The Royal Australian Survey Corps

Doppler Satellite Years 1971-1992

This story is dedicated to the memory of Flight Lieutenant Ralph Taylor, 9 Squadron RAAF (Iroquois UH-1H), CENDERAWASIH FORCE, who was killed in a helicopter crash on 29 July 1977, while positioning a Doppler satellite (Geoceiver) team in the Central Highlands of Irian Jaya (now Papua) Indonesia. He is commemorated on the Australian War Memorial Roll of Honour https://www.awm.gov.au/collection/R1729459

The author and Doppler satellite surveying. *My time with Doppler satellite surveying began in 1975 in Papua New Guinea (PNG) serving with 8 Field Survey Squadron (Popondetta and Wewak). Doppler satellite field surveys included: Operation SANDY BUSH Phase 3 in the Louisiade Archipelago in Milne Bay Province (Operations Sergeant - Computations, Survey Records and Communications); 2 Fd Svy Sqn Operations CENDERAWASIH 1976 and 1977 Irian Jaya, Indonesia (Geoceiver reconnaissance/clearing team and Geoceiver team); 4 Fd Svy Sqn Op NERVOSE 1982 Arnhem Land NT (Operations Officer) and Op NEURATION 1983 Central NT (Officer-in-Charge). Training: School of Military Survey 1/76 Geoceiver Operator Course held at Randwick NSW and Instructor Support School of Military Survey 1/77 Geoceiver Operator Course. As a 'civil schooling' student at Western Australian Institute of Technology (now Curtin Univ) my final year major project (directed by Directorate of Survey – Army) was to inquire into the relationships between the geodetic systems used by the Doppler satellite system and the Australian Geodetic Datum/Australian Height Datum. As a staff officer at Directorate of Survey Army Headquarters, I provided advice on Doppler satellite operational and technical matters including participation in National Mapping Council working groups on standards and specifications and survey practices. Email: canberrasvycorpsassoc.pres@gmail.com*

Preamble

This story is not a formal history of Geoceivers (Transit Doppler satellite geodetic receivers – *AN/PRR-14* and *MX-1502*) as used by the Royal Australian Survey Corps (RA Svy)[1] but is a mix of factual information from papers and reports and also recollections of those who used the equipment and all that went on around using it. After each Geoceiver operation there was a comprehensive report as much covering 'lessons learnt' for future planning as reporting what was done. What this does not cover in any depth is the other associated survey work, such as theodolite and electromagnetic distance measurement traverse and other forms of conventional survey, astronomic azimuth, heighting by airborne laser terrain profiling and aerial photography in particular station identification photography, all of which were often done at the same time as the Doppler satellite surveys.

[1] Common abbreviations used are: Royal Australian Survey Corps – RA Svy; Directorate of Survey – Army Headquarters – DSVY-A; Field Survey Squadron – Fd Svy Sqn; Royal Australian Electrical and Mechanical Engineers – RAEME; Australian Army Aviation Corps – AAAvn, Sydney Workshop Company – Syd Wksp Coy, US Defense Mapping Agency – DMA, US Naval Surface Weapons/Warfare Centre – NSWC; Detachment – Det; Australian Defence Force – ADF; Defence Cooperation Program – DCP; Exclusive Economic Zone – EEZ; Army Reserve - ARES

Some nominal rolls of those who were involved exist, but for reasons of consistency and completeness, the numbers of those involved, if known at this stage, is summarised rather than lists of personnel.

It is not intended that this story try and cover all that is in those reports. Moreover, such a short story will never cover all aspects of this era, or indeed be complete in those aspects mentioned, but I do hope that it is gives a broad picture of the 'what, why, where and how' of the Corps' Geoceiver years and that what is said is as factual as possible.

Acknowledgement of those who have sent to me documents, stories, recollections and photographs is at the end of the story and in footnotes. All photographs may be used for purposes of the Survey Corps Associations but are not to be used for other purposes without approval of the Association.

This version (revised – January 2025) includes information sent to me in response to the initial draft (June 2024), Version - August 2024 and Version – September 2024. There are gaps in the story which will be filled, and corrected, when information is forthcoming. Please email to me at: canberrasvycorpsassoc.pres@gmail.com

The story was published in The Globe, the journal of the Australian and New Zealand Map Society, No 96 November 2024. It was reformatted for publishing and printing and did include information in addition to that in the Version – September 2024.

Introduction

For nearly 19 years, 1974 to 1992, the Transit Doppler satellite Magnavox AN/PRR-14 Geodetic Receiver (*Geoceiver*) and second generation Magnavox *MX-1502* Satellite Surveyor, also called a Geoceiver, were major geodetic and topographic survey equipments of RA Svy. To avoid confusion of equipment names in this paper, the AN/PRR-14 is named *Geoceiver* and the *MX-1502* just that. These were the common names used at the time. A *Geoceiver* (NSN 6675-00-113-1815) and a *MX-1502* (NIC-0166) are in the RA Svy Collection of the Australian Army Museum of Military Engineering at Holsworthy NSW.

The Corps established about 2,000 Doppler satellite survey stations in Australia and its Territories (internal and external), Papua New Guinea, Indonesia and eight island nations of the South-West Pacific in Australia's area of primary strategic interest.[2] Both Doppler satellite receivers observed and recorded Doppler data from signals from the US Navy Navigation Satellite System, known as Transit or NAVSAT, which was developed in the early 1960s for navigation of nuclear ballistic missile (Polaris) armed nuclear powered submarines to update inertial navigation systems. Transit was a word not an acronym. NAVSAT also became the popular name for the Transit satellites and is used for that purpose in this story. The man-portable Geoceivers provided the capability of single or multiple instruments being deployed for 24 hour three-dimensional geodetic quality surveying in any weather anywhere in the world. They replaced the Corps' geodetic traversing and astronomy systems and *Aerodist* (airborne electromagnetic distance measurement (EDM) system) for

[2] From the unique Doppler Satellite Station Processing Numbers allocated for each station processed using precise satellite ephemerides. Numbers started at 10,000 with the last number found 11,903 for a station on Op ALGUM 86. Not included in this summary number is the post-1986 surveys before the GPS and IPS era, those *Geoceiver* stations processed by US Defense Mapping Agency in the mid-1970s and those stations computed as *MX-1502* translocations using predicted satellite ephemerides.

large area surveys especially for 1:100,000 topographic mapping. But they were a capability a lot more than that. However they did not replace all survey methods and equipments which at times were used in conjunction with the Doppler satellite receivers.

In Australia the major role of the Geoceivers was to provide supplementary mapping control for the scale 1:50,000 defence mapping program mainly across northern Australia (about 1,900 maps). In Papua New Guinea they enabled the completion of the field surveys for horizontal control, by the end of the 1970s, for the scale 1:100,000 mapping program. They were essential to the military survey assistance projects in remote provinces of Indonesia over 11 years from 1974 to 1984. From 1978 Geoceivers were used extensively for Defence Cooperation Program (DCP) projects in Solomon Islands, Vanuatu, Fiji, Kiribati, Tuvalu, Tonga, Western Samoa and Nauru for surveys assisting those nations to establish their Exclusive Economic Zone (EEZ) under the UN Convention on Law of the Sea, to upgrade existing geodetic networks and for topographic surveys for mapping. The survey intelligence resulting from these operations was also beneficial to Australia. The Corps history notes '*the Corps was expanding its horizons with a new form of activity that would continue taking its members beyond Australia's borders for the next two decades, Indeed, for much of the period until the 1990s, the Corps was the most visible element of the Army outside Australia.*'[3] These surveys, mainly enabled by the Doppler satellite receivers, were potent instruments of Australia's foreign policy and influence in the region in the 1970s and 1980s. An example of the importance of the work, to both cooperating nations, especially in diplomatic terms, was said to Major Don Swiney MBE [4], Force Commander CENDERAWASIH FORCE, by Australia's Ambassador to Indonesia in 1977 when he visited the unit at BIAK in Irian Jaya – *'since the incident with the Sydney Morning Herald, and all that stuff, the only official contact I have had with the Indonesian Government has been about your survey project. You have been our only line of contact with them across the whole diplomatic spectrum'*[5].

It was the DCP operations, especially those in the South West Pacific assisting the island nations to establish their EEZ, which showed the Corps' capability of conducting geodetic quality surveys over vast very remote areas thousands of kilometres from Australia with limited logistic support from Australia relying on local and regional resources. These projects challenged the initiative, adaptability and resolve of all involved. Pacific neighbours helped each other, with Fiji and New Zealand offering their naval ships to support the surveys which they recognised as helping all of the nations in the region.[6] Fiji and Western Samoa hosted staging bases and Cook Islands a main base for part of the projects with neighbouring Kiribati, Tuvalu and Nauru. DCP projects were combined collaborative operations relying on host countries for coordination and liaison and often with military officers and soldiers or Government survey staff integrated into all elements of the operations. For some projects, staff from DCP host countries attended training at School of Military Survey, Bonegilla VIC.

[3] CD Coulthard-Clarke, *Australia's Military Map-Makers, The Royal Australian Survey Corps 1915-1996*, p160, Oxford Press (2000)
[4] Later Colonel, Director of Survey Army Headquarters and Head of the Royal Australian Survey Corps
[5] CD Coulthard-Clarke, *Australia's Military Map-Makers, The Royal Australian Survey Corps 1915-1996*, p166, Oxford Press, (2000)
[6] CD Coulthard-Clarke, *Australia's Military Map-Makers, The Royal Australian Survey Corps 1915-1996*, p170-171, Oxford Press, (2000)

Geoceiver formal training was a specialist course conducted by the School of Military Survey. Initially operator training was for the RA Svy trade Topographic Surveyor Grades 1, 2 and 3. When the RA Svy trades were restructured in 1976, the new trade Technician Cartographic (replacing Topographic Surveyor and Topographic Draughtsman) included field survey skills. A specialist Control Survey Course was later introduced for Technicians Cartographic and this was generally the prerequisite course for the *Geoceiver* course as it included subjects such as astronomic azimuth and electromagnetic distance measurement which were necessary especially for team leaders.

The AN/PRR-14 *Geoceiver* (a military equipment) was not a real-time navigator but recorded Doppler data which when later combined with post-orbit precise satellite ephemerides, produced geodetic quality absolute three-dimensional 'point positions', independent of any other field instrument, accurate to about 1.5 metres in each axis (x,y,z) (90 percent confidence) in a world geodetic system. This depended on the number of satellite passes, the number of data points in each pass and the balance of satellite-station geometry. The *MX-1502* (available commercially) was both a real-time navigator and geodetic receiver which could be used for geodetic 'point positioning' but also to determine in the field 'relative positions' over hundreds of kilometres accurate to about a metre.

Operations information is drawn from operation project reports, unit reports in the National Bulletins of the Survey Corps Associations, the Survey Corps Magazine – Parare, the Survey Operations webpage on the Survey Corps Associations website www.rasvy.org and from information from individuals who were involved in the work.

