ acquired the Auckland University of Technology's radio astronomy observatory at Warkworth, north of Auckland. At the same time, we took a long-term exclusive lease on Spark's nearby 30 metre diameter antenna, which we are now augmenting to provide space operations for lunar missions. Progress is such that we tracked the Orion capsule to the Moon and back for NASA's Goddard Spaceflight Centre earlier this year.

[44] At Warkworth, we found that the performance of the antennas had been seriously degraded since they were commissioned by strong signals from cellphone towers and a weather radar in adjacent radio bands.

These were overloading the low noise amplifiers in the antennas' radio receiving chains. Filtering out these signals compromises the antennas' performance and we have thus elected not to expand the Warkworth site in favour of Awarua SGS This is despite Warkworth having the same EMI protection in the 2200 – 2290 MHz band as Awarua SGS and Mahia through RSM's 2020 Decision [*RSM Re-planning-decision-for-frequency-bands-within-1710-2300-mhz.pdf*], and Auckland Council protection Designation 7501 – Warkworth Satellite Earth Station Restrictions [*Spark New Zealand Trading Ltd Designation 7501.pdf*].

[45] The deterioration in the station's performance between 2012 when the Warkworth "VLBI" station was established and the present day highlighted to us the importance of dealing with cumulative effects.

SpaceOps NZ's activities

[46] SpaceOps NZ effectively operates two businesses at Awarua SGS: the prime business is hosting other's antennas and facilities. These antennas are owned by either a spacecraft operator for communicating with their own spacecraft, or ground station network providers who lease time on their antennas to satellite operators. The latter is also known as Ground Station as a Service (GSaaS).

[47] Currently, over 30 antennas larger than 3 metres in diameter and two antennas of 12 metres diameter are hosted at Awarua SGS. There are over ten antennas between 2 and 3 metres and five yagi antennas operated by customers.

[48] SpaceOps NZ owns and operates two 3.7 metre antennas, one 3.2 metre antenna and five smaller antennas at Awarua SGS. These antennas are leased to customers so that they can communicate with their own spacecraft. All but one antenna is leased on a per-minute basis, and one antenna is leased long-term to a ground station network operator.

[49] Following on from the ESA's ATV launch campaigns, SpaceOps NZ is establishing itself as a provider of antenna time for launch campaigns and "launch and early operations phase" (LEOP). LEOP is the most critical part of a spacecraft's launch, when satellites are brought into

service and critical systems monitored and, if necessary, worked on to save the mission. To this end SpaceOps NZ has built two antennas and operating software optimised for this work. Currently, SpaceOps NZ has successfully supported three of eighteen Ariane 6 launches with its AWA-4 antenna.

[50] An aerial view of Awarua SGS is shown below. Since the photograph was taken, two more antennas have been erected. Two further antennas are to be erected before Christmas and at least eight more by April 2027. The station site plan is presented in [*Awarua_site_layout -3000 - 2026-03-13.pdf*].

Figure 1. Awarua Satellite Ground Station, looking to the south-east, as at May 2026.

[1] A number of research and calibration antennas and sensors are also hosted at Awarua SGS. These include a magnetic field sensor for the Solar Tsunamis Project (https://solartsunamis.otago.ac.nz/), and global navigation satellite reference stations for the ESA Navigation Support Office (https://navigation-office.esa.int/OPS-GN_Navigation_Support_Office.html) and Earth Science New Zealand. These sensors play important roles and their location is highly valued.

International significance of Awarua SGS

[2] I now address the importance of Awarua SGS to the international space community. Because of commercial sensitivity and the large number of satellite missions and (to a lesser extent) launch campaigns using Awarua SGS, I can only provide representative examples.

[3] To protect ESA's use of the Awarua SGS, an Arrangement between ESA and the Government of New Zealand was signed on 29 March 2007, having been ratified by the ESA Council on 13/14 December 2006 [*ESA - NZ Arrangement 2008.pdf*]. Venture Southland and CNES are the implementing agencies under the Arrangement.

[4] The Arrangement was renewed in Paris on 17 December 2021 [*ESA - NZ Arrangement Extension 20211223.pdf*] and the New Zealand Space Agency is about to renew it for a further term.

[5] Because of its location at (more or less) the antipodes of Europe, Awarua SGS's southernmost location (outside of South America) with route-diverse fibre-optic connectivity, Awarua is considered to be an important ground station internationally.

[6] As of 9th September 2026, SpaceOps NZ holds 716 radio licences on behalf of customers with spacecraft in low Earth orbit, indicating that Awarua SGS currently supports well over 700 spacecraft and satellite constellations.

[7] S___, a well-known telecommunications satellite operator, operates a telemetry antenna at Awarua SGS. This is one of (we understand) three such antennas around the world which are used to command and control some thousands of spacecraft used by S___. S___ also has a "gateway" antenna array at Awarua SGS, comprising nine 2 metre antennas that carry customer data.

[8] Three large antennas and a small data centre at Awarua SGS provide safety of life services for many cellphone users in New Zealand. The data centre and antennas are being augmented.

[9] Lockheed Martin, under a $AUD 1.18 billion contract to Geoscience Australia and Land Information New Zealand, operate two 12 metre

antennas at Awarua SGS. The antennas and associated equipment are key components in the SouthPAN precision GPS service, [www.linz.govt.nz/sites/default/files/2024-11/SouthPAN%202024%20-%20One%20Pager.pdf]. The antennas and facilities provide safety of life services. Once qualified next year, the SouthPAN system will allow aircraft to fly into Queenstown Airport with virtually no visibility, amongst many other things.

[10] The SouthPAN facilities include three GNSS reference antennas that take at least two years to qualify. We are advised by Lockheed Martin's contractors that there should be no sources of multipath signals (where the antenna receives signals reflected from objects as well as the main signal).

[11] ESOC have operated a similar antenna and equipment at Awarua SGS for calibrating EGNOS, the European equivalent to SouthPAN, since 2013. It is important that the antennas only move with the Earth's crust and not for any other reason.

[12] KSAT (Kongsberg Satellite Services) operates 11 antennas at Awarua SGS. These antennas form part of KSAT's global network that is used by spacecraft operators to stay in contact with satellites almost anywhere in orbit. KSAT's network is considered in the space industry to be the largest and most significant commercial ground network in the world, serving government, defence, and commercial customers globally. KSAT has advised us that they consider Awarua Satellite Ground Station to be a very important station in its network [supporting letter to be supplied].

[13] KSAT's antennas at Awarua SGS range in size from 3.7 meters to 6 metres in diameter. The antennas are used to support missions in low Earth orbit through to Lagrange Point 1 on the Sun-Earth System. KSAT is planning to erect two further antennas in mid-2027.

[14] SpaceOps NZ currently holds 506 radio transmitting licences for KSAT, supporting at least as many spacecraft from Awarua SGS.

[15] The following map shows the scope of KSAT's operation.

Figure 2. A map of the world showing KSAT's ground stations (after KSAT).

[16] The highly regarded ground station network provider, Leaf Space, based near Milan, Italy also operates antennas at Awarua SGS. Leaf Space is an international provider of Ground Segment as a Service (GSaaS), delivering satellite communications, tracking, telemetry and command (TT&C), and mission support services through a global network of ground station assets. Through its Leaf Line network, Leaf Space enables satellite operators to communicate reliably with spacecraft in orbit and supports a wide range of commercial, institutional, and scientific missions.

[17] Leaf Space considers Awarua Satellite Ground Station to be an important strategic location within its global ground network. The station's southern latitude, excellent radio environment, reliable infrastructure, and favourable horizon profile make it an attractive site for supporting spacecraft in low Earth orbit and beyond [supporting letter to be supplied].

[18] Leaf Space has four antennas at Awarua Satellite Ground Station that operate under 114 separate radio transmitting licences.

[19] Other GSaaS providers at Awarua SGS include ATLAS Space Operations from Michigan [https://atlasspace.com/], RBC-Signals [https://rbcsignals.com/] and Skynopy of France [https://skynopy.com/].

[20] New Zealand is at an important location for downrange ground stations for launch support. Awarua SGS was carefully chosen as the best place in New Zealand to support the Ariane 5 ATV launch campaigns and plays important roles for Ariane 6 Kuiper launches and Rocket Lab launches to the south. The importance of Awarua SGS for launch campaigns is now discussed.

[21] Orbital launches are international events that require downrange stations across the world in critical locations. A launch campaign will cost upwards of $NZD 10 million for a Rocket Lab Electron launch while an Ariane 5 launch was understood to cost €150-200 million.

[22] Acquiring telemetry data from the launch vehicles[4] in real-time is a priority, noting that the telemetry sent from, for example, a Rocket Lab launcher will contain the status of some tens of thousands of sensors. This information is critical to the launch as it provides information on the launcher trajectory, the trajectory of the payload once the payload spacecraft is ejected, and the health of the launch vehicle. The trajectory information is needed in real time so that subsequent downrange ground stations can acquire signals at the right time and point on the horizon, and flight controllers can immediately attend to any difficulties the launcher may encounter.

[23] The ground track for the first Ariane 5 ATV launch shown below gives a flavour of a launch involving Awarua SGS. The ground track starts at ESA's International Space Port in Kourou, French Guiana. Immediately after launch, the launch vehicle was tracked by a ship-mounted antenna in the Atlantic and then from a ground station on the Azores. Two stations in Australia tracked the launcher as it passed over Australia through to the Tasman Sea, where tracking was handed over to Awarua SGS. Shortly after the launcher signals were acquired at Awarua SGS, a critical Stage II burn and engine-cutoff manoeuvre (K2.2 and H3.2)

[4] We use the word "launcher" rather than "rocket" as the international space community finds the word "rocket" too closely associated with "missile" and fireworks.

was performed to “circularise” the launcher orbit into transfer orbit. As the launcher approached the eastern horizon for Awarua SGS, the ATV payload was injected into orbit (H4.1). Telemetry data before, during and after each of these manoeuvres were relayed in real time by duplicated transmission paths to the Kourou Mission Control Centre.

