New Zealand's role in the global geodesy supply chain through collaboration and innovation.

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SUMMARY

New Zealand plays a pivotal role in the global geodesy supply chain through its strategic location and collaborative efforts. Positioned in the southwest Pacific, New Zealand is uniquely situated to monitor tectonic activity and sea level changes and provide data critical to the global geodesy community.
Over the decades, New Zealand has contributed to and supported many global geodetic initiatives. These include operating the VLBI station at Warkworth, supplying GNSS data from our PositioNZ network to the IGS, hosting a DORIS/REGINA station on the Chatham Islands, supporting absolute gravity campaigns, and sharing our data to contribute to global geoid models. These efforts highlight our commitment to international collaboration.
However, as is common within the global geodesy supply chain, our infrastructure is aging, and the global, regional, and even local benefits of such systems are not widely known or appreciated. Addressing these challenges requires innovation to develop new solutions and maintain our contributions.
Geodetic infrastructure within New Zealand came to the forefront of the geodetic community's concerns in late 2022 when the Warkworth VLBI came under threat of closure. With support from the international community, New Zealand Government moved swiftly to find a new supplier, SpaceOps NZ, so that the supply chain has remained intact. This situation demonstrated our resilience and ability to adapt quickly to ensure continuity. With the help of the international community, we have advanced through steep learning curves of VLBI operation and the more technical aspects of the VLBI contract.
However, this is only a small piece of a much larger problem. The VLBI at Warkworth is approaching its 20-year anniversary, and it is an opportune time to develop a strategy to ensure the continuity of VLBI measurements in New Zealand for the next few decades. This includes improving the resilience of the station, an issue highlighted in late 2024 when a failure of two parts resulted in an outage of several months as replacement parts were sourced.
New Zealand's strategic location and long-standing commitment to global geodetic initiatives demonstrate our commitment to maintaining and advancing geodetic infrastructure. As we face the challenges of aging infrastructure and evolving operational needs, it is crucial to continue fostering international partnerships and combining resources to invest in innovative

solutions. By doing so, we can ensure that New Zealand remains a vital contributor to the global geodesy supply chain, providing critical data for the benefit of our communities.

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INTRODUCTION

New Zealand sits in the southwest corner of the Pacific Ocean. As shown in Diagram 1 below, the country's two largest islands straddle the boundary between the Pacific and Australian plates. This plate-fixed model shows the average plate tectonic movement in New Zealand relative to the International Terrestrial Reference Frame 1996 (ITRF96), the global frame upon which the local geometric datum is built.

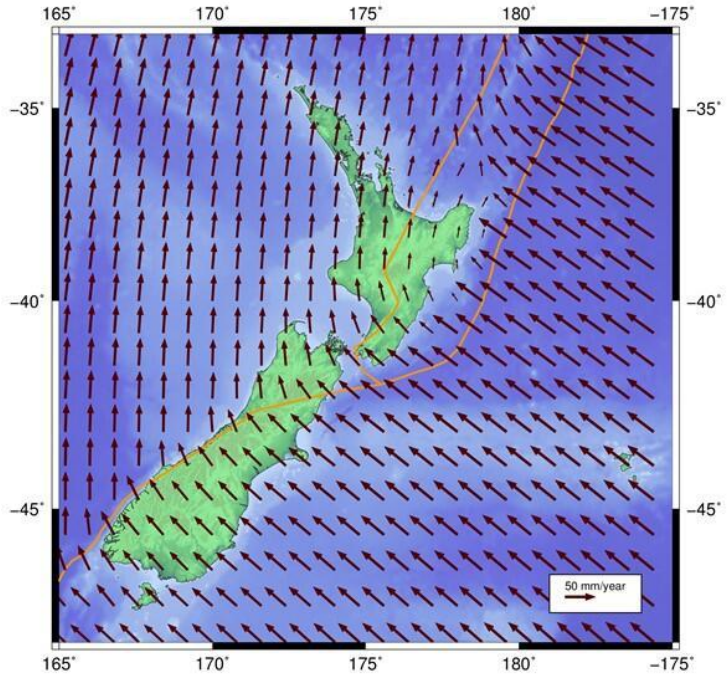

Diagram1: Shows vectors of approximately 5cm a year (north-west for the Pacific Plate and north for the Australian Plate) superimposed over a map of New Zealand.