Base and field maintenance support for all of the Doppler satellite equipment was Survey Support Section Sydney Workshop Company (Syd Wksp Coy) based at Mascot NSW.

The list and timings of Doppler satellite operations (below) shows that there was rarely a period of a few months or so from 1974 to 1986 when the Geoceivers were not deployed on operations somewhere between Sumatra Indonesia and Cocos (Keeling) Islands in the north-west, Victoria in the south and Kiribati in the north-east. A factor was the seasons sometimes limiting access to areas to be surveyed.

From early-1970s, Geoceivers were the tools of small Doppler teams of three men on 'short notice to move to anywhere in the world' of 512 STRE (Specialist Team Royal Engineers)[7] and US DMA Geodesy and Geophysics Dept, both based at DMA Hydrographic Topographic Centre outside Washington DC. Together they exercised their national interests and influence in what seemed to be an endless list of invitations from many nations of the world. Canadian Forces also used *Geoceivers*. "*The defence of North America keeps us very close to US technology*"[8]. The Corps assisted New Zealand by computing 'point positions' from precise ephemerides for the Royal New Zealand Navy Hydrographer.

The start date for this story is 1971 when the first Doppler satellite familiarisation and training was undertaken by an officer in the US.

[7] 2/1 Australian Corps Field Survey Company, (Royal Australian Engineers) Australian Imperial Force (1940-42) served in the Middle East in the Second World War with 512 Army Field Survey Company (Royal Engineers) which was the ancestral unit of 512 Specialist Team Royal Engineers.
[8] Colonel Dave Carney (Retd), Corps of Royal Canadian Engineers, Director of Survey Canadian Forces

The Corps' Doppler satellite capability was replaced by the GPS (Global Positioning System) and IPS (Inertial Positioning System) field and computing systems commencing 1987. The Doppler capability was retired from service in 1992 when the GPS 'point positioning' from 'precise ephemerides' computing system was operational at Army Survey Regiment.[9] [10] [11]

Transit development

The dynamics of artificial earth satellites was first profounded by Sir Isaac Newton in the summer of 1687. Two hundred and seventy years later on 4 October 1957, Drs WH Guier and GC Weiffenbach[12] of the John Hopkins University Applied Physics Laboratory (APL) observed a significant difference in the transmitted frequency and the received frequency (Doppler effect or shift[13]) of signals from the USSR SPUTNIK 1 which was the first artificial earth satellite. They found that the orbit of the satellite could be determined from Doppler observation at a single ground station. Within five months and from the imagination and direction of Dr FT McClure, also of APL, they showed that from the observed Doppler shift the orbit solution could be inverted to solve the position of earth stations from the known satellite orbits. Over one weekend in March 1958, McClure and Dr RB Kerschner (APL) designed all of the essential parts of what became the US Navy Navigation Satellite System, Transit. All of the work was sponsored by the US Navy for the Polaris submarine program. Kerschner, a brilliant mathematician and engineer, became the Transit program manager leading system developments.[14]

APL built 14 development and prototype Transit satellites launched 1959 - 1961. Like all space development projects some failed at launch and some failed to operate as expected. The first operational satellite (also APL) being the type Oscar (phonetic alphabet O for Operational), was launched in December 1963 with the first Polaris submarine navigation fix in January 1964. From 1964 to 1988 there were 24 Oscars successfully launched and operational. Transit was released to the public by US Presidential Executive Order in 1967 and declared fully operational for civilian use 11 October 1968[15]. It was the first freely available to the public global system for accurate positioning, navigation and timing.

Oscars were extremely reliable satellites lasting much longer than their design life. Two were operational for 20 years. They were light weight, and spare satellites were stacked as pairs on what was known as SOOS (Stacked Oscars on Scout rocket) launched two at a time into low earth orbits. RCA built later Oscars and was then contracted to store the spares on-

[9] Captains P Clarke, P Jensen, J Mobbs, *The RA Svy GPS Experience 1987/88*, The Australian Surveyor, Vol34, No6 (1989)

[10] S Malys, Major P Jensen, *US Defense Mapping Agency, Geodetic Point Positioning with GPS Carrier Beat Phase Data from the Casa Uno Experiment 1988*, Geophysical Research Letters, Vol17, No5, pages 651-654, (April 1990)

[11] Survey Corps Magazine – Parare, Issue 9, (1992)

[12] Guier WH, Weiffenbach GC, *Genesis of Satellite Navigation*, Johns Hopkins APL Technical Digest 18(2), 178–181 (1997)

[13] Named after Christian Doppler who first described the phenomenon in 1842

[14] Pisacane VL, *The Legacy of Transit,* , Johns Hopkins APL Technical Digest Vol19 No1 (1998)

[15] Sentman, O.L. and Danchik R.J. and Rueger, L.J., 1986, *Joint Paper on the Navy Navigation Satellite System (TRANSIT) Status and Plans*, Proceedings of the 4th International Geodetic Symposium on Satellite Positioning, Austin Texas 28 Apr -2 May 1986.

orbit launching three SOOS from 1985 to 1988 to maintain 12 satellites in Transit with 7-8 operational at any time.[16]

NAVSATs were known with different designations. The NSWC numbers 59, 68, 105 etc were used by RA Svy as that was used for satellite predictions, Geoceiver observations and precise ephemerides identification. The other common satellite identifier was the five digit NNS/APL number eg 30130, 30140, 30480 etc.

A Transit Improvement Program (TIP) of three satellites was launched 1972–1976. The successful TIP resulted in the second generation operational satellites known as Nova (new), built by RCA, of which three were launched by Scout rockets: Nova 1 (105/30480), 15 May 1981; Nova 3, October 1984 and Nova 2, June 1988. Nova design improvements, especially as low atmospheric drag satellites, resulted in predicted orbits accurate for up to a week instead of 24 hours. Navigation solutions converged faster with improved accuracies.

NAVSATs were low-earth orbiting at an altitude of about 1,075km in polar circular orbits with an orbital period of about 100 minutes. A minimum of five satellites in an equal spread of orbital planes and phase between satellites were required to meet the US Navy requirement that anywhere in the world navigation fixes were available between 20 minutes near the poles and one hour at the equator. Predicted satellite orbits and ephemerides were computed from observations at four Transit OPNET (OPerational NETwork) stations, all in the US, and regularly uploaded to the satellites for broadcast messages necessary for real-time navigation solutions. Transit Doppler frequencies were 400 and 150 MHz.

Transit was continually upgraded. Initially real-time position fixes from a single satellite pass were accurate to a few hundred metres with this improved to a few tens of metres over time. The Polaris submarine Transit Doppler receivers were able to read an encrypted broadcast message giving access to better timing information and therefore improved position accuracies. This was similar to the PRN (Pseudo Random Noise) system used later in GPS satellites for access to more accurate ranging signals. After what was an extraordinary 32 years of service to military and civilian positioning, navigation and timing users, with 100% system availability and 99.77% single satellite reliability, Transit was retired in 1996. The satellites were then re-used as part of a US Navy Ionospheric Monitoring Program. The US Navy Transit system was replaced by the US Department of Defense GPS (Global Positioning System) used from the early-1980s and declared operational in 1994.

Transit developments benefitted other satellite programs with Doppler methods found to be the most accurate and reliable for orbit determination for low-altitude and low-earth orbiting satellites (160 km – 2,000 km)[17].

> From the two original pioneers, WH Guier and GC Weiffenbach[18]: '*The use of range instead of range rate (Doppler) for aircraft navigation was evident at an early stage, but the technology was not yet available. The present Global Positioning System is the result of APL's pioneering work with Transit, progress in electronics, and the global economy. Of course, we underestimated progress in electronics. In particular, we did not predict the incredible extent to which size and cost would be reduced for everyday*

[16] R Danchik, *An Overview of Transit Development*, John Hopkins Univ APL Technical Digest, vol19 no 1, (1998)
[17] ibid
[18] Guier WH, Weiffenbach GC, *Genesis of Satellite Navigation*, Johns Hopkins APL Technical Digest 18(2), 178–181 (1997)

applications for the mass market, e.g., navigation systems for our automobiles and pleasure boats, and even handheld units for hikers. We will always look back with enormous gratitude and pride that we were part of it all.'

Geodetic quality Doppler satellite surveys, mostly by government agencies, soon covered much of the earth adding to the various methods of other global surveys. Transit was included in the mix of data for development of WGS 72 (World Geodetic System) and later WGS 84. In October 1976 the First International Geodetic Symposium on Satellite Doppler Positioning was held at Las Cruces, New Mexico, USA. Another three such symposiums were held every three years until 1986. Such was the significance of the Transit system to geodesy and geodetic surveying for many applications. At the second symposium in January 1979 there were 282 scientists from 32 countries. Typically the symposiums were sponsored by DMA and NOAA (National Oceanographic and Atmospheric Administration) National Ocean Survey and hosted by APL.

TRANET

Although classed as a navigation program, and not a geodetic program, Transit Doppler was soon utilised for geodetic purposes. Doppler instruments similar to Transit were included on various geodetic and special satellite programs. The fixed OPNET stations satisfied the Transit navigation requirements but a global-spread network of stations was necessary for those applications needing non-real-time post-orbit 'precise satellite ephemerides'. For these purposes TRANET (TRAcking NETwork) systems, under technical direction of APL, were built for deployment globally either as fixed sites or later mounted in mobile TRANET vans. From 1959 to 1974 there were 13 permanent TRANET stations established but numbers and locations fluctuated over the life of the system.

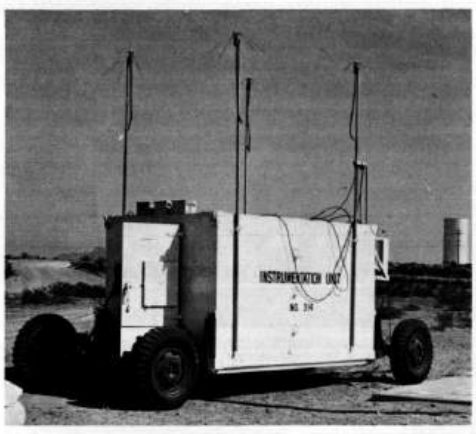
Australia's involvement in the Transit program from 1961 was under a bi-lateral Australia/United States Exchange of Notes (EON) signed 5 June 1961 (Australian Treaty Series 1961 No 10)[19]. Under this arrangement a permanent TRANET station was located at Smithfield SA, about 30 km north of Adelaide, being operational for 32 years from 25 August 1961 to 30 June 1993[20]. Initial arrangements were between the Australian Department of Supply (DOS) and the US Navy. The station was accommodated in a small building of DOS Weapons Research Establishment (WRE) and manned by WRE staff and a member of Physical Sciences Laboratory New Mexico State University until 1967. Initially the antennas for frequency pairs 400/150 MHz and 324/162 MHz (geodetic and special satellites) were located on two platforms, one above a John Hopkins Univ APL plaque (east platform) and the other above a RA Svy bronze plaque (1962) set in concrete (west platform). In October 1965 the antennas were co-located as a square array on the east platform about 6 metres above the John Hopkins University APL plaque set in concrete[21] (Figures 1b and 1c). Early TRANET could also track 54 MHz used in developmental Doppler satellites.