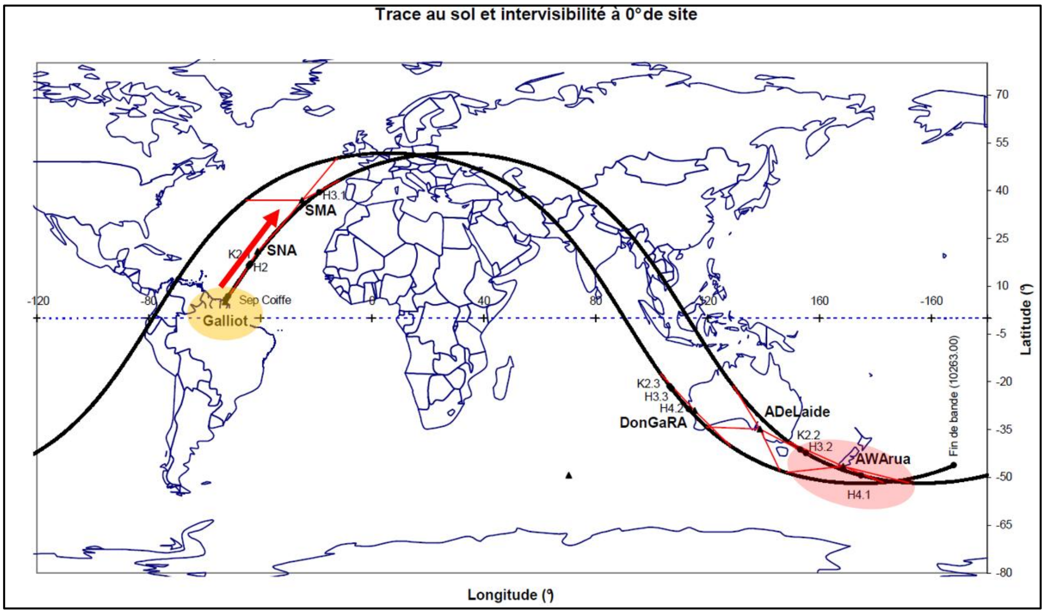
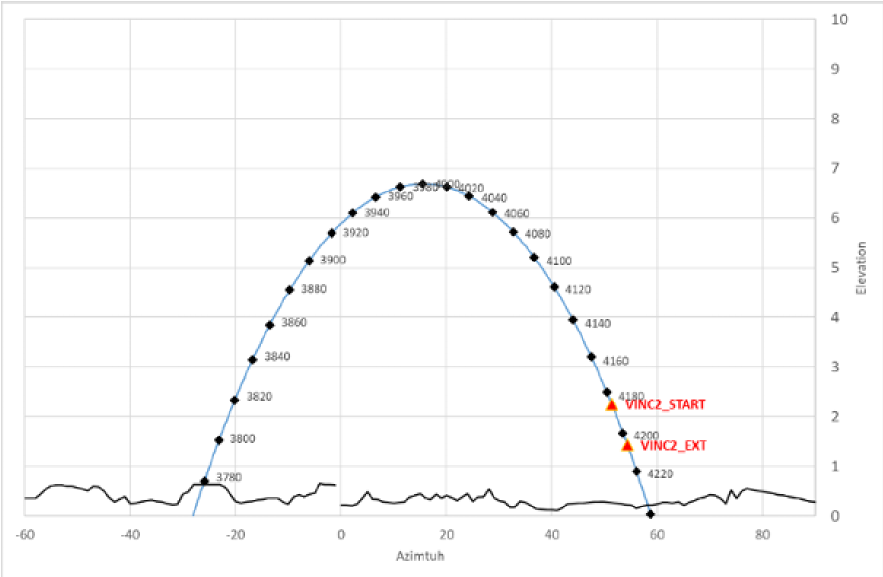


Figure 3. Ariane 5 ES ground track and launch events for ATV-1 launch, 2008.

[24] The importance of Awarua SGS to ESA for the five ATV launch campaigns became apparent when they were prepared to spend €200,000 to assist establishing Awarua SGS.

[25] The French Space Agency (CNES) continue to use Awarua SGS for launches: currently SpaceOps NZ has a contract to support 18 Ariane 6 Kuiper launchers from Awarua. The field of view for a pass is shown below. See also *CNES Site Survey 20250613.pdf* for other launch trajectories in this series.



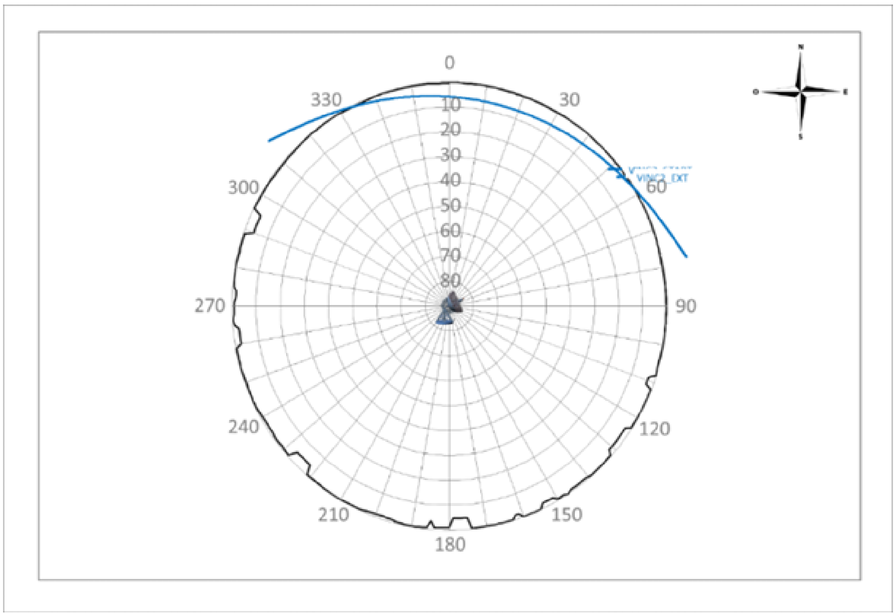


Figure 4. Antenna elevation-azimuth (top) and sky-track (bottom) for AWA-4 antenna required to support the launch of one of the planned Ariane 6 Kuiper launches (after CNES New Zealand Site Survey DTS/SDS/AS-2025.0006045 section 4.3.1.1). In the top "Elevation-Azimuth" chart, the numbers are seconds elapsed since lift-off. The start and finish of a critical manoeuvre are marked in red, occurring between 1.4° and 2.1° elevation.

[26] Antennas operated by KSAT at Awarua SGS have an important role in Rocket Lab's Electron launches from Mahia. Signals from the Electron launcher are first acquired approximately two minutes after launch, to provide back-up to Rocket Lab's Chatham Island ground station. More importantly, around 100 minutes later, the launcher is again acquired at Awarua SGS and provides to Rocket Lab's launch teams the actual state vectors (position and direction) of the launcher when its payload spacecraft were injected into orbit. It is important that this information is acquired quickly so that other ground stations around the world can

prepare to communicate with the payload spacecraft. Screenshots from the Rocket Lab live stream of a typical launch are shown below.

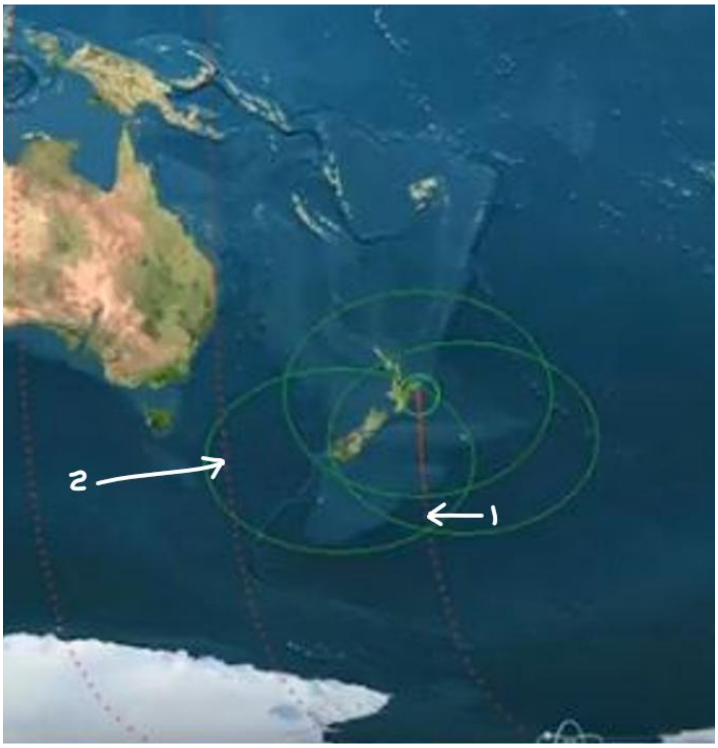


Figure 5. Rocket Lab Electron launch ground track. Awarua SGS acquires signal approximately 2 minutes after launch from Mahia (shown as 1) and approximately 100 minutes later (2). The third pass (far left of the map) is not visible from Awarua SGS.

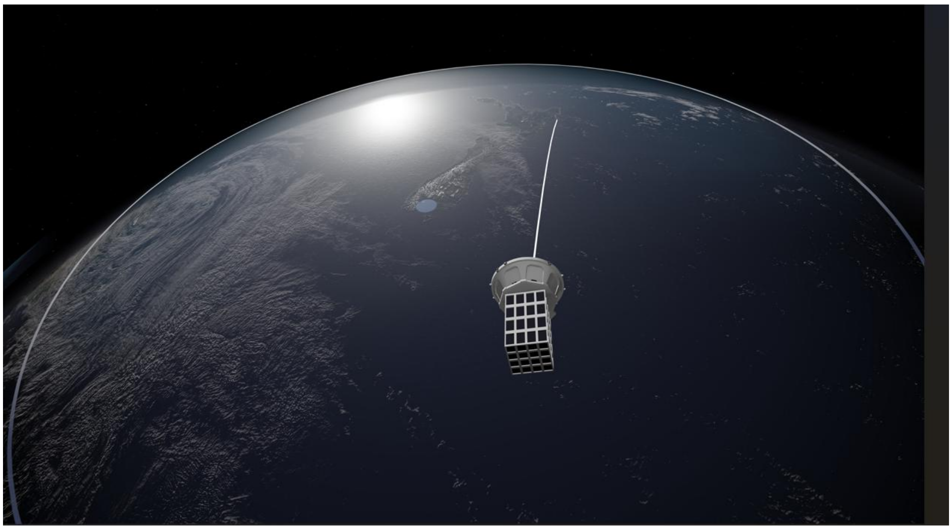


Figure 6. An artist's impression of the final stage of the Electron launcher and its payload, looking back to Awarua SGS.

[27] The look-angles for these passes are shown below.

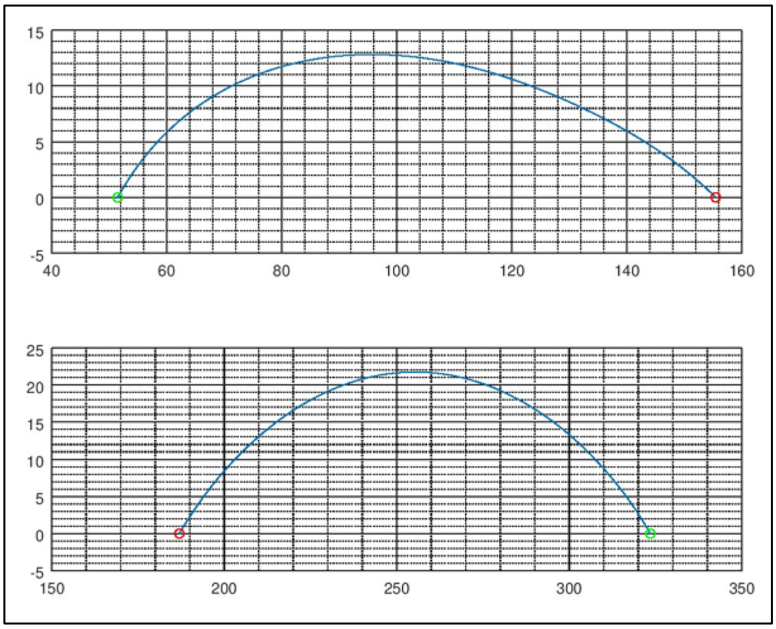


Figure 7. Nominal elevation/azimuth look-angles for a Rocket Lab Electron launching to the south. The top look-angles are for the first pass, shortly after launch an the lower look-angles are for the critical pass after injecting payload spacecraft. The green circles indicate the start of the pass and the red circles indicated the finish of the pass.

Horizon Mask

[28] My evidence now turns to the need for protecting Awarua SGS' horizon mask.