Due to its geographic position, tectonic activity, and strategic location, New Zealand plays a pivotal role in the geodetic supply chain. The country is uniquely positioned to provide data critical to the global geodesy community, serving as one of the final large landmasses at the southwestern edge of the Pacific Ocean.

GEODESY IN NEW ZEALAND

Toitū Te Whenua Land Information New Zealand (LINZ) is the government department responsible for New Zealand's geodetic and survey control systems (CSA, 2002). In New Zealand the Geodetic System and the Cadastral System are closely aligned, so the key responsibilities of the geodetic group at LINZ include the provision and maintenance of national geodetic and vertical datums, the establishment of control marks to provide connection to the datums, updating geodetic coordinates and the national deformation model, and maintenance of survey marks and beacons.

More substantial geodetic infrastructure is often provided, operated and/or supported by taking a collaborative approach with interested parties both nationally and internationally. As LINZ has an open data policy, any geodetic data collected by LINZ is shared publicly under a CC-BY 4.0 licence.

The two official datums of mainland New Zealand are New Zealand Geodetic Datum 2000 (NZGD2000) and New Zealand Vertical Datum 2016 (NZVD2016).

NZGD2000 is the official geodetic datum of New Zealand. It is a semi-dynamic datum, meaning that while the coordinates appear static over time, tectonic and regional deformation is accounted for in a deformation model. This model adjusts modern coordinates to relet the ongoing movements, ensuring they appear static to users of the datum NZ. It is aligned with ITRF96 at epoch 2000 (Blick, 2005).

NZVD2016 is the official vertical datum of New Zealand. (LINZ, 2016). The datum enables consistent normal-orthometric heights to be produced across the country from GNSS. It is based on the reference surface New Zealand Quasigeoid 2016 (NZGeoid2016), which is an update of the previous New Zealand Quasigeoid 2009 (NZGeoid2009). The update includes data from the 2014-2015 airborne gravity surveys, the flightlines can be seen in Diagram 4 (in the section below)

THE GEODETIC SUPPLY-CHAIN

The geodetic supply-chain is a concept to describe the process of deriving geodetic products, like ITRF2020, from geodetic ground station observations. The types of ground station observation techniques include Global Navigation Satellite System (GNSS), DORIS, Satellite Laser Ranging (SLR), and Very Long Baseline Interferometry (VLBI). The data collected from these observations is then processed and analysed, and from the analysis products like Earth Orientation Parameters, global reference frames, and gravity field models are produced. The products are then adopted by users, which includes a wide variety such as navigation,

safety of life services, financial systems, energy sectors, and telecommunications (UNGGIM, 2025).

GEODETIC INFRASTRUCTURE IN NEW ZEALAND

LINZ plays an active role in providing various elements of geodetic infrastructure within New Zealand, including operating the PositioNZ (https://www.linz.govt.nz/products-services/geodetic/positionz) CORS network and a network of co-located tide gauges, maintaining absolute gravity sites, hosting a DORIS/Regina station, and facilitating the operation of a VLBI-capable antenna.

PositioNZ is a national network of 37 continuously operating reference stations (CORS), including one at Scott Base in the Ross Sea Region of Antarctica. These stations are operated in partnership with GNS Science, a Crown Research Institute. Six of these sites are part of the International GNSS Service (IGS). The locations of these sites within New Zealand are shown in Diagram 2 (Gentle, Gledhill and Blick, 2016). Services related to the PositioNZ network include real-time streaming, a RINEX data archive, and an online coordinate post-processing service