[19] https://www.austlii.edu.au/au/other/dfat/treaties/ATS/1961/10.html
[20] GPS fixed station Smithfield co-operated by DMA and RA Svy 1981 – 1994 was co-located with TRANET
[21] https://geodesyapps.ga.gov.au/cache/files/020422-01.pdf
https://geodesyapps.ga.gov.au/cache/files/020422-00.pdf

The US advised Australia in March 1970 that TRANET would soon cease to be of interest to the US Navy for development and testing of Transit navigation, and that it proposed to close the station in June 1971. Up until 30 June 1971 it was fully funded by the US. Australia recognised the value and benefits of continued participation in the TRANET program, inparticular for mapping, charting and geodesy in the Australian region and considered, but never implemented, direct Army involvement in station operation by RA Svy and RAEME personnel and relocating the station to Perth WA. The 1961 EON was renewed in 1971, with part operational funding responsibility for the station transferring to Australia and the station remaining at Smithfield and continuing with WRE staffing (and its successor organisations) and management on behalf of Australia.

After the US Defense Mapping Agency (DMA) was established in 1972, a bilateral Memorandum of Mapping, Charting and Geodesy Arrangements was signed by Australia and the US in 1973. This arrangement became a cornerstone in the relationship between RA Svy and DMA and supported cooperative activities including geodetic projects and the supply of TRANET derived Transit post-orbit precise ephemerides to RA Svy for its use and that of national and state agencies responsible for mapping, charting and geodesy and for research universities. In return survey results were provided to DMA. In 1973 DMA assumed responsibility for contract management and funding of operations and management and equipment upgrades of TRANET stations by New Mexico State Univ Physical Sciences Laboratory[22]. A 1979 Memorandum of Implementing Procedures, under the 1961/1971 EON, allowed the aging TRANET I to be replaced with TRANET II equipment. For Smithfield this remained the arrangement until TRANET station closure 30 September 1993.

Over the life of the Smithfield TRANET station its number changed with equipment upgrades. Numbers were: 012 (1961); 112 (1965 - antenna upgraded and moved to above John Hopkins Univ plaque, and 1974 – upgrade to a rubidium oscillator); 412 (August 1979 - TRANET II replaced TRANET I) and 545 (June 1983 – antenna upgrade – Figures 1b, 1c).[23]



US Navy mobile TRANET vans were deployed globally with VAN 307 operational in Australia from March 1964 to August 1966. For periods of one to five months the van observed at established geodetic stations previously included in other global geodetic programs. The stations were at: Perth, Darwin, Cocos Island, Townsville, Manus Island (TPNG), Woomera, Canberra, Thursday Island and Culgoora.[24]

Figure 1a (above). A US Navy mobile TRANET van (weight 4 tonne). Van design changed from the original semi-trailer size to this van which varied in length from 12ft to 19ft long. Each of the four whip antennas was for one of the four

[22] Physical Science Laboratory, New Mexico State Univ, Las Cruces, New Mexico, '*The History of the Satellite Ground Instrumentation Section 1958-1993*' (December 1993)
[23] ibid
[24] ibid

frequencies Transit 400/150MHz and geodetic/special satellites 324/162MHz. Vans were transported either by US Air Force aircraft or ship (Thursday Island QLD).[25] [26]

The vans were replaced by the AN/PRR-14 *Geoceiver* for point positioning and orbit determination from 1970.

Figure 1b. TRANET Smithfield SA – west antennae platform (left) above a RA Svy plaque and east antennae platform (right) above a John Hopkins University plaque. The tracking and recording equipment is in the red brick building. (Photo: the author 1983)

Figure 1c. TRANET II Station 545 Smithfield SA – next to the GPS receiver equipment (p17) not in this photograph. Note the first generation 8-inch floppy disc removable media on the floppy drive cabinet. (Photo: the author1983)

[25] ibid
[26] NASA Directory of Observation Station Locations, Goddard Space Flight Centre, 3rd edn, (November 1973)

Observation methods

Observation methods for surveying were absolute 'point positioning' and 'simultaneous point positioning', which resulted in survey station coordinates independent of any other, and relative positioning such as 'translocation', 'short-arc' and 'semi-short-arc' where one or more station coordinate sets were determined relative to other stations. Relative positioning of secondary stations mainly used predicted satellite orbits, not requiring post-orbit precise ephemerides, but did require a higher level of coordination to ensure that at least two receivers were observing the same satellite at the same time.

The Corps' observations with the *Geoceivers* were 'point positioning' as it was the easiest logistically when the Corps had access to the post-orbit precise ephemerides. A mix of 'point positioning' and relative positioning by 'translocation' was used from 1982 with the *MX-1502* receivers.

Observation programs were determined by the Doppler teams in the field from predictions provided by DSVY-A from DMA. The computer prediction printouts, on 132 character wide folding paper, were for all satellites not only those for which precise ephemerides would be available. Teams developed the observation program from the satellites with precise ephemerides, requirements of number of suitable passes, above 10 degrees elevation, balanced north going and south going, east-west and equal elevations if possible. Numbers of acceptable passes to meet station accuracy standards were generally in accordance with the standards of the Australian National Mapping Council. These standards were consistent with US forces evaluation of the *Geoceiver* in 1971[27].

[27] Physical Science Laboratory, New Mexico State Univ, Las Cruces, New Mexico, *The History of the Satellite Ground Instrumentation Section 1958-1993, p34* (December 1993)

Observation standards

3.4 Classification - Doppler position fixing

The absolute coordinates determined by Doppler point positioning are classified thus:

Class	Reference System	Characteristics
1.	Precise Ephemeris	. minimum of 35 acceptable precise ephemeris passes . expected accuracy is 1.5 metres in each component at 90% confidence interval
2.	Precise Ephemeris	. between 20 and 34 acceptable precise ephemeris passes . expected accuracy is 2.0 metres in each component at 90% confidence interval
3.	Precise Ephemeris	. between 12 and 19 acceptable precise ephemeris passes . expected accuracy is 2.5 metres in each component at 90% confidence interval.
4.	Precise Ephemeris	. between 6 and 11 acceptable precise ephemeris passes. . expected accuracy is better than 4 metres in each component at 90% confidence interval.
5.	Onboard Ephemeris	. minimum of 20 acceptable onboard ephemeris passes (75 passes optimum) . expected accuracy is about 10.0 metres in each component at 90% confidence interval.
6.	Onboard Ephemeris	. less than 20 acceptable onboard ephemeris passes. . solution is unreliable.

where the two-sided 90% confidence interval is equivalent to about 1.65 standard deviations.

Figure 2. NMC Standards and Specifications for Control Surveys SP1 Edn 3 1981

This does not include errors in the transformation from the precise ephemerides datum to a local datum.

Satellite ephemerides and geodetic systems

The geodetic system for the post-orbit precise ephemerides, and therefore the Geoceiver absolute point positions, was based on the coordinate set of the global TRANET stations used to compute the precise orbits. Orbit computations were developed and done by the US Naval Weapons Laboratory (NWL), later renamed Naval Surface Weapons Centre (NSWC) and Naval Surface Warfare Centre at Dahlgren, Virginia, using computer program CELEST (1971 – early 1990s) - a word not an acronym[28]. The precise orbits were reference the NWL

[28] Swift E, *History of Satellite Orbit Determination at Naval Surface Warfare Centre, Dahlgren Division* (2018)

9D /NSWC 9Z2 coordinate set from October 1971 and the NWL 10E[29] earth gravitation model from January 1973 and updated 1984. '*Two-day fits (*48 hour TRANET network observations and numerical integration of the equations of motion*) were done for the orbits and accuracies improved to about the three metre level. With continual CELEST modeling improvements, the absolute positioning accuracy reached the one meter level around 1980. Un-modeled higher order ionospheric refraction effects limited the accuracies attainable using the Transit satellites'*[30]. Computation of the precise ephemerides passed from NSWC to DMA in April 1975. CELEST also supported satellite-to-satellite tracking where low-altitude satellites (160 -200 km) with Transit Doppler receivers tracked higher altitude NAVSATs (1,000 km altitude). TRANET, mobile TRANET vans and *Geoceivers* were all able to track the low-altitude satellites (324/162 MHz) for orbit determination. From 1979 to 1982 precise orbits were computed from 19 TRANET and the 4 OPNET stations[31] [32]. In early-1989 Transit precise ephemerides transitioned to the World Geodetic System 1984 (WGS-84) and *Geoceiver* and *MX-1502* 'point position' solutions were reference that system from that time.[33] The predicted broadcast ephemerides, read and recorded from the satellite message by the *MX-1502*, and used for relative positioning, was reference the WGS 72 and then the WGS 84 from early-1989.

Whenever possible survey connections (vertical) were observed between the Doppler satellite antennas and sea level for direct relationships between geoidal (sea level) and spheroidal (Doppler) heights.

Point position computations

Initially the *Geoceiver* data on paper tapes was transmitted via telex direct to NWL/NSWC for processing[34]. From 1977 *Geoceiver* paper tapes were copied to magnetic cassette tape in the field using HP9863A tape readers and HP9815A calculators for despatch to DSVY-A for processing. Doppler 'point positions' were processed by DSVY-A using DMA provided program DOPPLR[35] installed on a Defence Univac 1100 and the CELEST derived precise ephemerides from DMA. In 1991/1992, this capability was transferred to the newly formed Geodetic Information Group, Air Survey Squadron, Army Survey Regiment (installed on a VAX computer) along with the geodetic computing element of the GPS TI4100 geodetic receiver system[36]. The field surveys were then all conducted by 4 Fd Svy Sqn (Adelaide).

DOPPLR used the integrated Doppler count based slant range differences between the satellite and receiver, along with the relevant precise satellite ephemerides derived from a polynomial interpolation of the satellite orbit arcs expressed as three position components and three velocity components for each 1 minute UTC time interval. The ephemerides tapes were for each satellite containing orbit data for up to a two week period. The Geoceiver three-

[29] Vetter JR The Evolution of Earth Gravitational Models used in Astrodynamics, Johns Hopkins APL TechnicaL Digest, VoLume 15, Number 4 (1994)
[30] Swift E, *History of Satellite Orbit Determination at Naval Surface Warfare Centre Dahlgren Division*, (2018)
[31] ibid
[32] Anderle RJ, *Doppler Satellite Characteristics*, NSWC TR83-353, (October 1983)
[33] Bangert JA (DMA), Cunningham JP (NSWC) *Preliminary Evaluation of Doppler Determined Pole Positions Computed Using World Geodetic System 1984*, released by DMA October 1986
[34] Sergeant Phil Bannister, 2 Fd Svy Sqn, NCOIC Survey Records Op CENDERAWASIH 1976
[35] DMA Topo Centre Technical Report 76-1, *DOPPLR – A Point Positioning Program Using Integrated Doppler Satellite Observations* (April 1976)
[36] Survey Corps Magazine, Parare, Issue 9 (1992)

dimensional position (reference NSWC 9Z2 / NWL 10E) was then determined from a convergent least squares multi-pass solution with the precise ephemerides held fixed. For Australian surveys, transformation of the point positions coordinates to the local datums (Australian Geodetic Datum 1966/84 and Australian Height Datum 1971) were in accordance with National Mapping Council recommendations.