[29] My prior evidence highlighted the need for operating the antennas at Awarua SGS at low antenna elevations (also known as look-angles).

[30] The operating frequencies for the antennas at Awarua SAGS are generally above 2 GHz. At these frequencies, the radio signals follow line of sight paths and any physical obstructions, such as the ground, will attenuate or block the signals. In this light, it is clear that a ground station must be well clear of hills and mountains.

[31] Awarua SGS's location was chosen because it enjoys a very low horizon mask, as can be seen below. The highest geographic obstruction is Bluff Hill/Motupohue to the south-southwest (260°E). The site layout is designed to ensure that no manmade obstructions are greater than 5° elevation from any antenna at 0.4 metres height.

[32] The horizon mask (360° panorama) for antenna AWA-4 at Awarua SGS below illustrates the low elevation mask at Awarua SGS. The mask surveys were independently prepared by SpaceOps NZ and CNES and

confirm that the geographic horizon is less than 2° elevation and no man-made structures exceed 5° elevation.

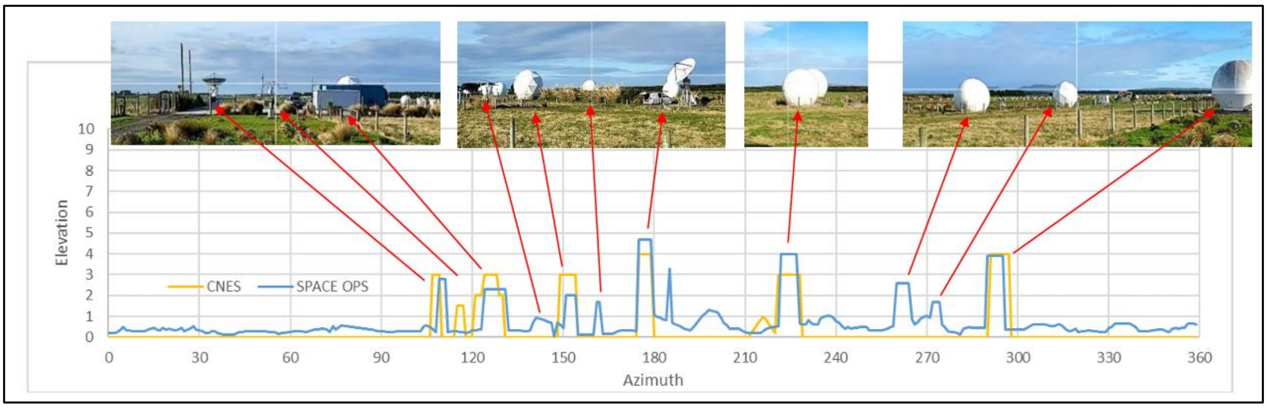


Figure 8. Horizon Mask for AWA-4 antenna at Awarua Satellite Ground Station (after CNES New Zealand Site Survey DTS/SDS/AS-2025.0006045 section 4.1.9).

[33] Not all customers require low horizons: one customer who operates their own spacecraft do not operate below 10° (see below) and another only operates above 20° elevation because they operate at sufficiently high frequencies that atmospheric water attenuates signals and require radio paths with short distances through the atmosphere. The SouthPAN antennas need only follow the "GEO-arc" (discussed later), operating mostly at around 40° elevation. These are the minority by far.

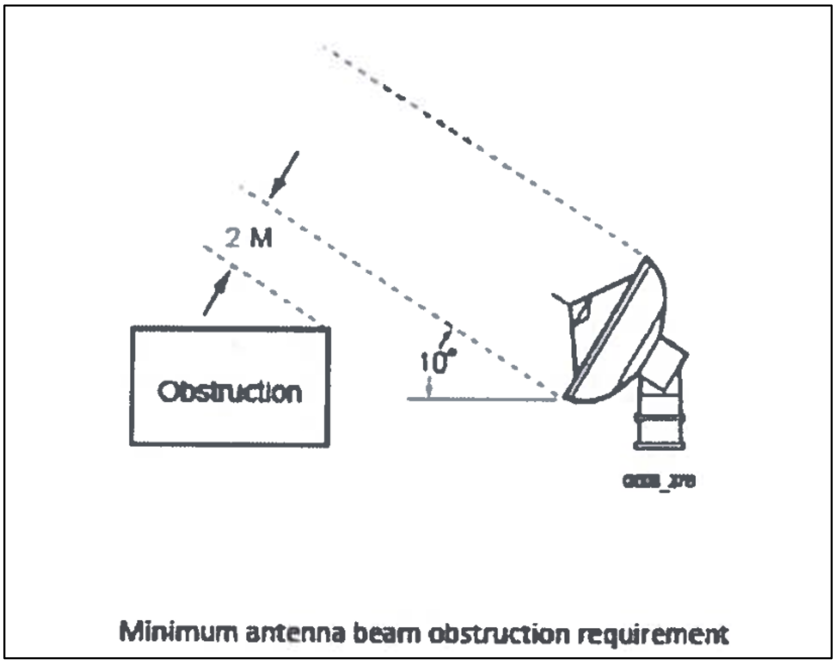


Figure 9. An example of a customer with a 10° elevation mask requirement.

[34] When visible at the horizon, spacecraft in low Earth orbit will be 2,400 or so kilometres away, making the signals some 40 times weaker than at

nadir (i.e. when the spacecraft is overhead). Thus, for normal operations, communications between a ground station and a spacecraft usually only occur when the spacecraft is at an elevation of 5° or more when conditions are favourable with the spacecraft in the order of 1,500 km away.

[35] For the first few hours after a spacecraft has been launched, it is vitally important to retrieve as much information as possible from the spacecraft to ascertain its health and to take remedial action if things are not well. This is known as Launch & Early Operation Phase (LEOP) and is the most critical part of a mission and where the mission is most likely to be lost. During LEOP, the ground station is generally only required to receive signals and the spacecraft operator will want to start acquiring data immediately after the spacecraft appears over the horizon and continue retrieving data until it disappears over the other horizon.

[36] For launch campaigns, telemetry data from the launcher is also critical as there is no chance of replaying the launch. Usually, the ground station will start to receive telemetry as soon as the launcher comes over the horizon. For the ATV launch campaigns, the CNES antenna was able to acquire useful data when the launcher was still below the horizon, at an elevation of -0.5°. Obtaining a very low horizon mask was one of the most important criteria for CNES when choosing Awarua for their ATV launch campaigns and again for their current Ariane 6 launch campaigns (see *Site Investigations for CNES: Awarua and Invercargill Airport,* (2024) and *CNES New Zealand Site Survey DTS/SDS/AS-2025.0006045, (2025)*).

[37] In short, with exceptions, all our customers highly value our extremely low horizon mask.

<u>Horizon Mask – Multi-path Interference</u>

[38] At high elevation angles, radio signals transmitted by a spacecraft to a ground station antenna will arrive only via a line-of-sight path, described as path D in Figure 101. When the spacecraft is low to the horizon, the ground station antenna field of view (its beamwidth) will include the ground. As a result, the ground station antenna will also receive signals reflected by the ground and any objects above the ground, shown in

Figure 11 as path D'. Should the reflecting object be good electrical conductor, it will reflect particularly well. The larger the object, the more this effect becomes obvious.

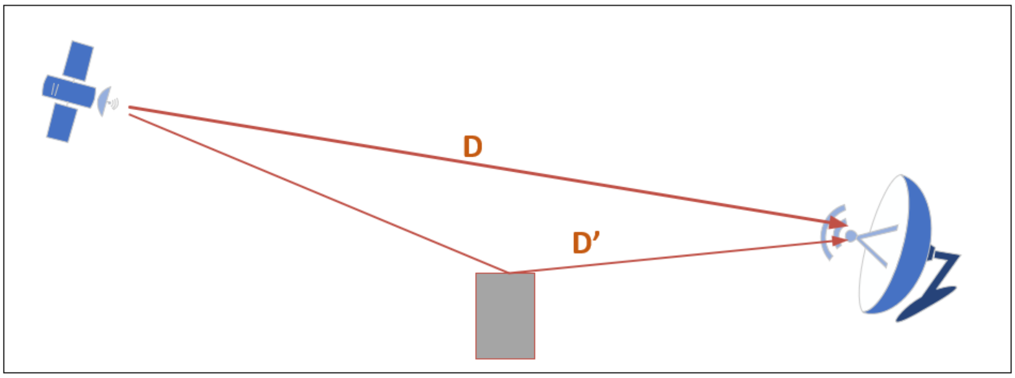


Figure 11. Radio paths between a ground station and a spacecraft.

[39] This description over-simplifies the real situation for the shape of the reflecting (or obstructing) object also introduces effects, but this is adequate for our purposes.

[40] The reflected signals will either constructively and de-constructively interfere with (i.e. add to or subtract from) the main signal, depending on the phase difference. At worst case, the received signal, being the sum of the main and reflected signals, will oscillate from twice the amplitude of the line-of-sight signal to completely disappearing as the distance between the ground station and the spacecraft changes. Radio engineers deal with this by ensuring that there are no obstructions within 0.6 of the diameter of a "Fresnel zone clearance".

[41] The first Fresnel zone radius at a point $d_1$from one end is $F_1 = \sqrt{\frac{\lambda d_1 d_2}{d_1+d_2}}$ (distances d_1 and d_2 are shown in the figure below, and λ is the wavelength of the radio signal), which simplifies to $F_1 \approx \sqrt{\lambda d_1}$ when close to one end of a long path.

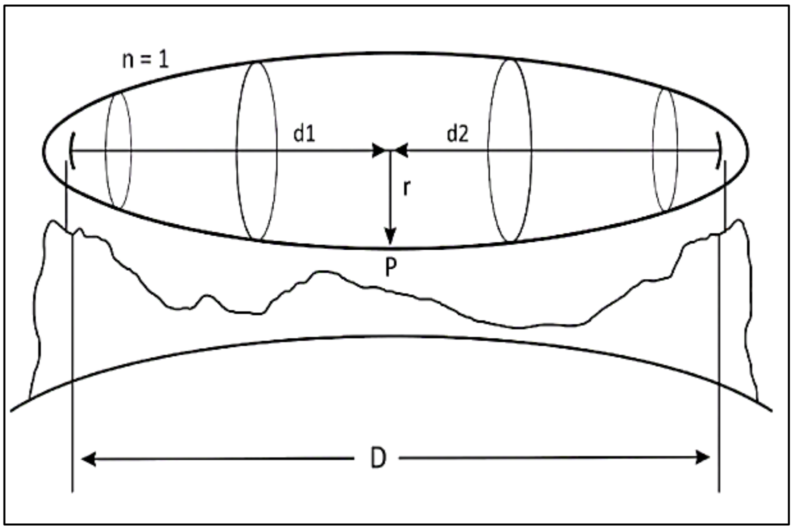


Figure 12. First Fresnel clearances for a radio path of length D. The clearance required at distance d_1 is r.

[42] The 0.6 First Fresnel clearances for a 2,500 km long radio path (a typical distance between a ground station and a spacecraft near the horizon) at 2.25 GHz in S-Band results in values below.

Table 1. 0.6 First Fresnel clearances for 2.25 GHz for a 2,500 km path.

Distance from antenna	**0.6 F1 clearance**
100 m	2.2 m
200 m	3.1 m
1 km	6.9 m
2 km	9.8 m
3 km	12.0 m

[43] These clearances need to be added to the actual height of an obstruction to give the required interference-free height needed. Because the Fresnel zone radius is dependent on the frequency being used as well as geometric considerations, we have chosen to ignore it in our determination.