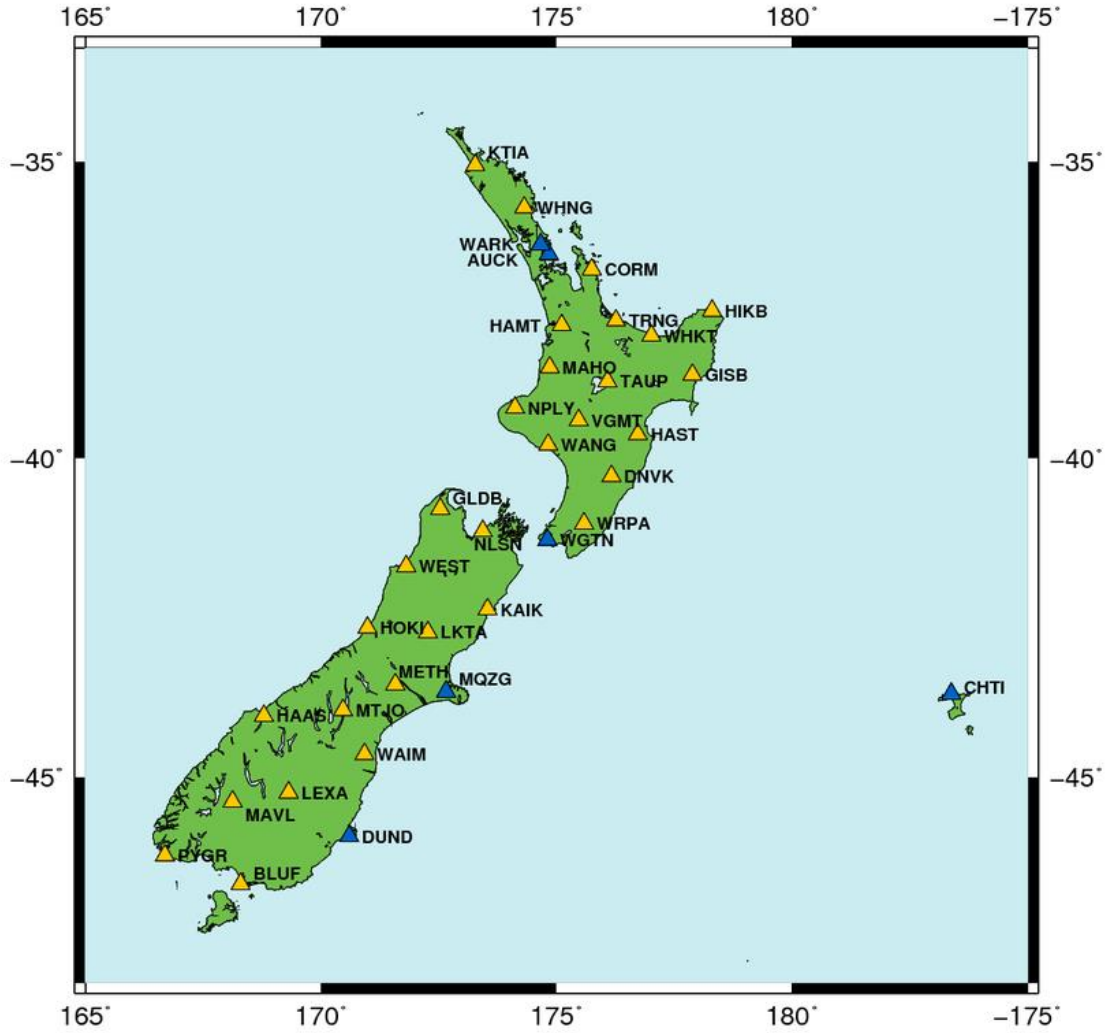

Diagram 2: The LINZ PositioNZ network (Yellow triangles) mainland New Zealand and the Chatham Islands, (Blue triangles) PositioNZ International GNSS Service (IGS) stations.

The New Zealand GNSS at Tide Gauge network, shown in Diagram 3, consists of 10 sites located around the main islands of New Zealand. Four of these sites are long-term installations at major ports, while the remaining six are either operational or in the process of being installed. These sites are operated by GNS Science under contract to LINZ. This network aims to establish sufficient collocated infrastructure along New Zealand's coastline to accurately determine absolute sea level changes and account for vertical land movement.