The two major sources of error, independent of the receiver type, were ionospheric and tropospheric refraction. Doppler count observations of the two coherent satellite frequencies (400/150 MHz) meant that the first order effect of ionospheric refraction was accounted for. Tropospheric refraction was not frequency dependent but was a function of temperature, humidity and atmospheric pressure. Correction for these components was computed from observations at the Geoceiver of dry and wet temperatures (from a psychrometer normally a clockwork instrument) and atmospheric pressure (baromec) at each satellite pass. If unaccounted for, slant range errors were about 12 metres at 10 degree elevation, 9 metres at 15 degrees and 3 metres at 60 degrees.[37]

AN/PRR-14 Geoceiver

In 1967 APL was contracted to the US Navy to design a light weight, small, man-portable geodetic quality receiver to replace the mobile TRANET vans for point positioning and satellite orbit determination.

Magnavox was awarded the build contract producing in 1970 the *Geoceiver* (geodetic receiver) with the military nomenclature AN/PRR-14. It was built to military specifications. About 55 *Geoceivers* were delivered. *Geoceiver* differed from TRANET stations in several respects: (a) *Geoceiver* used the integrated Doppler counting technique, in which a measure of the *change* in satellite to station range was obtained by counting the number of Doppler cycles received between successive markers; (b) *Geoceiver* was man-portable and much smaller and lighter (40kg) than the mobile TRANET van (4,000kg); (c) the data format resulted in at least a 10-to-1 reduction in the number of data points from a satellite pass; (d) the requirement for calculation of clock errors and clock corrections by station operators was obviated by obtaining epoch from NAVSATs automatically in the course of tracking operation; and (e) the *Geoceiver* was adaptable with few changes to a semi-automatic mode of operation.[38] [39]

In November-December 1971, the US Navy, Army and Air Force tested the accuracy and reliability of the *Geoceiver* at 21 locations in the US[40]. The tri-service test proved that the *Geoceiver* could be used in 'point positioning' mode with an accuracy of 1.5 meters in each coordinate (x, y, z) at a 90% confidence level with 35 data passes[41]. Later tests by DMA showed that 25 passes, well balanced north-south going and equal elevations, could achieve similar results.

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[37] HS Hopfield, *Tropospheric Refraction Effects on Satellite Range Measurements*, APL Tech Digest, (Mar-Apr72)
[38] TA Stansell, *GEOCEIVER: An Integrated Doppler Geodetic Receiver*, APL/JHU Report TG710 (Rev) (Nov 1968)
[39] *Report of the DOD Geoceiver Test Program*, Defense Mapping Agency Report 0001 (1972)
[40] Lieutenant Dan McCluskey, 1 Fd Svy Sqn, was attached to US Army Topographic Command late-1971 and may have been there to attend the trials.
[41] Physical Science Laboratory, New Mexico State Univ, Las Cruces, New Mexico, '*The History of the Satellite Ground Instrumentation Section 1958-1993*' (December 1993)

Geoceiver had ten operating 'modes', five for receiver testing, three for Transit observation 400/150 MHz and two for observing the geodetic and special mission satellite Doppler frequencies 324/162 MHz.

Satellite signals on the two coherent frequencies were received and compared with frequencies synthesized from the *Geoceiver*'s oscillator, giving a beat frequency in the range of tens of kilocycles. The Doppler count was the number of wavelengths of the beat frequency received over a measured time interval. One Doppler count represented a change in slant range between satellite and receiver of one wavelength which for 400 MHz was 0.75 metres. Integrated Doppler count intervals were over two minutes in four sub-intervals of about 28 to 32 secs. The satellite oscillator was deliberately offset by an amount that exceeded the maximum expected Doppler shift, so that the beat frequency never passed through zero. This offset ranged from -35 to -85 parts per million in APL-built satellites. The maximum Doppler shift for satellites at about 1000 km was about 25 parts per million. The beat frequency was produced in the receiver detector and contained the desired Doppler information, phase modulation if present, and noise. It was this signal which was tracked in the phase lock tracking loop. Only the 400 MHz signal Doppler count was used in the position solution. The 150 MHz signal was only used for the ionospheric refraction correction. The *Geoceiver* was more precise and accurate than other receivers because it was capable of a 'partial cycle count' so determined from both the satellite and receiver clocks.

The *Geoceiver* had five basic parts: antenna, pre-amplifier, receiver, punched paper tape recorder on which all of the Doppler and refraction count information and station information was recorded and 12VDC power supply. The station information was entered by the operator using the receiver front panel switches creating a header before the pass and a trailer with station meteorological data after the pass. As the satellite approached (signal tracked and locked on), the increasing frequency noise could be heard in the earphone and then decreasing frequency after CAP (closest approach point). After the pass was complete the operator could decipher the tape information to check that there was about an equal number of 30 second Doppler count intervals either side of the CAP. CAP was identified as the point where the Doppler count, or number of wavelengths received over the constant time interval, was a maximum. Depending on satellite elevation, satellite passes were between 10 and 18 minutes in time. A minimum of Doppler counts for four minutes either side of CAP were specified.

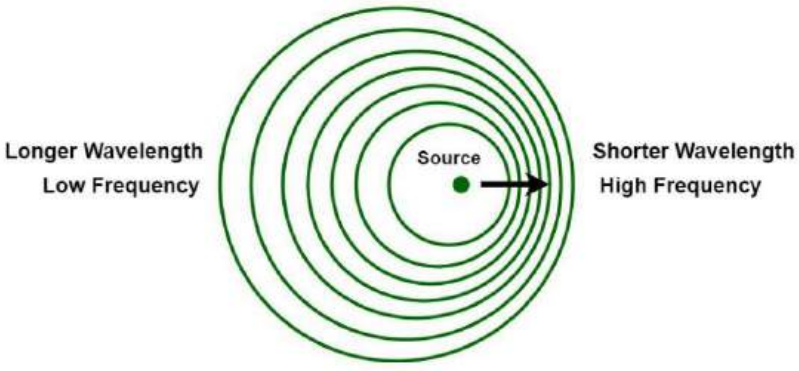

Figure 3. Doppler effect as the source transmitting a constant frequency (satellite) moves towards and away from the stationary Geoceiver with more wavelengths received as the satellite approaches the Geoceiver

To ensure that the receiver was working correctly 'mode' checks and 'alternate data' checks were run each day at about 0800hrs so that the receiver could be repaired or replaced that day if necessary.

Geoceiver unit costs were about US$50,000 (equiv US$375,000 in 2024 = AS$566,250). It is believed that RA Svy's six AN/PRR-14 *Geoceivers* and spares, delivered in early-1975, were acquired through the Foreign Military Sales (FMS) program from the original build of about 55 for US agencies [42]. FMS which had to be beneficial to the national security of both Australia and the US shortened the materiel procurement system as the development, tests and evaluations to ensure that the equipment met the required standards had been done. RA Svy *Geoceivers* serial numbers were DHQ 051, 053, 054, 056, 057 and 058. Five of the six *Geoceivers* were issued to 2 Fd Svy Sqn (Randwick NSW) to be allocated to field survey units and School of Mil Svy as directed by DSVY-A. The sixth *Geoceiver* was allocated to Survey Support Sect Syd Wksp Coy RAEME, for maintenance training. Deployment of the *Geoceivers* was from single sets and up to five sets for larger operations where it was originally intended to deploy four in the field and keep one in main base as a spare. *Geoceivers* were extremely reliable in all operating environments, normally over 98% availability (their design requirement), resulting at times in all sets being deployed in the field. To a large extent the main operational limiting factors were logistic support and operator fatigue on the 24/7 roster, which if precise ephemerides was available for all five satellites, usable satellite passes were in blocks but on average less than two hours apart. Although the receiver could operate unattended, attendance was needed to ensure that the paper tape recorder worked properly especially in humid tropical conditions.

Figure 4. Op CENDERAWASIH 76 AN/PRR-14 Geoceiver – receiver on the right, punch paper tape recorder (lid closed) next to it, both on the white watertight transit boxes. The bottom transit box is for the antenna and the other is for the receiver. The HF radio AN/PRC-F1 is on the left. The alarm clock was set to UTC which was the satellite pass prediction time. The satellite prediction computer printout is in the folder in the foreground. The personal short-wave radio kept the team in touch with world news and music. (Photo: Gary Hunter)

[42] The bilateral RA Svy/DMA Mapping, Charting and Geodesy Memorandum of Understanding was signed 1973

As the *Geoceivers* were so reliable, the attached Syd Wksp Coy technicians were often deployed as operators on *Geoceiver* teams or with reconnaissance and clearing teams to fill out the teams and to provide respite for what was otherwise a job with little to do. RAEME technicians did carry spares kits which were not often needed in the field.

Figure 4a. AN/PRR-14 Geoceiver – punch paper tape recorder. The paper tape for each pass spooled into the tray with holes in the top. After the pass, the tape was annotated with station and pass information, rolled up and stored in a circular cigarette tobacco tin with a screw seal lid. The daily 'mode' and 'alternate data' checks were also recorded on the punch paper tape then deciphered manually (Photo: author).