[44] It is not trivial to calculate the actual degradation of radio communications caused by reflections: metallic reflectors are much more troublesome than, for example, trees. For this reason, a precautionary approach is required where the worst case is assumed until proved otherwise. This is the approach taken in Spark's Designation 7501 Warkworth Satellite Earth Station Restrictions *[Spark New Zealand Trading Ltd Designation 7501.pdf].*

[45] Using the standard, worst-case conditions takes a precautionary approach. SpaceOps NZ accepts that there may be occasions where

structures or vegetation penetrating the recession plane may not cause appreciable degradation to radiocommunications with spacecraft. These exceptions need to be each assessed on their own merits and may be found acceptable after modelling or physical testing shows this is the case.

<u>Horizon Mask —Vegetation</u>

[46] Vegetation has the potential to significantly attenuate radio signals at the frequencies used at Awarua SGS.

[47] The vegetation would only be a problem for lower elevation angles, but this is when the spacecraft are farthest away and signals are the weakest. Hedges and trees blocking the spacecraft from the antenna is most undesirable.

[48] The amount of attenuation can be calculated using equations in *ITU-R Recommendation P.833-10* (see www.itu.int/dms_pubrec/itu-r/rec/p/R-REC-P.833-10-202109-I!!PDF-E.pdf) and to a first approximation can be considered to be in the order of 0.4 dB/m at S-Band and 1.1 dB/m at X-Band. A macrocarpa hedge 6 meters thick could thus be expected to attenuate signals by 2.4 dB (42%) at S-Band and 6.6 dB (78%) at X-Band.

Spacecraft operation

[49] I now explain the different types of spacecraft supported by SpaceOps NZ at Awarua SGS so that the importance of having visibility to the horizon in all azimuths can be gauged. In order I address:

(a) Geostationary Earth Orbit spacecraft

(b) Low Earth Orbit spacecraft

(c) Deep Space support

(d) Launch support

(e) Global Navigation Satellite System reference stations

Geostationary Earth Orbit

[50] SpaceOps NZ currently hosts two 12 metre antennas used to track spacecraft in Geostationary Orbit (**GEO**). Spacecraft in GEO orbit the Earth 30,000 km above the Equator in the same direction as the Earth's rotation. The orbit period for a spacecraft at this height is exactly one day, resulting in the spacecraft appearing fixed in the sky to an observer on Earth.

[51] From Earth, all GEO spacecraft will appear to be confined to an arc across the northern sky (in the Southern Hemisphere). This is known as the GEO arc and is shown below for Awarua SGS.

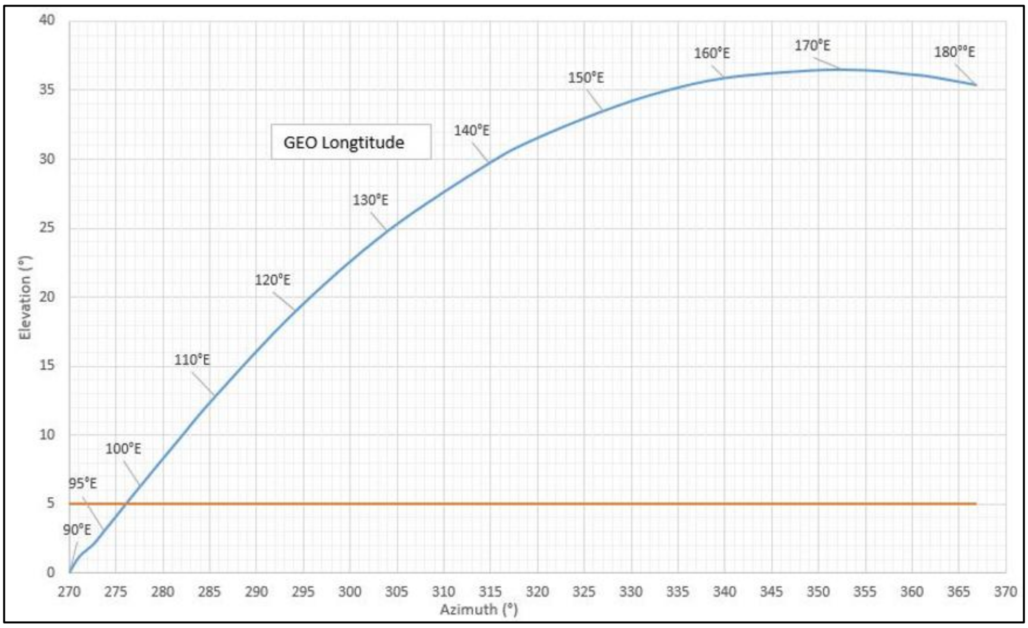


Figure 13. The Geostationary arc seen from Awarua SGS, covering west to north of the station. Geostationary spacecraft will be found on the blue line, starting at the horizon at 270° (due west) azimuth, rising through 10° elevation at 283° azimuth. (The arc does not continue to the east as there is little demand in New Zealand for spacecraft in that sector at present).

[52] From time to time, satellite operators with spacecraft in GEO wish to transfer the locations of their spacecraft above the Equator. Last year SpaceOps NZ tracked a spacecraft transitioning from a location in Indian Ocean Region (IOR) to Pacific Ocean Region (POR), beginning tracking at the horizon. This in known as a "Bring into Use" (BIU) manoeuvre. We foresee in the next two years the likelihood of the GEO antennas at Awarua SGS undertaking similar manoeuvres. This will require the horizon from 275°E to 283°E being unobstructed.

Low Earth Orbit spacecraft

[53] Low Earth Orbiting (**LEO**) spacecraft orbit the Earth at altitudes ranging from 400 km to 600 km.

[54] LEO spacecraft orbit the Earth every 1½ hours or so, depending on the actual orbit height, travelling at around 8 km/second. The spacecraft are only visible from a ground station for a short period of time: at best, a spacecraft passing directly overhead of the ground station would be "visible" for around 8 minutes. Other passes, where the spacecraft never rises much above the horizon, may only be visible for two or three minutes.

[55] As the spacecraft passes over a prearranged ground station, it will establish communications to undertake one or more of: (1) report the status of its systems, (2) accept commands, (3) upload software patches, and (4) download payload data. Typically, a LEO spacecraft will be scheduled to communicate with two or three ground stations per orbit, and during a pass duration of only a few minutes, will need to download all the files that it has generated and stored since its last pass of a ground station.

[56] Some spacecraft may only communicate with one or two ground stations around the world, meaning that a large amount of stored data will be downloaded as the spacecraft will only have ten or so opportunities each day to communicate with a ground station. For example, SpaceOps NZ has an agreement to communicate with a spacecraft that has Berlin as its only other ground station it can communicate with. Every minute of these passes becomes extremely valuable.

[57] A particularly useful LEO orbit takes the spacecraft close to over the North and South Poles on each orbit, enabling the spacecraft to be contacted to be commanded and, if appropriate, for the payload data to be downloaded from the same ground stations at or near the North Pole. There are many ground stations at these high latitudes for this purpose; however, so many ground stations viewing the same part of the sky causes congestion and many applications require a faster turnaround than 1½ hours, which makes ground stations as close to the South Pole very attractive.

[58] Because the Earth rotates under the orbiting spacecraft, the satellite ground track appears to shift 22.5° to the west for each consecutive pass. As can be seen by examining the example ground tracks in the figure below of the KIPP 43157 spacecraft (which was commanded from Awarua SGS before it de-orbited), for these passes the spacecraft would rise to the east-north-east and set to the south-east on the first pass; on the second pass it would rise from the north-north-west and set to the south-west.

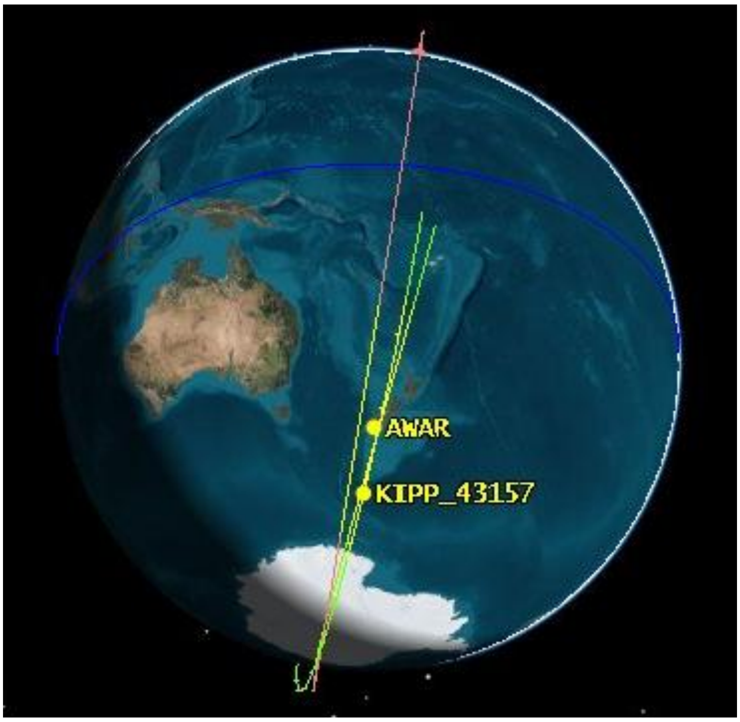


Figure 14. A typical LEO spacecraft in sun-synchronous orbit. In this example, the spacecraft is KIPP 43157. Awarua SGS is labelled “AWAR”.

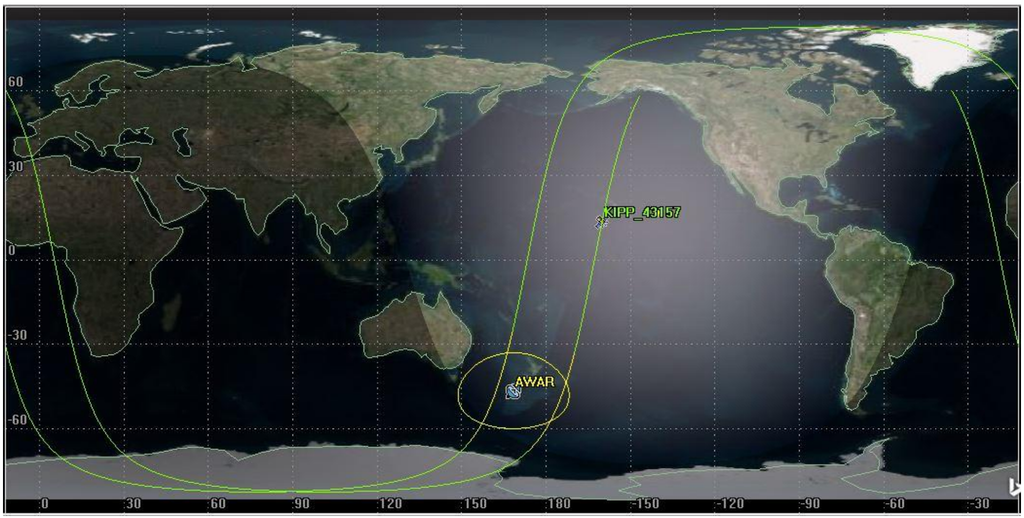


Figure 15. The "ground-track" for KIPP 43157, showing two "passes" of Awarua SGS (labelled AWAR). The yellow circle around shows the field of view limit for Awarua SGS for a spacecraft at the same altitude as KIPP 43157. The two passes are approximately 180 minutes apart.