Diagram 3: The GNSS at Tide Gauge Network is comprised of four existing sites (shown in orange), and six newly installed sites (shown in grey).

There are six absolute gravity sites in New Zealand, which are observed irregularly, and often as “opportunity campaigns” such as when an absolute gravity meter is transiting through New Zealand to Scott Base to support projects such as POLENET (Rogister, Yves, et al, 2013). The location of these sites is shown in Diagram 4.

Diagram 4: The six absolute gravity sites shown as triangles, and flight lines from the 2014-2015 airborne gravity survey campaign that contributed to NZVD2016.

New Zealand supports CNES, the French space agency, and IGN, the French geographical information agency by hosting a DORIS/REGINA station on the Chatham Islands, one of our more remote and sparsely populated islands, 800km east of the South Island.

Photo taken during the 2016 DORIS/REGINA local tie survey (LINZ, 2016).

VERY LONG BASELINE INTERFEROMETRY

Very Long Baseline Interferometry (VLBI) is a geodetic observation technique, that has other applications, where multiple radio telescopes across the globe simultaneously observe celestial objects. These observations are used to help define earth orbit parameters and international celestial reference frame and other geodetic products (Schuh and Behrend, 2012).

WARKWORTH SPACE CENTRE

One of New Zealand’s key geodetic infrastructures is the Warkworth Space Centre, located approximately 60 kilometres north of Auckland. This facility includes a 12-metre antenna, a 30-metre antenna, and a hydrogen-maser clock. Originally, the observatory was used for satellite telephone services and broadcast the televised 1974 Christchurch Commonwealth Games. The 12m antenna was installed in 2008, and VLBI observations started in 2010. This 12m antenna is capable of X-band and S-band observations (Gulyaev and Natusch, 2008).

Diagram 5: Warkworth Space Centre’s 12m antenna

Over time, the site has become vital for radio astronomy and geodesy in the Southern Hemisphere. Compared to the many Northern Hemisphere VLBI stations, which are densely concentrated in Europe, North America, and East Asia, the Southern Hemisphere, has far fewer stations. ITRF2020 used 41 years of VLBI data from 117 sites, and of those sites only 14 were from the southern hemisphere (Altamini et al, 2023). In addition, not all the southern 14 stations are still active. This scarcity of distribution is partly due to the geography, population density and other factors, making each Southern Hemisphere site is particularly critical to the supply-chain.

CONTRIBUTION TO INTERNATIONAL GEODESY

The four space geodetic techniques (DORIS, GNSS, VLBI and SLR) all contribute to computing International Terrestrial Reference Frame (ITRF). The International VLBI Service for Geodesy and Astrometry (IVS) is an international consortium organisation involved with VLBI operations. The IVS has various analysis centres which process VLBI data, to contribute to ITRF models (Altamini et al, 2023).

As an IVS station, Warkworth participates in multiple weekly sessions which are crucial for creating the ITRF and monitoring Earth Orientation Parameters. The station also contributes to the AUSTRAL sessions, alongside the AuScope and Hartebeesthoek stations. These observations, combined with data from other IVS stations, enable precise measurements of Earth's rotation and orientation with such parameters as Polar motion, Polar motion rate, Length of day, UT1 minus UTC, and Nutation offsets.

THREAT OF CLOSURE

In late 2022, the Warkworth site was scheduled to close, which would have meant the end of the VLBI observations conducted there. As previously mentioned, this site is significant to the international community due to its geographic location. Its closure would have deeply reduced the number of active VLBI stations in the Southern Hemisphere. New Zealand received an overwhelming response from the international community, helping to demonstrate the importance the site’s importance. This external input helped decision-makers understand the critical nature of this infrastructure, not only to New Zealand but also the global community.

The New Zealand Government, quickly moved to find a new supplier capable of operating a satellite ground station, with SpaceOps stepping in to ensure the ongoing operation at Warkworth. Adapting to new challenges is crucial to maintaining an unbroken geodetic supply-chain remains unbroken. This level of resilience is essential for ensuring continuous delivery, as key parts of the supply-chain are often sustained on an informal and voluntary basis.