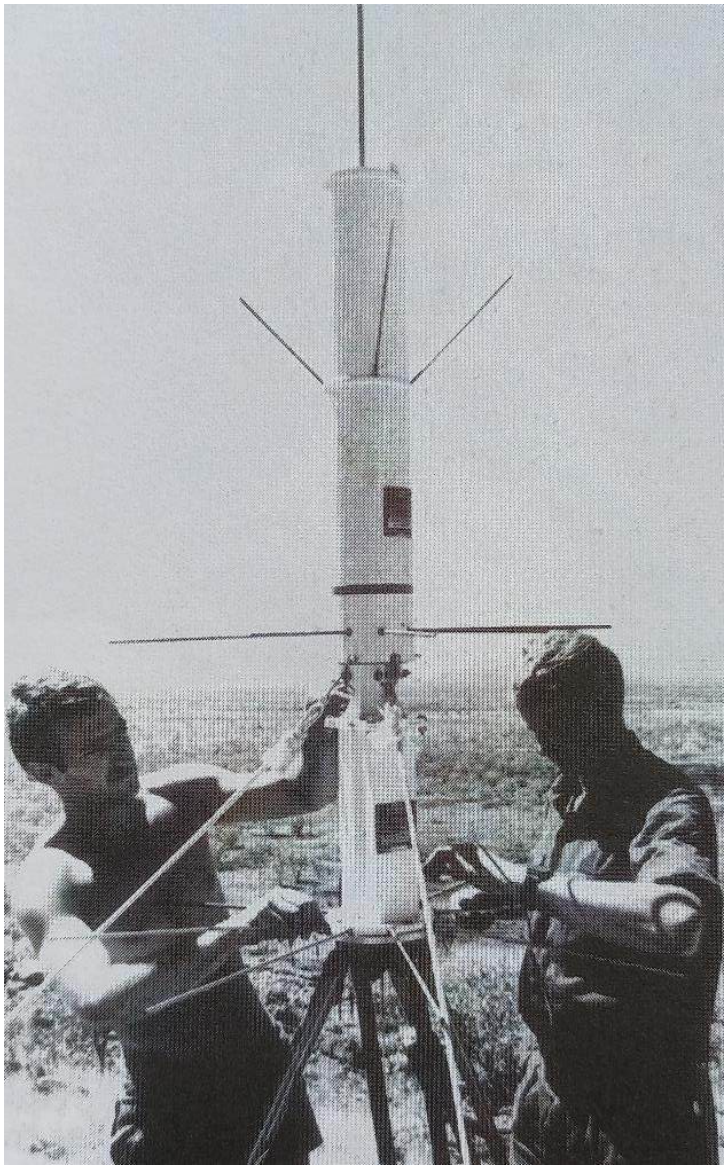

Figure 5 Op MIZMAZE 85 (Aug 85). Sapper A Matison and Corporal J Smith (both 5 Fd Svy Sqn) assembling a Geoceiver antenna/preamplifier – the various series of 'screw-in' rods were to stop interference reflections into the antenna (top section) and the pre-amplifier (bottom section). The line on the antenna just above the rods above their heads is the electrical centre of the antenna and the reference point of the computed spheroidal height. The two guy ropes are to stop the antenna being blown over (Photo: CD Coulthard-Clark, Australia's Military Map Makers, RA Svy 1915-96, p182)

Antenna masts

Three light weight and compact 75 foot Canadian Astromasts were procured for use with the *Geoceiver* antennas to avoid clearing vegetation to get the observing horizon below 10 degrees. The triangular tower comprising light alloy tubes about 10mm in diameter joined with pin hinges and with light locking wires was erected by placing the collapsed stacked tower on a very level base plate and anchor pin and rotating one section, about 1 foot high, at a time with the help of the tripod hoist. Guy wires at 25, 50 and 75 feet were attached 120 degrees apart. The tower could be secured at any of those heights. The towers were transported in two drums (standing near the base of the tower in Figure 6) – one being for the collapsed tower and the other for the assembly tripod with winch and the guy wires and ground stakes etc. The assembled antenna was screwed to a plate on the tower top before erection. A 200 foot signal coaxial cable was attached to the preamplifier with the other end attached to the receiver in the *Geoceiver* tent. Height of the antenna electrical centre above the ground mark was measured by either the antenna cable or a 30 metre cloth tape taped to the antenna.

It must be said that although trained how to erect and dismantle the tower it was not a particularly popular item as it seemed to have a mind of its own. Site preparation was the key, especially having a level base and well planned guy wire anchor locations. Otherwise it was a case of getting out a yellow 'Loss and Damage' report pad and giving a junior Lieutenant a job as Inquiry Officer.

> From the author*: As the instructor on the 1/77 Geoceiver course at School of Military Survey, I was starting the 'tower' lesson when Major Jim Corless appeared. He asked me did I really have to erect the Astromast rather than showing the parts, then only erecting it to 25 feet. I insisted, telling him that it was important to know how to prevent the tower from twisting, corkscrewing and falling. Not convinced, he said 'well it's on your head' and watched from the sidelines. I guessed that he didn't want to have to call DSVY-A to say that we have one less tower for use in Papua New Guinea or Indonesia. It did not fall then but there were accidents and one tower ended up just over 25 feet high.*

The Astromasts were not to be climbed and woe betide anyone who forgot to attach the antenna cable to the pre-amplifier. 4 Fd Svy Sqn (-) on Op SEA KING 1974 found that a team of at least three men were required to safely erect the tower and lower it, although lowering was more difficult and 'did not look at all safe'. [43]

Two 70 ft (21 metre) telescopic pneumatic Hilomasts were purchased by Strategic and International Policy (SIP) Division for use with *MX-1502* in Vanuatu (Op ALGUM 1984 – 4 Fd Svy Sqn). For helicopter transport the masts had to be under-slung carried because of the tower length when collapsed. Those masts were later used for GPS TI4100 Geodetic Receiver antennas.

[43] Project Report Op SEA KING 1974 provided by Warrant Officer Class One Allan Adsett and Major Dave Carney – Canadian Exchange Officer, 2IC Op SEA KING, later Colonel Director of Survey Canadian Forces

Figure 6. AN/PRR-14 Geoceiver antenna atop a 75 foot Canadian Astromast. This tower is intentionally leaning to place the station ground mark plumb under the antenna using a Wild T2 theodolite. The two storage/transport drums and the winch tripod are near the base of the tower. The antenna/pre-amplifier is connected by a 100 foot coaxial cable to the receiver in the tent. (Photo: author)

MX-1502 Geoceiver

With the release of the Transit system to the public in 1967, electronics companies produced receivers for the commercial navigation and surveying markets as well as military receivers. Magnavox was one of those producing a mix of commercial and military receivers before releasing the commercial second generation dual-frequency *Geoceiver*, the *MX-1502 Satellite Surveyor*, in 1978. The *MX-1502*, from its *Geoceiver* roots, became the 'gold' standard for survey and geodetic Transit Doppler satellite receivers. The receiver and data recorder were in the one unit weighing 21 Kg being half that of the *Geoceiver* and a much smaller and lighter antenna (Figures 7 and 8).

In March 1982, a set of two *MX-1502* were procured for RA Svy as a commercial-off-the-shelf purchase funded by Strategic and International Policy (SIP) Division Headquarters Australian Defence Force for Defence Cooperation Program (DCP) projects.[44] The purchase also included two 12/24VDC Honda generators to charge 12V wet cell batteries for the *MX-1502s*. Hondas were lighter and promised to be more reliable than the standard Army 500W generator. By then the Corps had successfully completed large Doppler satellite survey projects in the DCP in Papua New Guinea, Indonesia, Solomon Islands, Fiji and Tonga. SIP Div would have expected such a purchase, and employment by RA Svy, to be low risk but high return especially in the context of assisting the South-West Pacific island nations to define their EEZ.

Unlike the *Geoceiver* the *MX-1502* could not observe the 324/162 MHz frequency pair used for Doppler signals on geodetic and special satellites. DMA replaced their *Geoceivers* in the early 1980s with the modified *MX-1502* the *MX-1502DS* Dual Satellite – 400/150 MHz and 324/162 MHz - to maintain the Transit and geodetic and special tracking capability. These with security and communications upgrades were used until the end of the tracking program in 1993. RA Svy was never equipped with the *MX-1502DS*.[45]

The two *MX-1502* were trialled by 2 Fd Svy Sqn for acceptance and introduction into service, and like the AN/PRR-14 G*eoceivers* they were issued to that unit for field deployment to field survey units and School of Mil Svy as directed by DSVY-A. They were used mainly in the 'point positioning' mode but also for rapid relative positioning by 'translocation' using the satellite on board predicted broadcast ephemerides. They were also used in 'navigation mode' to find existing survey stations, to confirm new station locations in featureless terrain and to find vehicle routes into stations. The recorded data on cassette tape was automatically checked to ensure its integrity. The receiver had an automatic self-test capability. This was a big advantage over the AN/PRR-14. 'Translocation' results were computed off-line on the *MX-1502* when the data cassettes were brought together at one *MX-1502*. 'Translocations' could be observed over distances of hundreds of kilometres with reported relative accuracies of about a metre from about 10 passes. The *MX-1502* could be left alone to operate automatically but that was never done. An Operators Manual, apparently used by Natmap, is at https://www.xnatmap.org/adnm/ops/prog/GPS/magvx.pdf

[44] Major Paul Pearson (later Lieutenant-Colonel) SO2 Equipment DSVY-A who was responsible for the purchase
[45] Physical Sciences Laboratory, New Mexico State University, *History of the Satellite Ground Instrumentation Section 1958-1993,* (December 1993)

The *MX-1502* would have been ideal for 1st Division Topographic Survey Section to rapidly densify or extend existing survey networks or to establish new theatre grids.

When using broadcast ephemerides for 'point positioning', observing times for similar accuracies to using precise ephemerides were typically 4 – 10 times longer. [46]

Figure 7. Op ARIGHT 85 Cape York (Det 1 Fd Svy Sqn) MX-1502, the data was recorded on the red cassette tape – the tape drive is behind the water tight cover with the Keyboard Code index (Photo: Mick McConnell)

Figure 8. Two MX-1502 antennas between two AN/PRR-14 Geoceiver antennas at School of Military Survey in Feb 1987 for acceptance trials of TI4100 GPS geodetic receivers. The MX-1502 were observing 'translocation' and the AN/PRR-14 were observing simultaneous 'point positions'. Six TI4100 GPS antennas are on the concrete in the background awaiting their turn on the tripods. (Photo: author)

[46] TA Stansell, *The Transit Navigation Satellite System – Status, Theory, Performance and Applications*, (June 1983)

Operations and Projects

1971

In late 1971 Lieutenant Dan McLuskey[47] (1 Fd Svy Sqn) was attached to Aust Army Staff (Washington) for ten weeks where he undertook Doppler satellite *Geoceiver* familiarisation training with the US Army Topographic Command (TOPOCOM). The *Geoceivers* were introduced into service there from 1970. TOPOCOM was one of the agencies to form the Defense Mapping Agency Topographic Centre on 1 January 72.

1973

The Corps history mentions '*In 1973 the Corps joined in a program run by the US Department of Defence to observe a series of US Navy Transit navigation satellites across a wide area of Australia. The Special Satellite (Mission) Tracking Program (SMTP) expected to run for four years, was aimed at developing a model of the earth's atmosphere, determining precise orbits for low-altitude satellites and deriving geodetic positions from Doppler observations of low-altitude satellites. This involved three man detachments from 2, 4 and 5 Field Survey Squadrons undertaking observations at Culgoora (NSW), Penong (SA) and Caversham (WA) respectively*.'[48] This project was not full-time but apparently ran from March 1973 to February 1976. The exact nature of the Corps' involvement in SMTP is not included in this version of this story. More than 40 *Geoceivers* were available globally for the program[49].

1974

Indonesia, Op GADING 4 (21 April – 9 August 1974). In 1974, the US Defence Mapping Agency (DMA) loaned RA Svy two *Geoceivers* (DHQ 009 and DHQ 034) along with a field geodesist Mr Allan Joll for training teams to use and maintain the equipment. The two loan *Geoceivers* and Mr Joll were deployed with 5 Fd Svy Sqn in Sumatra, Indonesia, to observe existing major geodetic stations. Stations included PADANG in Western Sumatra which became the PADANG DATUM being the single station coordinate set of the Indonesian Datum 1974 (ID74) and those major stations occupied on Op GADING 3 1973 by *Aerodist* for trilateration ties across the Strait of Malacca to the Malaysian Peninsula.[50]

Northern Australia, NT and QLD 1974. Following on from GADING 4, the two DMA *Geoceivers*, along with Mr Joll, were deployed to Darwin at (or near) RA Svy station U605 SECOR 1968 Emery Point in Larrakeyah Barracks, Darwin, and a Cape York HIRAN station[51].