[59] New Zealand is also an important location for communicating with spacecraft on an orbital inclination that includes both the South China Sea and New Zealand. The spacecraft may be tasked in New Zealand to gather satellite scenes or other information from the South China Sea for downloading in, say, Japan or vice versa shortly afterwards to provide near real-time domain awareness. Spacecraft seen from Awarua SGS ascending in this orbit will normally be expected to rise in the south-east and set to the north-west, and the other way around for descending passes. SpaceOps NZ is in advanced discussions with at least one potential customer for such use.

[60] The inclination of a spacecraft's orbit around the Earth is carefully chosen by the satellite operator to optimise the purpose of the mission. Spacecraft with orbit inclinations between 46.5° and 93° have the potential to pass directly over Awarua SGS. Lower inclination orbits will only pass to the north of the station. A sample of satellite passes for SpaceOps NZ's AWA-1 antenna shown below illustrates this.

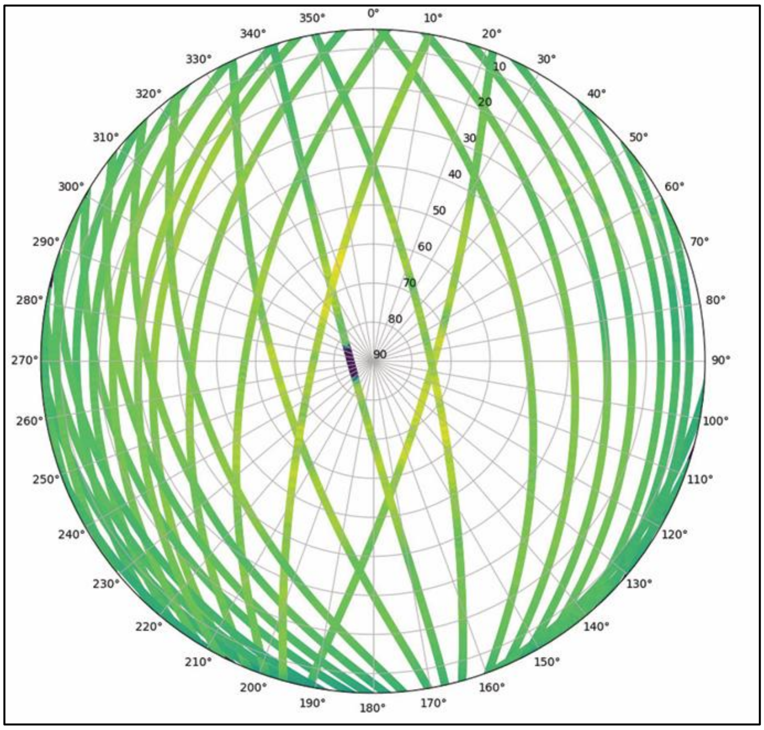


Figure 16. A sky-tracks for the AWA-1 antenna showing 37 consecutive passes of the Aqua spacecraft. The centre of the circle is directly up and the circumference is the horizon at 5° elevation. The colour of the sky-track indicates the signal strength. The antenna can be seen to be receiving the spacecraft's signals with strong signal-strength at 5° elevation (the design of AWA-1 limits its minimum elevation to 5°).

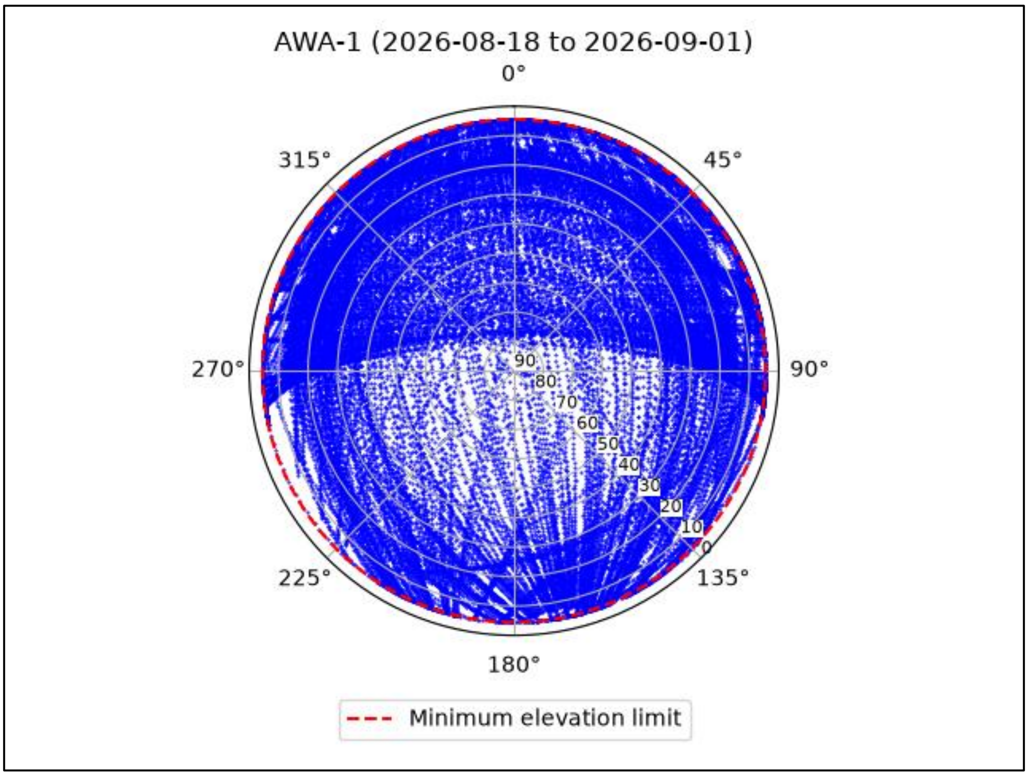


Figure 17. Sky-tracks for AWA-1 antenna showing passes for the fortnight 18 August 2026 – 1 September 2026.

Deep space support

[61] KSAT has a 6 metre antenna at Awarua, which is primarily tasked with communicating with the Solar Winds Follow On Mission spacecraft (SWFO-L1). SWFO-L1 orbits Lagrange Point 1 on the Sun-Earth system, a point 1.5 million kilometres away, directly in line with the sun. The mission provides real-time space weather observation and enables space weather watches, warnings, and alerts. Such information is important for safeguarding spacecraft, and electricity grids on Earth, amongst other things.

[62] From sunrise to sunset the antenna tracks SWFO-L1 from horizon to horizon. Depending on the time of year, SWFO-L1 rises from between 50° and 120° azimuth and sets between 230° and 305° azimuth.

Launch support

[63] The most critical part of a launch is when the payload spacecraft separates from the launch vehicle (sometimes called a rocket). With exceptions, separation is undertaken when the launcher reaches apogee (the part of the orbit where it is highest above the Earth). When it reaches apogee, the launcher will undertake an “apogee burn” to “circularise” the orbit and will then “inject” the payload spacecraft into this now circular orbit. This injection is also known as “separation”.

[64] The launch operator needs to know as quickly as possible the orbital parameters (direction and velocity) of the launcher when it injects the payload spacecraft to inform the payload owner how successful the launch has been, i.e. how well the actual orbit the spacecraft has been injected into matches the planned orbit. The payload spacecraft operator needs this information as soon as possible so that downrange ground stations can be immediately informed where and when should look to find their spacecraft to undertake LEOP (described later).

[65] For launches, the ground station receives telemetry data from the launch vehicle and does not transmit to the launcher. CNES consider it imperative to receive as much telemetry data as practicable to download as much data about the launch vehicle and its performance as possible. This means that the ground station will seek to start receiving as soon

as the spacecraft rises above the horizon and continue uninterrupted until it disappears below the horizon.

[66] The first launch campaigns supported at Awarua SGS were for ESA’s ATV launches. Publicly available estimates give the cost of getting each of the ATV spacecraft to space at €425 million.

[67] The ground track below shows the trajectory of the launcher and the five ground stations supporting the launch, including “AWArua" are labelled. Visibility of the trajectory is shown by red lines connecting to the ground track. Awarua SGS was critical for acquiring telemetry data at and after H3.2 (a second burn of the launcher engine) and H4.1 (separation). Awarua was also very important for tracking the launcher after event K4.2 when it was commanded to de-orbit. The elapsed time of the launch was 10,263 seconds (2 hours 51 minutes), but there were months of testing and launch rehearsals preceding it.

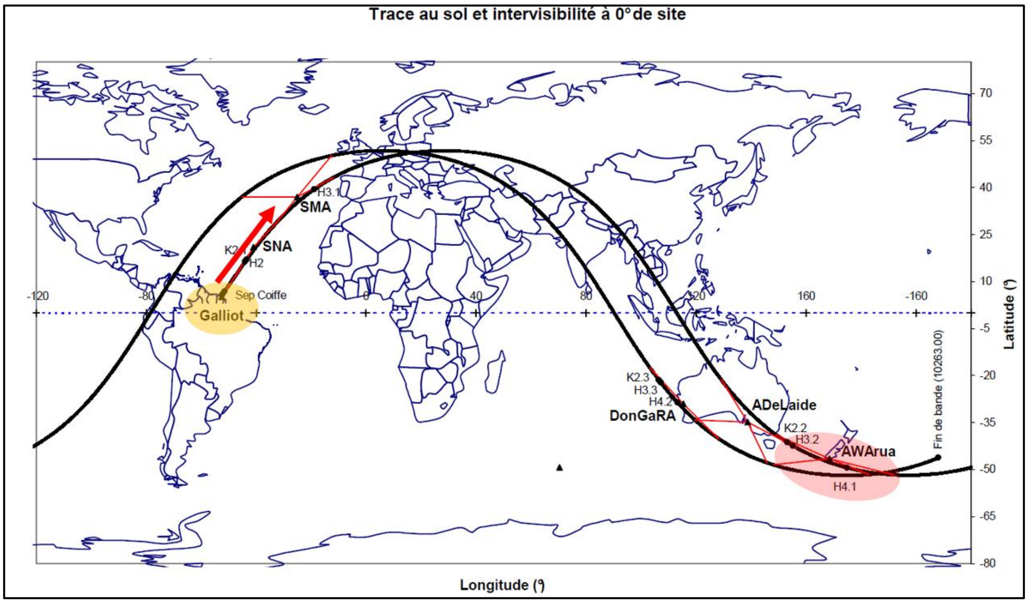


Figure 18. Ariane 5 ES ground track and launch events for ATV-1 launch, 2008.

[68] At the time of writing, SpaceOps NZ is preparing to support CNES for the fourth of eighteen Ariane 6 launches for CNES as they take Amazon’s Kuiper constellation to orbit. The launch trajectory depends on the orbital “shell” the constellation is to enter. This launch support is discussed in [*New Zealand Site Survey DTS/SDS/AS-2025.0006045*, 12/05/2025]. The elevation and azimuth of the SpaceOps NZ’s AWA-4 antenna required to track one of the launches is shown below. Each launch series has its own specific trajectories.

[69] SpaceOps NZ has a binding contract with CNES to provide downrange services for all the Ariane 6 Kuiper launches, which are to continue for the next two years. It would be reputationally and financially disastrous for SpaceOps NZ if Awarua SGS were unable to provide these services and it would be highly problematic for CNES to establish a replacement downrange station—most likely CNES would need to arrange for a shipborne antenna, at a cost of some million Euro per launch.