THE BENEFIT OF COLLABORATION

New Zealand is committed to international geodesy, supplying outputs from our infrastructure. While we support the wider community and hope to see improvements worldwide, New Zealand has much to gain by supporting international geodesy, as we are also reliant on the global products that are produced by the international community. For example, an accurate, up-to-date ITRF model helps ensure we have an accurate New Zealand geodetic datum. Through international collaboration, we achieve outcomes that would not be possible with our own geodetic capabilities and capacity.

As such, LINZ had to pivot quickly to continue to support the VLBI observations, which meant that there was little time to develop a deep VLBI technical capability. We have had to acquire knowledge on the go, demonstrating the importance of resilience in maintaining the supply chain together.

Engaging with our international partners has been incredibly valuable in formalising our VLBI relationship with SpaceOps. Discovering that some other international partners run their VLBI observations in a similar structure to ours was of significant benefit, and knowing that we are not the only ones taking this approach was reassuring. However, the real gain was obtaining insights from those with hands-on experience in managing these relationships, helping us to understand what is important and where to direction our attention.

LOOKING FORWARD

While New Zealand is not currently looking to install a new VLBI station, it is worth considering the potential opportunities that a new site could offer. The original location of the Warkworth site was chosen based on its proximity to Auckland, New Zealand's largest city, and the presence of existing infrastructure. While the key consideration for any new VLBI station would be its ability to be co-located with other geodetic infrastructure. At a minimum, it would be co-located with a CORS (Continuously Operating Reference Station) GNSS site, as Warkworth is now.

Looking beyond GNSS CORS, New Zealand has only one DORIS/REGINA site on the relatively remote the Chatham Islands, and no SLR (Satellite Laser Ranging) stations. A new VLBI site, would ideally include multiple other geodetic infrastructure, similar to Australia's Yarragadee Geodetic Observatory.

Environmental factors for the new site would include low humidity and rainfall, stable underlying geography, higher elevation and a relatively quiet zone for radio frequencies. Practically, this means that the site would be away from urban areas and future development or key transport networks.

New Zealand will continue to support the international geodetic mission by continuing to supply its products. However, with our key geodetic infrastructure aging we need to review our strategy going forward. The modernisation of core geodetic infrastructure will be a focus, including ensuring the longevity and reliability of our VLBI capabilities, and other infrastructure.

CONCLUSION

New Zealand's strategic geographic position and commitment to geodesy have established it as a crucial player in the global geodetic supply chain. Through the efforts of Toitū Te Whenua Land Information New Zealand (LINZ) and collaborations with international

partners, New Zealand provides essential data and infrastructure that support global geodetic models and research.

Key infrastructures, such as the PositioNZ network, the GNSS at Tide Gauge network, and the Warkworth Space Centre, play vital roles in monitoring Earth's geophysical processes. The Warkworth Space Centre, in particular, has become indispensable for radio astronomy and geodesy in the Southern Hemisphere, contributing significantly to the International Terrestrial Reference Frame (ITRF) and Earth Orientation Parameters.

The potential closure of the Warkworth site highlighted the importance of international collaboration and resilience in maintaining geodetic capabilities. The swift response from the New Zealand Government and the support from the international community ensured the continuation of critical geodetic observations.

Looking forward, New Zealand remains dedicated to modernising its geodetic infrastructure and exploring new opportunities for collaboration. This commitment will ensure the continued accuracy and reliability of geodetic data, reinforcing New Zealand's pivotal role in the global geodesy community.

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BIOGRAPHICAL NOTES

Matt Wightman is a Geodetic Surveyor/Geospatial Specialist who works in the Datums Squad in Land Information New Zealand. He is involved in various geodetic work, such as initiating the GNSS at Tide Gauges installation, VLBI among others. He graduated with Bachelor of Science majoring in Survey Measurement from Otago University, and Post Graduate Diploma in GIS from Victoria University of Wellington.

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