Papua New Guinea, Op SEA KING 1974. The DMA team then moved to Territory Papua New Guinea with 4 Fd Svy Sqn (-) which was establishing mapping control mainly by *Aerodist* and helicopter born barometric heighting for the scale 1:100,000

[47] Later Lieutenant-Colonel
[48] CD Coulthard-Clarke, *Australia's Military Map-Makers, The Royal Australian Survey Corps 1915-1996*, Oxford Press, p179-180, (2000)
[49] Swift E, *History of Satellite Orbit Determination at Naval Surface Warfare Centre Dahlgren Division*, (2018)
[50] Captain Peter Bates-Brownsword (later Lieutenant-Colonel) 5 Fd Svy Sqn, Ops GADING 3 and 4 Operations Officer
[51] ibid

topographic mapping program. Two *Geoceiver* teams of three men (Mr Joll, four 4 Fd Svy Sqn Topographic Surveyors and one Syd Wksp Coy Geoceiver technician) observed 11 First Order geodetic traverse stations (40 acceptable passes) from the Indonesian border in the north-west, to Torres Strait, to Rabaul East New Britain and 11 stations mapping control (12 acceptable passes) originally in the *Aerodist* program. Two satellites were available with precise satellite ephemerides for most of the time, but at one point there was only one. Some difficulty with station occupation reinforced the long known value of preliminary survey reconnaissance. *Geoceiver* paper tapes were duplicated on a communications Siemens Telex for safe keeping. For shorter occupation mapping control stations the benefits of having 'light scale' teams for that work was highlighted. It was essential to observe the specified oscillator 'warm-up' time of 3 – 4 hours so that the receiver reference frequencies were stable. The *Geoceivers* did not have internal battery power and 'warm up' was attempted in the transit boxes but was unsuccessful as the receivers overheated. It was recommended to investigate design of boxes allowing 'warm up' during transit.

With the success of the *Geoceivers* and an extension of the loan equipment from DMA for a month, the operation was extended to collaborate with 8 Fd Svy Sqn (Popondetta PNG) on Op SEA WASP in the Vitiaz Strait area between New Britain and New Guinea to establish mapping control and to establish five new stations (20 acceptable passes) adjacent to airstrips for trials of the then new aircraft mounted laser terrain profiler WREMAP2 Airborne Profile Recorder (APR).

Geoceiver reliability was unquestionable at over 97% with 49 hours downtime from over 1,900 hours of operation during Op SEA KING. *Geoceiver* DHQ 009 which had a total of 25,000 hours of operation since manufacture, had 34 hours downtime and *Geoceiver* DHQ 034 with 10,000 hours of operation since manufacture 15 hours downtime. The punched paper data recorders had the most reliability issues mainly paper jamming with humidity and dust. One problem was the satellite predictions provided by DSVY-A which appeared to have been caused by a longitude input error of 100 degrees longitude. Tracking issues were identified with the antenna on the Astromast, with noise and sometimes loss of signal lock above 65 degrees satellite elevation especially around the critical four minutes either side of satellite closest approach point (CAP). This may have been ground reflections and required a few more passes to be tracked.

When the operation was extended, helicopter support changed from 9 Sqn RAAF Iroquois UH-1H to 5 Sqn RAAF Iroquois UH-1H.

After a successful *Geoceiver* phase of the operation the project report concluded:

'*The Geoceiver has shown itself to be an extremely reliable piece of equipment which can be used to obtain both horizontal and vertical control under any meteorological condition and most terrain conditions'*.[52]

[52] Op SEA KING 1974, Project Report, 4 Fd Svy Sqn also provided by Major Dave Carney – Canadian Exchange Officer, 2IC Op SEA KING, later Colonel Director of Survey Canadian Forces

1975

Training development. Initial *Geoceiver* training/course development by School of Military Survey was by a small team of Lieutenant Frank Young and one other (name unknown) using all that was known about the *Geoceiver* at that time[53]. There was the field experience of 5 Fd Svy Sqn in Sumatra and 4 Fd Svy Sqn in Territory of Papua New Guinea, all that Mr Allan Joll (DMA) had passed on and all that Captain Dan McLuskey knew from his attachment to US Army TOPOCOM in late 1971.

Pre-operation *Geoceiver* training in 1975 was conducted for 5 Fd Svy Sqn (Op GADING 5) and 8 Fd Svy Sqn (Op SANDY BUSH).

Indonesia, Op GADING 5 (6 May – 22 August 1975) 5 Fd Svy Sqn was the first unit to use the Corps' own *Geoceivers* once again in Sumatra, Indonesia based at PADANG. These stations, along with the 1974 Doppler stations and the PADANG DATUM 1974 then became a major part of the extensive geodetic survey network adjustment (VARYCORD) prepared and computed by the Survey Sect DSVY-A of Indonesian, Dutch, Australian, Japanese, British and Malaysian geodetic surveys over many years and connected to ID74.

Papua New Guinea, Op SANDY BUSH PH 3 (1 October – 30 November 1975). *Geoceivers* allowed survey control in the remote outlying islands of PNG to be established by Det A 8 Fd Svy Sqn (Wewak) for the national/defence 1:100,000 topographic line mapping program. The Det included four *Geoceiver* teams of two men and two teams of two employed on conventional surveys. In support was: PNGS Salamaua (LCH - Landing Craft Heavy) for the survey duration; Det 38 Sqn RAAF Caribou (Port Moresby) for force insertion, extraction and moving bases; AAAvn 183 Recce Flt (Lae) Pilatus Porter reconnaissance and general support; charter Bell 206 Jetranger helicopter survey team transport and support; civil charter Queen Air air photography Wild RC10. Det A personnel included: 8 Fd Svy Sqn (14), 2 Fd Svy Sqn (2), Army Svy Regt (2), Syd Wksp Coy Geoceiver Tech (2), 183 Recce Flt (Lae) pilot (1) and RAEME Aviation (1), civil pilot (Bell 206) (1), civil pilot (Queen Air) (1), civil aircraft engineer (Queen Air) (1).[54]

Over the next five years, *Geoceivers* were used (not a full-time endeavour) to fix 202 Doppler satellite stations across all parts of PNG to geodetic and mapping quality standards.[55]

From Dennis Puniard[56] '*Operations Sandy Bush and Lahara were conducted in 1975 and 1976 respectively and acquired all the necessary ground control required for mapping of the island chains to the north and east of Samarai in Milne Bay province. The tasks carried out included the establishment of permanent survey marks, including the clearing of stations, suitable marking and referencing. Each station was occupied by parties of two soldiers for a period of 2-4 days each with geoceiver equipment used*

[53] Email Frank Young

[54] 8 Fd Svy Sqn Op Instruction 8/75 Op Sandy Bush Ph 3 dated 24 Sep 75

[55] Dennis J, Puniard, *Australia's Role in the Mapping of Papua New Guinea: from colonial outpost to independent nation*, 100 Years of National Topographic Mapping Conference (2011)

[56] Lieutenant (later Major)

to record a minimum of 14 satellite overpasses to fix the points to 3rd level accuracy. Some additional survey work by tellurometer and astro fixes was also completed. The points were panelled with black or white plastic panels (black was used on sandy white beaches) and identification photography flown over each point using Wild RC 10 cameras mounted in a civil hire Queen Air aircraft. Parties were generally inserted and relocated by Bell 206 civil hire helicopters. The operational support to position and move the whole operational detachment included PNGDF Landing Craft (LCH), RAAF Caribou and PNGDF Dakota aircraft. Air support was also supplied from Australian Army Pilatus Porter aircraft for some redeployment and spot photography work. 8 Fd Svy Sqn personnel were supplemented by other soldiers on detachment from Australian based Survey units. Local labour was hired to assist with porterage and ground clearing tasks. The main base moved as required between Samarai, Goodenough Island, Lousia in the Trobriand Islands and Misima Island. The major operation (Operation Sandy Bush) were in 1975 but, as not all tasks were completed that year, another operation (Lahara) was mounted in 1976 to complete the ground control acquisition. This work had additional support from PNGDF Patrol Boats and some civil hire local shipping to move the ground parties to required observation points.'

Figure 8a. Op SANDY BUSH Ph 3 – Det 8 Fd Svy Sqn – the two PNGDF LCH (Landing Craft Heavy) PNGS Salamaua and PNGS Buna at sea in the Trobriand Islands. (Photo: Russ Larsen[57])

[57] Corporal (later Warrant Officer Class One)

Figure 9. Indonesia areas of Doppler satellites survey operations – Sumatra area (Ops GADING, NUSA TIMUR, NUSA BARAT) in the west to Irian Jaya (Op CENDERAWASIH) in the east. Maluku (Moluccas) (Op PATTIMURA) is between Kalimantan in the west and Irian Jaya in the east.

1975-1977

The Division of National Mapping report of the Australian Doppler Survey 1975-1977 mentions RA Svy observing seven stations[58].

1976

Training, 19 January – 13 February 1976. School of Military Survey conducted 1/76 Geoceiver Operators Course, at 2 Fd Svy Sqn, Randwick NSW, in preparation for Op CENDERAWASIH in Irian Jaya, Indonesia later in the year.

Queensland, Op SUNBIRD 76. Based in Normanton, Det 1 Fd Svy Sqn conducted a joint 40 personnel Army/RAAF *Geoceiver* operation.

Cocos Island (16 March – mid May 1976). A two man detachment from 5 Fd Svy Sqn was attached to a US DMA satellite observation program.

Papua New Guinea, OP LAHARA. Early in 1976, 8 Fd Svy Sqn (Wewak) continued *Geoceiver* operations in the Trobriand, Woodlark and Ninigo Islands groups.