[70] The following examples below show the effect possible obstacles would have for SpaceOps NZ and its customers, noting that these are launch supports that SpaceOps NZ has existing commercial commitments in place. In this example we have shown four of the medium distant wind turbines proposed in Stewart Family Assets Ltd concession application to establish a wind farm in the Awarua Quadrant. (Two turbines, Turbines 6 and 7, proposed in the concession are not shown as they would overwhelm the drawing, noting that proposed Turbine 7 would subtend an angle greater than 43° elevation). The blue ellipses describe the turbine blade obstructions and the orange lines are at the hub height of the turbines.

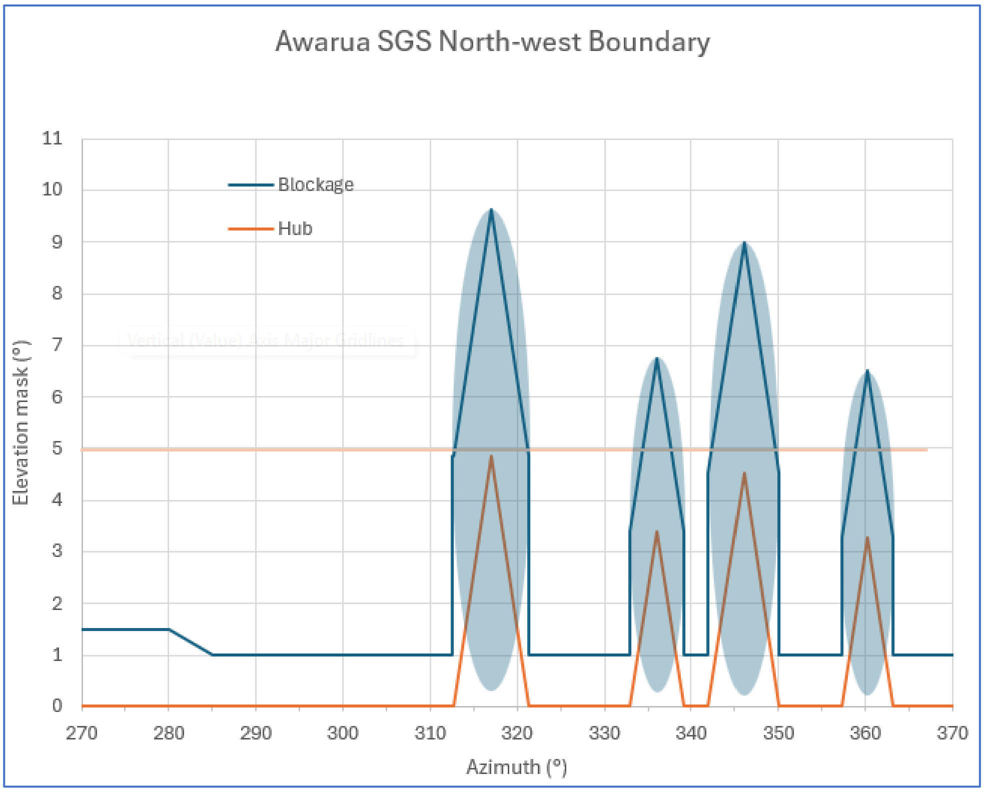


Figure 19. Potential wind turbine physical obstruction to North-west of Awarua SGS. The example wind turbines shown are Vestas V162 turbines, with hub height of 110 metres with tip height of 210 metres at distances of (from left to right) 1300 metres, 1860 metres,1400 metres and 1930 metres from the north-west boundary of Awarua Satellite Ground Station. The total azimuth range affected spans 50.6°.

[71] The yellow highlighting on the Ariane 6 Kuiper launch shown in the elevation-azimuth chart below indicates the part of the pass that would be blocked by the turbines. The numbers on the chart are the elapsed seconds since lift-off and it can be seen that a quarter of the pass would be obstructed by the turbines.

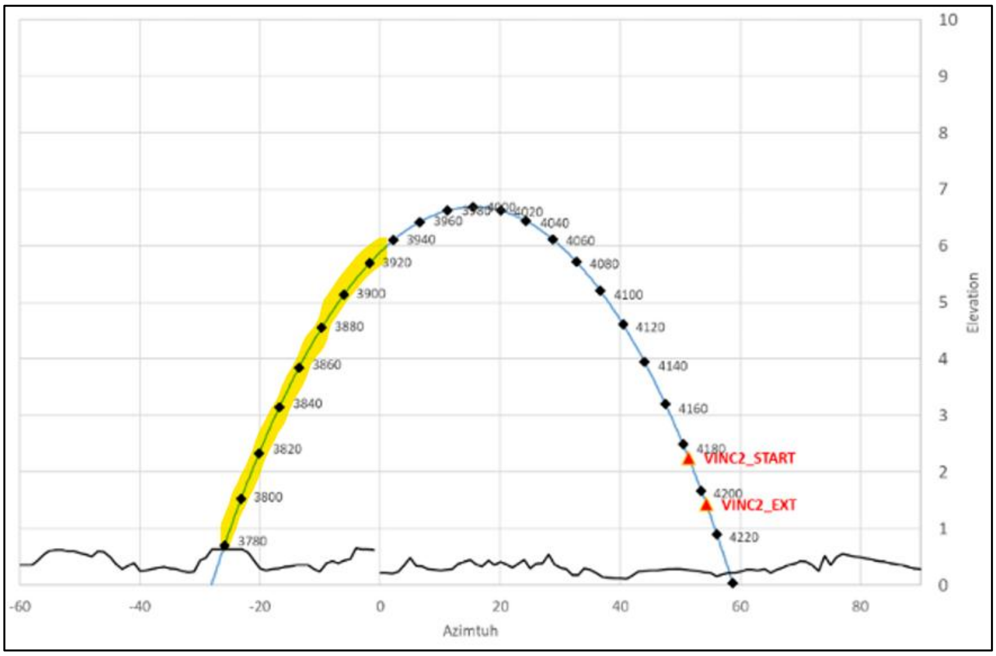


Figure 20 Just on 25% of the time the Ariane 6 launcher should be visible would be blocked by the wind turbines, shown above in yellow (i.e. 160 seconds of 640 seconds).

[72] The elevation-azimuth chart below describes the trajectory of Rocket Lab's first successful Electron orbital launch, "Still Testing" as it passes south above the Tasman Sea, as seen from Awarua. This pass provides the first confirmation of the success of separation. Again, the part of the trajectory viewed from Awarua SGS that would be obscured by the wind turbines is marked up in yellow.

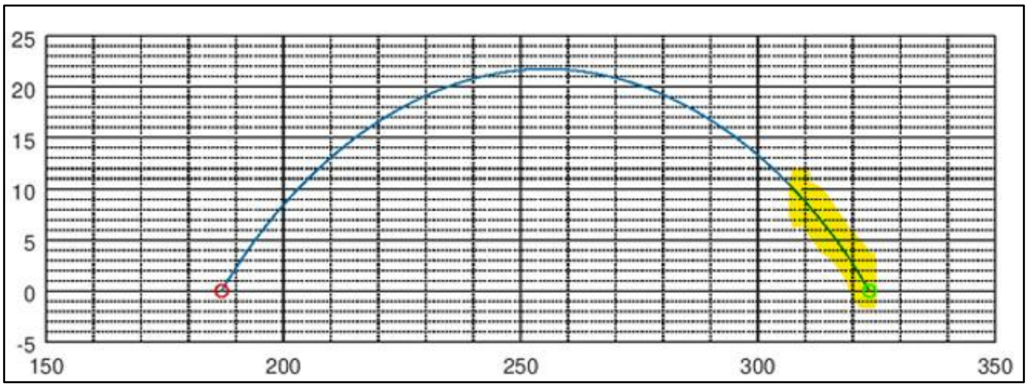


Figure 21. Rocket Lab's "Still Testing" launch nominal critical second pass would be partly blocked by the wind turbines shown above (blocked part of the pass is marked in yellow).

[73] Antennas at Awarua SGS continue to provide launch support for the Electron launches and because of Awarua SGS' location with respect to Rocket Labs' Launch Complex-1 facility at Mahia, it is difficult to see how this could change.

Global Navigation Satellite System reference stations

[74] The Global navigation satellite system (GNSS) spacecraft are commonly called GPS satellites and play important roles in positioning and timing. GPS is the most well-known GNSS constellation, and Galileo is the European equivalent.

[75] Lockheed Martin operate two 12 metre antennas at Awarua SGS to transmit reference data to spacecraft in GEO to be relayed to users in order to provide real-time time and position corrections to GNSS. The correction data is sourced from a network of calibrated reference stations, three of which are at Awarua SGS. The stations measure the distance between where they are known to be and where the GNSS data indicates they are. The suppliers of the reference antennas take great pains to ensure that there is no possibility of multipath signals reflected off neighbouring objects being received by the reference antennas.

[76] The European Space Agency Navigation Office has a reference station at Awarua SGS for use in the EGNOS service. It can be seen from a sample data set shown below that the reference station is looking to the horizon in all directions.

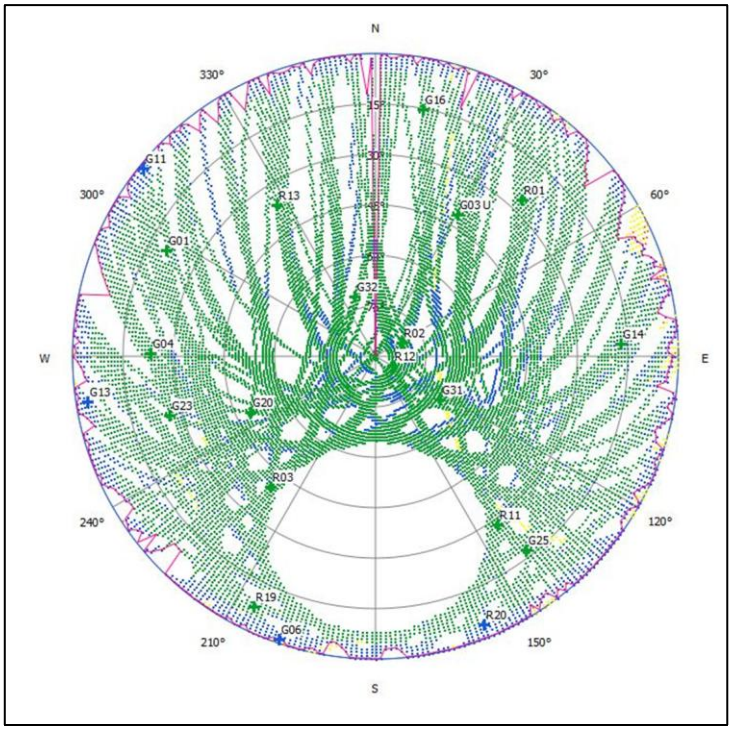


Figure 22. A random sample of GNSS spacecraft sky tracks as seen from the ESOC GNSS antenna for two hours. The centre of the circle is directly up and the circumference is the horizon at 0° elevation. (The inclination of GNSS spacecraft orbits mean that they appear from the ground to avoid the South Celestial Pole).

Horizon Mask implications for adjacent landowners

[77] Vegetation has the potential to significantly attenuate radio signals at the frequencies used at Awarua SGS. The amount of attenuation can be calculated using equations in 'ITU-R Recommendation P.833-10' (see *www.itu.int/dms_pubrec/itu-r/rec/p/R-REC-P.833-10-202109-I!!PDF-E.pdf*) and to a first approximation can be considered to be in the order of 0.4 dB/m at S-Band and 1.1 dB/m at X-Band. A macrocarpa hedge 6 meters thick could thus be expected to attenuate signals by 2.4 dB (42%) at S-Band and 6.6 dB (78%) at X-Band.

[78] Such vegetation would severely impair the reception of spacecraft were it to block the ground station antennas view of the spacecraft it is to communicate with. To avoid the risk of signal impairment, forestry plantings must be at least 430 meters distant to Awarua SGS and macrocarpa hedges more than 110 metres distant.

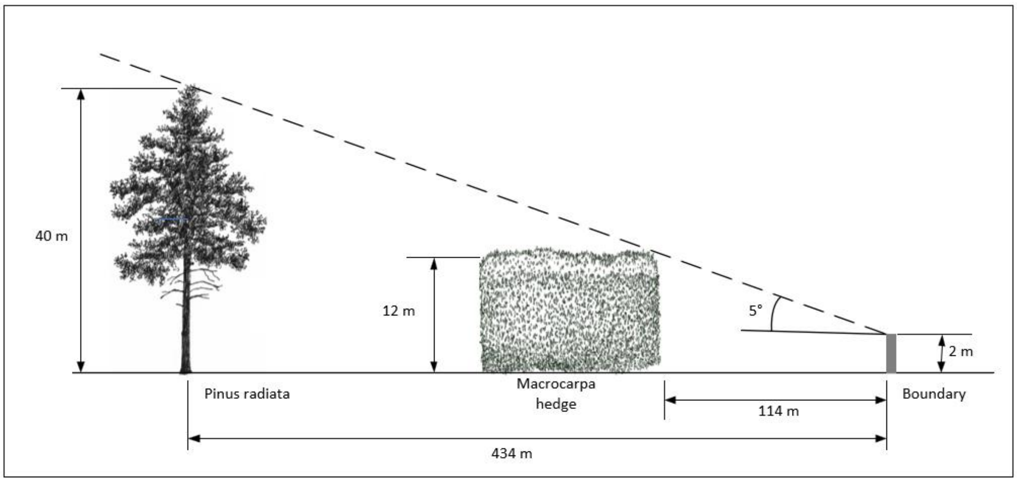


Figure 23. Proximity limits for trees and hedges for a 5° horizon mask.

[79] Predicting the impact of forestry blocks are less straightforward as the radio waves will to some extent diffract around them, which could make the blocking effect less pronounced. Engineering analysis is required to determine the effects and the ITU Recommendations describe the methodology.

[80] Buildings would seriously impair reception were they to block the spacecraft from the ground station. Buildings up to 35 metres high could be erected in the Awarua Quadrant and this would be acceptable providing they were at least 377 metres distant from Awarua SGS, as shown below.

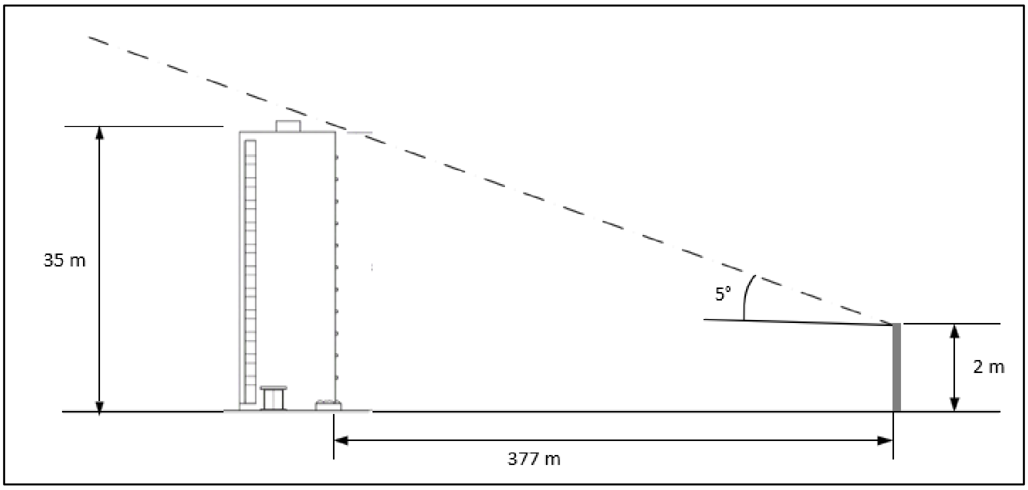


Figure 24. Horizon mask to a possible 35m permitted structure in the Awarua Quadrant.

[81] Depending on the shape and material of the structure, this limit could be relaxed. Again, detailed analysis is required to provide certainty.

[82] Wind turbines with turbine blades are made of carbon composite or other conducting material penetrating the horizon mask would be problematic. In practice, only some of the blade is likely to be made of conducting material and depending on a number of factors, may or may not be so problematic. It is not possible to predict how much or little a turbine blade will affect radio waves reflecting off it without undertaking measurements or detailed modelling. A turbine blade that was made of non-conducting material of a width in the order of wavelengths at the radio frequencies of interest may not interact with radio waves and so possibly not create problems. They would need to be studied on a case-by-case basis. Modelling the effects of wind farms on radio propagation is a research topic generating some interest, suggesting that understanding their effects is non-trivial.

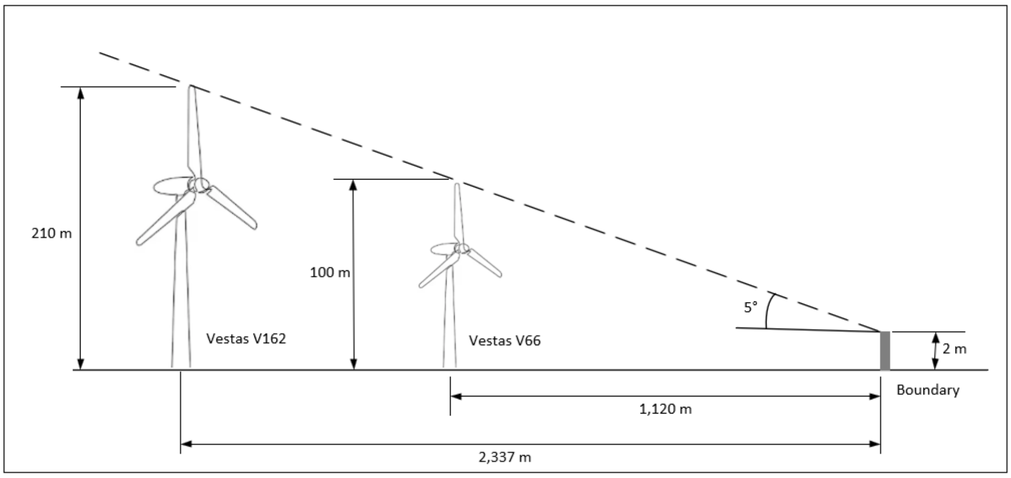


Figure 25. Proximity limits for nominal wind turbines for a 5° horizon mask.

[83] Experience at Awarua SGS indicates that power poles can attenuate signals by up to 2 dB or so (40%), depending how far they are from the antenna. The effects of the power line conductors are very frequency dependent and we do not have good data on the effects. We have not observed any EMI originating from the existing power lines. The design of the station to date has been to keep antennas away from power lines and to keep the power poles under the 5° pointing angle for the antennas, as shown in the figure below.

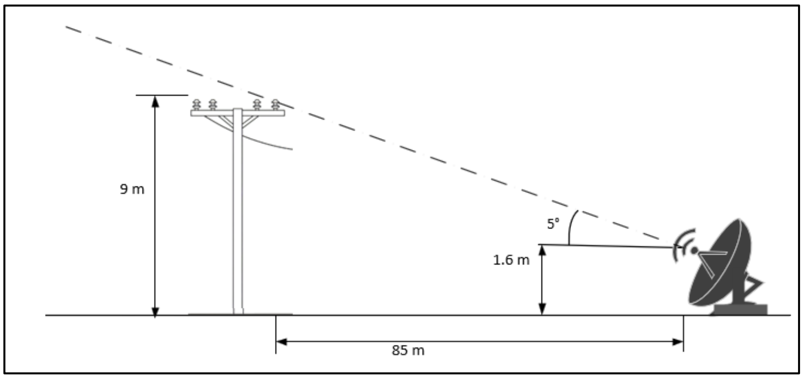


Figure 26. Power line clearance.

[84] An exception is the S___ gateway which operates at pointing angles higher than 20° and so this gateway station of nine antennas is much closer to the Colyer Road power line.

[85] In order to supply a customer at Awarua SGS who has requested a 750 kVA transformer for their facilities, SpaceOps NZ has contracted PowerNet to extend the power line along Awarua Siding Road to connect with the 11 kV three-phase power line on Colyer Road presently feeding transformers supplying the station.

[86] To avoid any existing customers' operation being affected by this power line, at its expense SpaceOps NZ is paying for the section of line to the north of the station to be undergrounded instead of using aerial power lines.

[87] We do not anticipate any further aerial pole lines will be established within 100 metres of Awarua SGS.

[88] In summary with respect to obstructions, although the requirement sets out a hard 5° elevation limit, there may well be cases where the obstruction does not interfere with the reception of signals at Awarua SGS. Such obstructions could be permitted, providing that they could be demonstrated beforehand to not materially affect reception.

<u>Horizon Mask practicalities</u>

[89] SpaceOps NZ chose to begin the horizon mask at 2 metres at the boundary of Awarua SGS as a concession to practicality. The 2 metre height also recognises that in order to ensure that neighbours and members of the public do not encounter non-ionising radiation from the

antennas above statutory limits, the antennas will necessarily be set back from the station boundary by at least 7 metres.

[90] Further, the station boundary security fence is some 1.8 metres high and so 2 metres is a pragmatic height for measurement.

Alternative methods to protect the horizon mask

[91] SpaceOps NZ considered carefully the horizon mask protection angle sought. From the above discussion, a 0° horizon mask would be ideal, but it is also impractical for even a typical 11 metre high macrocarpa hedge would have to be some 11.8 kilometres away to not intercept it, allowing for curvature of the Earth. It was for this reason that the exact siting of Awarua SGS was chosen, so that ATV would be seen to rise on the obstruction-free western horizon and set in gap between two distant macrocarpa hedges to the east.

[92] Similarly, an elevation plane recession angle of 3° was contemplated, to match discretionary RSM ground station transmitting rules. Although this would be practicable in the rural zone, it would mean that an object 35 metres tall in the Awarua Quadrant would need to be at least 670 metres distant, which we felt would be unachievable to secure.

[93] Worldwide, the industry expectation is that spacecraft in low Earth orbit should be contactable above 5° elevation. 5° is also the lowest limit that RSM and FCC (the USA equivalent to RSM) will normally licence a ground station to transmit at. In addition, 5° elevation is seen to provide a reasonable balance between maximising contact time with the spacecraft, acceptable propagation losses, tolerable multipath, terrain blockage and reduced antenna pointing errors.

[94] Exceptions to objects intruding into the horizon mask can be considered on a case-by-case basis, as discussed elsewhere. However, any exceptions would need careful consideration and take into account the material, size and location of such objects. Detailed engineering analysis could be required.