[58] Australian Doppler Survey 1975-1977, Division National Mapping Tech Report No 21

Figure 10. Op Lahara – PNGDF Dakota DC3 transporting Det 8 Fd Svy Sqn to the area of operations (Photo: Dennis Puniard)

Irian Jaya, Indonesia, Op CENDERAWASIH 1976 (3 August – 13 November 1976). Based on the island of BIAK, Op CENDERAWASIH 1976 based on 2 Fd Svy Sqn (Randwick NSW) and combined with Indonesian Army (TNI-AD) Corps of Topografi (JANTOP) established 76 *Geoceiver* stations in the western half of the province for horizontal and vertical control for scale 1:100,000 topographic maps of the Indonesian province Irian Jaya. This was the first phase of a two phase *Geoceiver* operation over two years. Over the 112 days the average completion rate was one station every 1.47 days. Average satellite passes per station was 27.4, or mainly Doppler 2 class. Five *Geoceivers* were available with four teams deployed in the field at any time. *Geoceiver* availability was excellent at 98.5%. Three NAVSATS were available with precise ephemerides. Each *Geoceiver* team was three Australians and two JANTOP. The JANTOP Doppler station plaques set in concrete blocks were prefixed SP (Satellite Point). Aircraft in support were: AAAvn – 2 x Pilatus Porter, air photo (Wild RC10) and general support; RAAF – 3 x 9 Sqn Iroquois UH-1H Geoceiver teams and reconnaissance/clearing, 2 x 38 Sqn Caribou short range transport, 2 x 2 Sqn Canberra - mapping photography (Wild RC10), C130 Hercules medium range transport – force insertion, sustainment, extraction; civil charter Queen Air APR. RAN LCH (Landing Craft Heavy) supported force insertion and extraction. Not including the

JANTOP component, Op CENDERAWASIH 1976 personnel included: 2 Fd Svy Sqn (31); other Army and RAAF on rotation (110).[59]

> From the author. *The Islamic holy month of Ramadan is related to the lunar calendar and not the commonly used solar based Gregorian year. In 1976 Ramadan was late-August to late-September, in the middle of Op CENDERAWASIH. During Ramadan, our JANTOP Muslim colleagues fasted from sunrise to sunset. On a Geoceiver team, sleeping and cooking was in one 22ft x 11ft Australian tent. This meant everyone was awake very early in the morning with the rattle of cooking pots, chatter and the smell of sweet coffee and Garam clove cigarettes from the far end of the tent. The only respite was for the duty Geoceiver operator who if not up recording a satellite pass slept in the Geoceiver 11ft x 11ft tent. One morning, on the coast north of Forward Base WASIOR, I was dozing under the mosquito net, when there was an almighty BANG. First sleepy thought was that a can of fish had exploded on the stove. No, it was a gunshot. One of our JANTOP friends was being a good soldier doing his daily pistol clean. All answered the 'r-u-okay' call. I have no idea what happened but we checked that he unloaded it, and put it, the magazine and ammunition all in the metal box where it all belonged. In the morning we checked the tent for a bullet hole. There was none. The tent end near the soldier was closed so the round must have either hit the ground somewhere in the tent or travelled the 20ft length of the tent, passed us on low stretchers, and out the open door with the tent flaps tied back.*
>
> *We did test fire their weapons over the ocean with stoppages and jams mainly from dirty and old ammunition.*

A story of a *Geoceiver* team on the Mapia Island group of three islands, 200 km north of the mainland, and a tsunami warning from an earthquake in the Philippines is in Canberra Survey Corps Assoc Newsletter 5/2011 – Pulau Bras. Thirty years later one of those islands, Pulau Bras, was honoured with the issue of a postage stamp with the description ***'Bras Island** is the outermost island of Indonesia located in the Pacific Ocean and borders the country of Palau. Bras Island is part of the government area of Supiori Regency, Papua province. The island is located north of Manokwari City with coordinates 0° 55'57" N, 134° 20'30" E.'* [60] [61]

[59] National Bulletin of Survey Corps Associations, No 13, Sep 1977
[60] https://id.m.wikipedia.org/wiki/Berkas:Stamps_of_Indonesia,_104-08.jpg
[61] From Colonel Don Swiney (Retd) MBE

Figure 11. Op CENDERAWASIH 1976 Irian Jaya, Indonesia – the reconnaissance/clearing team at a new village under construction in the 'Birds Head'. From the left: a JANTOP soldier, Sapper Gary Hunter (2 Fd Svy Sqn – Topographic Surveyor), Craftsman John Cassim (Syd Wksp Coy RAEME– Geoceiver Technician) with village men clearing the new village of trees and building huts (Photo: author)

Figure 12. Op CENDERAWASIH 1976 Irian Jaya, Indonesia - Geoceiver team waiting for a 9 Sqn RAAF Iroquois UH-1H to be moved to the next station. The Astromast tower (C) is the two drums on their sides. The three white boxes are for 12V wet-cell batteries for the Geoceiver and Tellurometer MRA301. They weighted down any light stores before the Iroquois landed next to the stack. Corporal Cameron Chapman[62] (2 Fd Svy Sqn – Topographic Surveyor) always had a few fresh fish on order from the forward base cook (Photo: author)

[62] Later Warrant Officer Class Two

Figure 13. Op CENDERAWASIH 1976 Irian Jaya, Indonesia - Island surveys were often a combination of Geoceiver at one point to establish an absolute 'point position' then a reciprocal sun azimuth (Wild T2 on the tripod above the ground mark) and Tellurometer MRA301 (on the left on a 90 deg offset eccentric) distance to establish another point at the other end of the island for azimuth and scale. The Geoceiver antenna is standing on a black cloth bunting panel used here for station identification photography (Wild RC10 mounted in an AAAvn Pilatus Porter) against a highly reflective white sand background. The station identification photography was flown while the Geoceiver team was on site to make sure the black panels were visible. This was one of the stations when the mapping photography (2 Sqn RAAF Canberra, Wild RC10, 40,000ft) was also flown when the Geoceiver team was on station. (Photo: author)

Figure 14. Op CENDERAWASIH 1976 Irian Jaya, Indonesia – a 'light scale' Geoceiver team making use of local resources. The Geoceiver had the four-star 11ft x 11ft canvas tent. (Photo: author)

Figure 15. Op CENDERAWASIH 1976 Irian Jaya, Indonesia – 9 Sqn RAAF Iroquois UH-1H transport and resupply for reconnaissance/clearing and Geoceiver teams. The pilot has his hand out the window waving to local fishing boat crews. (Photo: author)

Figure 16. Sapper Wally Chilcott[63] (2 Fd Svy Sqn – Topographic Surveyor) observing (Wild T2 theodolite) the vertical angle to a tide gauge. This was an observed vertical survey connection between sea-level (the geoid from the tide gauge) and the spheroid (from the Geoceiver). (Photo: author)

[63] Later Sergeant

Figure 17. Op CENDERAWASIH 1976 Irian Jaya, Indonesia – Geoceiver team JANTOP officers looking at what appeared to be a floating anti-shipping mine, presumably from the Second World War, while waiting for the rising tide to have a salt water bath. (Photo: author)

1977

Papua New Guinea, Op NYALAUN KUP PH 1 (20 February - 8 May 1977) Det 8 Fd Svy Sqn conducted *Geoceiver* operations in the islands east and north of the mainland completing the horizontal survey control for the nationwide 1:100,000 mapping program. Use of *Geoceivers* through the islands and support from the PNG Defence Force especially the Maritime Element expedited completion. This was the end of a topographic survey (horizontal control) program commenced in 1964 with *Aerodist* surveys tied to the geodetic surveys commenced in 1962 by RA Svy and 1963-65 by Division of National Mapping and the US Air Force HIRAN 1962-63 network. The *Geoceivers* also connected the 1954-1957 RA Svy and US Army Map Service ship-shore triangulation surveys of New Britain and New Ireland (Operations XYLON and CUTLASS respectively) to the world geodetic system.

Irian Jaya, Indonesia, Op CENDERAWASIH 1977 (9 May – 10 October 1977) This was year two of the collaborative project with the Indonesian Army Corps of Topografi (JANTOP) to map the province Irian Jaya. CENDERAWASIH FORCE of 2 Fd Svy Sqn and other ADF units in support, completed 46 *Geoceiver* stations at the rate of one station per 1.41 days – this was a period of continuous operations. This was about the same rate as 1976. Another four stations were completed in the two weeks following. Four and sometimes five *Geoceiver* teams were field deployed. Like 1976, precise ephemerides was available for three NAVSATS. Operations were hindered by security concerns in some areas slowing progress and by long-line logistic support for the Forward Base directly supporting the *Geoceiver* teams. Some stations were moved

from the planned locations due to weather limiting access in the mountainous terrain. In 1977 the prefix for the JANTOP Doppler station plaques set in concrete blocks was changed from being SP (Satellite Point) in 1976 to D (Doppler). Aircraft in support were: AAAvn – 2 x Pilatus Porter, air photo (Wild RC10), reconnaissance and general support; RAAF – 3 x 9 Sqn Iroquois UH-1H Geoceiver and reconnaissance/clearing, 2 x 38 Sqn Caribou short range transport, 2 x 2 Sqn Canberra - mapping photography (Wild RC10), C130 Hercules medium range transport – force insertion, sustainment, extraction; civil charter Queen Air - APR. RAN LCH (Landing Craft Heavy) supported force insertion and extraction. The force size was similar to 1976, about 150: 2 Fd Svy Sqn (33); AAAvn/RAEME (9), Porter for air photography and reconnaissance; other Army attached full-time (43); RAAF components on rotation. The operation report is online at National Archives of Australia. [64]

On 29 Jul 77, Flight Lieutenant Ralph Taylor, 9 Sqn RAAF, was killed when the Iroquois UH-1H which he was captaining crashed into rain forest jungle at 7,500 ft while trying to negotiate a route into a valley leading to *Geoceiver* station D108 at APALAPSILI about 50 km north-east of WAMENA. The flight of two Iroquois was inserting Sergeant Kevin O'Halloran's *Geoceiver* team of five people. Flight Lieutenant Taylor is commemorated on the Roll of Honour at the Australian War Memorial https://www.awm.gov.au/collection/R1729459 Four others on board, two RAAF crew (Flight Lieutenant Greg Cashmere - Pilot, Aircraftsman Peter Sinclair - Crewman) and two *Geoceiver* team members (Craftsman Phil Edwards[65] – Syd Wksp Coy Geoceiver Tech, Lieutenant Subandi – JANTOP) were injured and were medically evacuated to Australia by RAAF C130 from WAMENA[66]. *Geoceiver* station D108 APALAPSILI was one of the stations that had been avoided because of security concerns (see Appendix 1).

Where *Geoceiver* stations were located on or near airstrips that were crossed, or planned to be crossed, by the laser terrain profiler WREMAP2 APR, a vertical profile of the airstrip centreline was surveyed, normally by conventional differential levelling connecting to the *Geoceiver* station. This allowed the spheroidal height of the APR airstrip crossing point to be estimated from the *Geoceiver* determined height then reduced to the geoid from the surveyed geoid/spheroid separation at local coastal *Geoceiver* stations. The Iroquois mounted *Geoceiver* reconnaissance/clearing team surveyed the 1976 *Geoceiver* station airstrips in the Birds Head area (western Irian Jaya) after the *Geoceiver* reconnaissance in the south-east around MERAUKE was completed.

[64] Op CENDERAWASIH IRIAN JAYA Op report 1977, NAA A6918/2
https://recordsearch.naa.gov.au/SearchNRetrieve/Interface/ViewImage.aspx?B=12916154

[65] Later Brigadier BM (Bravery Medal)

[66] Canberra Survey Corps Assoc Newsletter March 2011

Honours and awards from CENDERAWASIH 1977: 1 x Member British Empire, 1 x Bravery Medal, 1 x Air Force Cross, 1 x Chief of General Staff Commendation, 2 x General Officer Commanding Field Force Command Commendations.