[95] At the same time, it would be necessary to ensure that the cumulative effects from multiple exceptions would not jeopardise the value of the station.

Electromagnetic Interference (EMI) protection

[96] It is critical that there is EMI protection for Awarua SGS: the signals received from LEO spacecraft are generally very weak. In in S-Band, the received signals will be in the order of -115 dBm to -130 dBm (3 x 10^{-15} Watts to 1 x 10^{-16} Watts) depending on where the spacecraft is in the sky. To receive such weak signals, the use of high-gain antennas and very sensitive receivers assisted by low noise amplifiers at the antenna are needed. Any EMI would desensitise the receive chains or overpower the spacecraft's signals and make communications with the spacecraft impossible.

[97] Until 2021, S-Band in New Zealand was managed spectrum for the mobile telephone service (cellphones). It was only by happenstance that the frequencies required for receiving spacecraft at Awarua SGS at the time were not in use by the mobile telephone service operators, although the ground station uplink frequencies were in use by them, which became very problematic.

[98] In conjunction with Rocket Lab, SpaceOps NZ was able to persuade Radio Spectrum Management (**RSM**) to make Awarua, Warkworth and Mahia special protection zones for space operations in S-Band in the abovementioned Decision when the mobile telephone service spectrum management rights expired in 2021.

<u>Alternative methods to EMI designation</u>

[99] There are no guaranteed ways to ensure that any exception made to the EMI designation would not deleteriously affect operation of Awarua SGS.

[100] Although hedges and vegetation will attenuate radio signals, they can only reduce interfering signals by a factor of 10 to 100 (-10 dB to -20 dB). Such attenuation is far too much for a spacecraft to ground station radio link to tolerate and would provide far too little attenuation to deal with a

terrestrial radiator, noting that the terrestrial emitter would be in the order of 20 million times stronger than the distant spacecraft.

Alternative sites

[101] In order to operate, modern satellite ground stations supporting LEO spacecraft require:

(a) Flat, drained land that, to be commercially viable, can accommodate at least ten antennas

(b) A horizon mask free of obstructions greater than (more than) 5° and preferably less

(c) Dual, route-diverse fibre-optic cable routes

(d) Reliable, three-phase electricity supply

(e) Absence of 8 GHz (X-Band) point-to-point microwave radio links

(f) Protection in 2 GHz (S-Band) spectrum from mobile telephone service operations

(g) Low EMI, associated with low population density

(h) Easy access to an airport

(i) Good logistics, including accommodation for visiting engineers

(j) Social licence.

[102] Each of these requirements is uncommon and meeting all of them has been found to be close to impossible. Venture Southland spent many months finding a limited use site at Lochiel that can accommodate one antenna, and Great South spent almost two years attempting to identify a suitable site in the north of New Zealand. These efforts are described shortly.

[103] The horizon mask requirements for LEO ground stations are fundamentally different to teleport ground stations. Teleports that

communicate with geostationary spacecraft, such as those operated by Spark at Warkworth and Gateway Teleport in Upper Hutt, need only “see” the geostationary arc, requiring only a moderately good northerly aspect. Further, the antennas can be mounted close to each other as they will not interfere with each other’s field of view. This simplifies the requirements for GEO teleports. This can be seen from inspecting Gateway Teleport’s ground station below.

Figure 27. Gateway Teleport's ground station in Upper Hutt (www.gatewayteleport.com) Because the antennas communicate only with spacecraft in GEO and point in roughly the same direction as each other, the teleport requirements are relatively undemanding.

[104] The need to have a horizon mask elevation less than 5° in all azimuth directions to communicate with most LEO spacecraft imposes strict conditions. Common constraints to achieve a 5° elevation mask on flat land (the distances increase for rising land) are:

(a) Macrocarpa hedges and shelter-belts need to be at least 100 metres away

(b) Plantation forests need to be at least 400 metres away.

(c) Single storey buildings should be at least 60 metres away.

(d) The site needs to accommodate the antennas at 40 – 50 metre spacing to prevent physical blocking.

[105] Finding land that meets these requirements is not trivial and as can be seen in the figure below, only around two antennas per hectare is achievable.

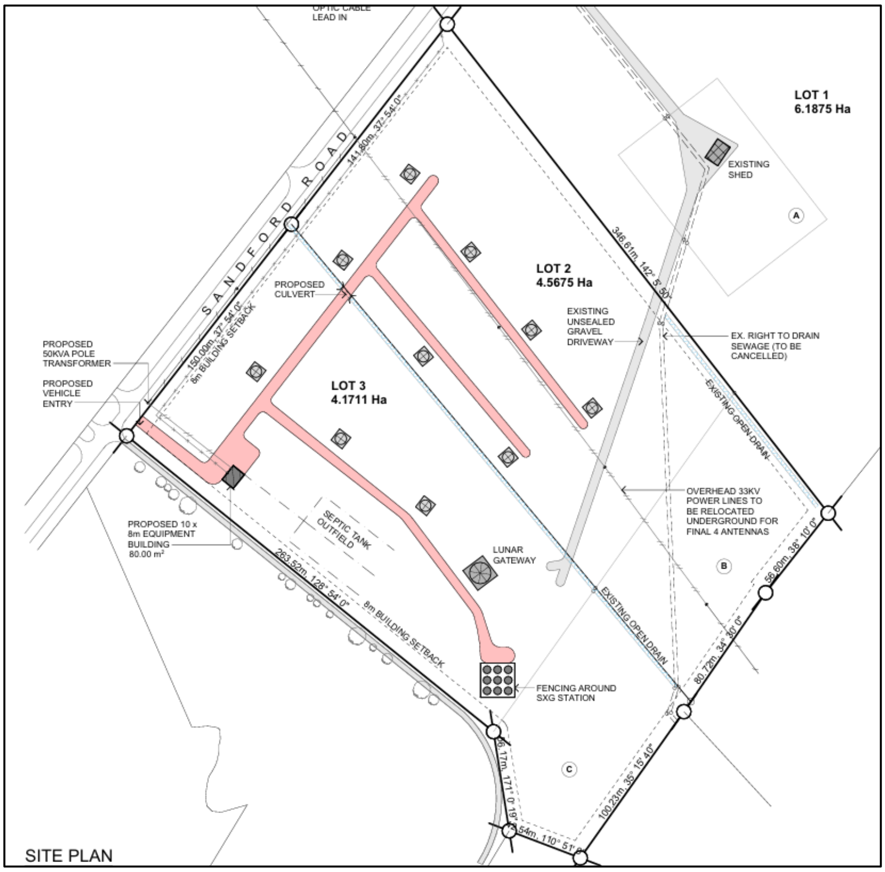


Figure 28. Proposed Great South Ruakaka Ground Station, showing a typical antenna layout for LEO support on a flat 4.6 ha green-fields site.

[106] The public and staff need to be protected from non-ionising radiation transmitted from the ground station antennas. To meet the current regulatory standards, the antennas at Awarua SGS must be at least 7 metres from any publicly accessible space [*Awarua SES EMR Assessment_v3.pdf*]. Notwithstanding, public concern (even if scientifically unwarranted) means that in practice that this distance needs to be substantially increased to achieve social licence (see below).

[107] The difficulties in establishing ground station is exacerbated by the need for the local community to extend social licence. Great South sought to establish a complementary station LEO station in the north of New Zealand in 2019-2021. It took some months to identify a location that could meet the requirements and more months to develop engineering plans and documentation that could be presented to the local community and local authority for consideration (*Ruakaka Station GS Board Submission 20201215.pdf, Ruakaka Ground Station - Permitted Activity as Network Utility Operator 20201221.pdf, Ruakaka Station Telfer*

Young Report.pdf, Ruakaka Station Site Layout Dawson Design 20200903.pdf). Great South went to considerable effort in an attempt to gain social licence (*Ruakaka Site Visits and Community Meeting 20210100.pdf*). In spite of this, the local community made it very clear that a ground station would be most unwelcome, even though the arguments presented were spurious. Eventually Great South was forced to abandon its efforts in this direction completely as no alternative site could be found.

Economic Impact of Awarua SGS

[108] All of SpaceOps NZ's customers operating at Awarua SGS are overseas owned and operated. As such, SpaceOps NZ in effect sells "Weightless Exports" and was able to win the 'NZAS Innovation in Export Recognition Award' in the Export Southland Recognition Awards in 2022 (https://southlandchamber.co.nz/hall-of-honour/).

[109] The thirty 3.7 metre class dish antennas at Awarua SGS cost in the order of $USD 500,000 - $USD 600,000 and the radomes covering the antennas cost another $USD 100,000 or so. Site works typically cost $USD 100,000. A team of specialist engineers will normally install and commission the antenna. A new operating antenna in this class will thus cost between $USD 800,000 - $USD 900,000 ($NZD 1.4 – $NZD 1.6 million) to establish.

[110] There are two 12 metre antennas at Awarua SGS, which cost in excess of $NZD 3 million each to erect and commission.

[111] Only the SpaceOps NZ antennas are owned by a New Zealand entity. The 30 antennas and two 12 metre antennas at Awarua SGS thus represent around $NZD 50 million of direct overseas investment.

[112] SpaceOps NZ currently comprises 11 fulltime staff and supports approximately three more staff providing consulting services. In addition, the Awarua Satellite Ground Station has attracted GlobalStar and Lockheed Martin to locate a total of 9 staff based in Invercargill. The Awarua SGS has thus attracted a total of 20 high-tech jobs to Invercargill and at least two more are anticipated in the coming months.

[113] More than a dozen engineers and others from overseas space companies visit Awarua SGS each year for several days or weeks at a time, contributing to the local hospitality industry. It is estimated that over 30 bed-nights were attributable to these visitors in March 2025.

Revised conditions

[114] SpaceOps NZ has considered concerns of submitters in respect of the restrictions proposed. The conditions proposed in Mr Dunn's planning evidence seek to address those concerns.

[115] The revised conditions also provide a substantive approval test. Where a penetration will not materially compromise the ability of Awarua SGS to acquire, track, or communicate with spacecraft, or where the effect can be appropriately mitigated, approval is to be available. Written reasons and a defined process improve certainty for landowners and developers.

[116] A defined process is necessary to ensure that sufficient rigour is applied when analysing the effects of a potential penetration into the recession plane to ensure that contracted and proposed support of spacecraft from Awarua SGS would not be affected and to ensure that cumulative effects remain manageable.

[117] Penetrations of a temporary nature could be dealt with through scheduling the erection of the temporary structure for periods when launches were not planned. Advanced notice of some months would still be required so that customers at Awarua SGS would have sufficient to modify their schedules (which may in turn require them working with their customers in the case of ground station network providers), or to advise that they would be supporting missions that make use of that part of the sky and that the erection would need to occur at another time.

Conclusion

[118] In my opinion, Awarua Satellite Ground Station is an infrastructure asset of national and international significance. Its operational value derives not only from the facilities established on the site, but from the unique physical and radio-frequency characteristics of its location.

[119] The evidence demonstrates that unobstructed low-elevation visibility and protection from electromagnetic interference are fundamental operational requirements for spacecraft support, launch support, GNSS augmentation services, and deep-space missions.

[120] The proposed designation is intended to preserve those characteristics and thereby enable the continued safe, reliable and efficient operation of Awarua SGS for existing and future users.

Dated: 14 September 2026

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Robin McNeill