Figure 19. Op CENDERAWASIH 1977 Irian Jaya, Indonesia – the Geoceiver reconnaissance/clearing team waiting for the weather to clear to advance up the valley to find a suitable Geoceiver station site in the area preferred on the mapping photography (Photo: author)

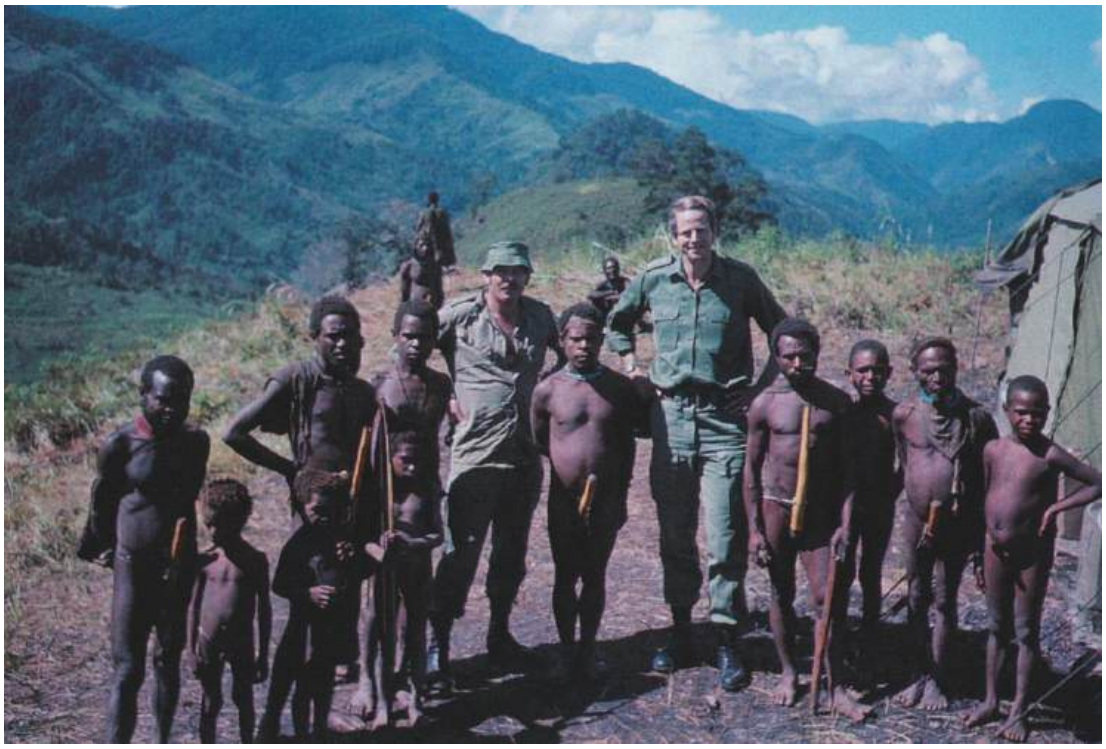

Figure 20. Op CENDERAWASIH 1977 Irian Jaya, Indonesia – Left: Major Don Swiney (Force Commander CENDERAWASIH FORCE) with Colonel John Coates (Colonel Operations Field Force Command and later Lieutenant-General AC MBE, Chief of the General Staff) at a highlands Geoceiver station (Photo: Don Swiney)

Figure 21. Op CENDERAWASIH 1977 Irian Jaya, Indonesia – the glacier-capped highest peak on the island of Papua New Guinea/Irian Jaya, Mt Puncak Jaya (Carstenz) 16,024 ft about five kilometres east of the Tembagapura Freeport mine at over 13,000 ft (Photo: author, photo taken by Sapper Jamie Lyle)

Figure 22. Op CENDERAWASIH 1977 Irian Jaya, Indonesia – the Geoceiver reconnaissance team testing an Iroquois landing zone making sure the aircraft didn't sink in the surface mud at a chosen Geoceiver site near AGATS on the south-east coast. Sapper Jamie Lyle[67], near the Iroquois tail rotor, is making contact with locals in the canoes coming to see what was going on. Jamie was a great asset on reconnaissance, having attended with distinction the short Indonesian language course at RAAF School of Languages at RAAF Base Point Cook.(Photo:author)

[67] Sapper Jamie Lyle was awarded a Chief of the General Staff Commendation for his bravery in an incident during the operation. That story by Major Don Swiney MBE was published in the Canberra Survey Corps Assoc Newsletter 6/11 December 2011 – Ballad of Running Bear

Figure 23. Op CENDERAWASIH 1977 Irian Jaya, Indonesia – JANTOP bronze ground mark plaque D83 – station not established. 'National control network – D83 Doppler Station - Damage is Prohibited, Not to be Disturbed – National Mapping – Corps of Topographi Indonesian Army' (Photo: author)

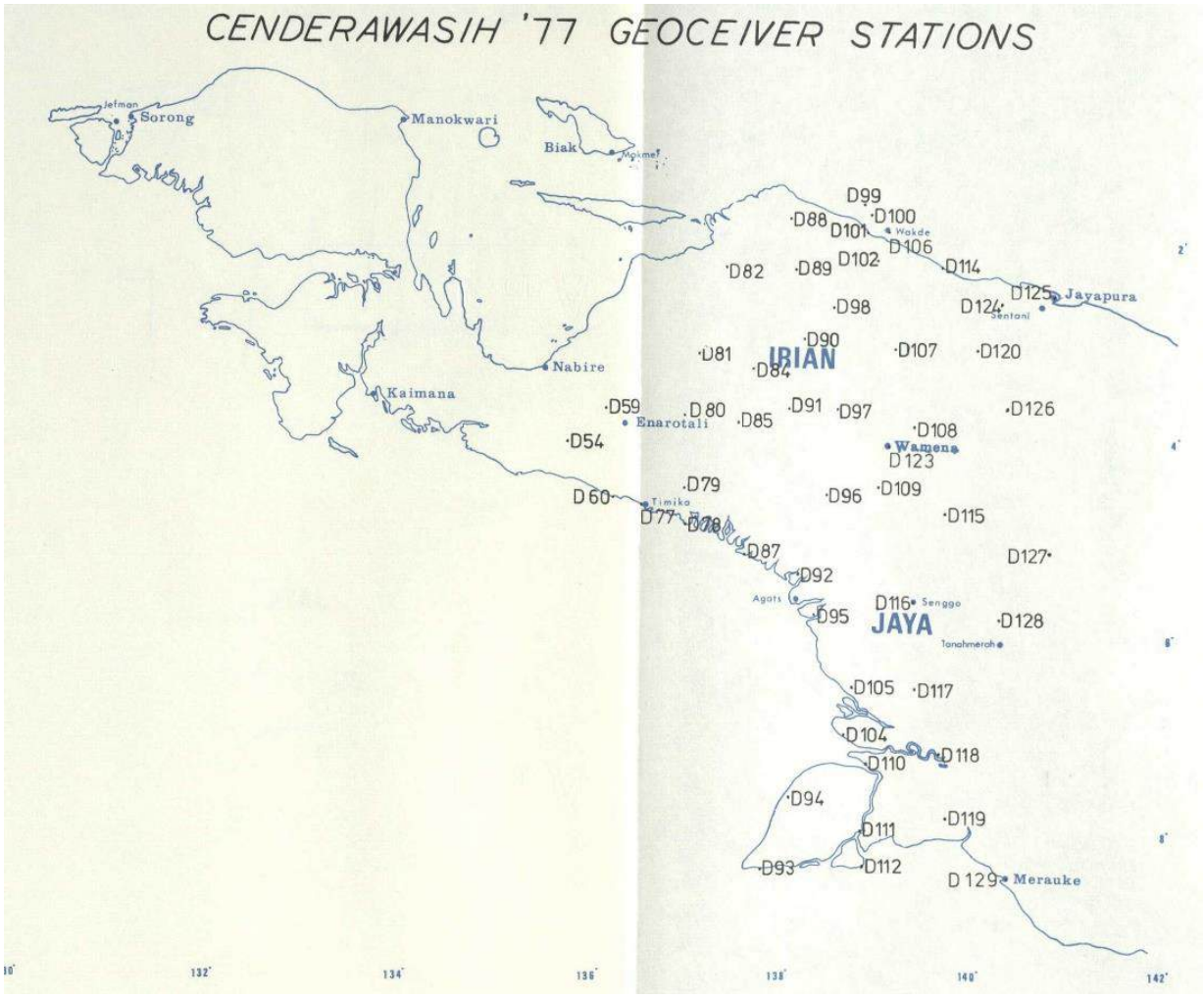

Figure 24. From operation report[68]. Op CENDERAWASIH 1976 Geoceiver stations covered the remainder of Irian Jaya to the west of the 1977 area

[68] Ref: Op CENDERAWASIH IRIAN JAYA Op report 1977, NAA A6918/2
https://recordsearch.naa.gov.au/SearchNRetrieve/Interface/ViewImage.aspx?B=12916154

Force security

Force security incidents are not included in the operation report.[69]

The central highlands, centred around the town WAMENA in the BALIEM VALLEY, was a high risk security area because of widespread civil disturbances. Reasons for this were given as inter-tribal fighting after a football match and activities of elements of the pro-independence Organisation of Free Papua Movement (OPM). Indonesian military forces, based at WAMENA, were conducting intensive operations in the area. The planned location and occupation schedule for some *Geoceiver* stations had to be modified accordingly. Op CENDERAWASIH had avoided that area but on completion of everything else two teams were to observe four *Geoceiver* stations supported from Forward Base (-) WAMENA. The aftermath of the Iroquois crash delayed the survey for more than a week.

Four significant security incidents are mentioned at Appendix 1 – AAAvn Pilatus Porter hit by ground fire, *Geoceiver* station D108 APALAPSILI, *Geoceiver* station D97 KARUBAGA and the reconnaissance team at TIMIKA.

Op HOME RUN (September 1977). Det 2 Fd Svy Sqn strengthened the survey network on the Lake Hume Photogrammetric Test Range based at School of Military Survey, Bonegilla VIC.

Training (26 September – 4 November 1977). School of Military Survey conducted 1/77 *Geoceiver* Operators Course at Bonegilla VIC. Instructor support was provided by 2 Fd Svy Sqn (Sergeant with recent operational experience – Op CENDERAWASIH 1977).

Georgetown area QLD (November 1977). Det 1 Fd Svy Sqn observed 6 existing stations in the Georgetown area with *Geoceiver*. For the first time a RAAF Chinook medium lift helicopter was used. It's load carrying and manouvering capability was used to advantage.

Geoceiver progress. The 1977 National Bulletin of the Survey Corps Associations reported that 250 *Geoceiver* stations had been observed in the first two years mainly in Papua New Guinea and Indonesia '*where it would have previously been impossible to establish geodetic control using conventional methods'*.

1978

Townsville QLD, GEOS-3. Det 1 Fd Svy Sqn observed NASA satellite GEOS-3 also known as GEOS-C (Geodynamics Experimental Ocean Satellite) launched 1975 (also known as Geodetic Earth Orbiting Satellite) assisting a US DMA geodetic program to map the earth's gravitational field. It was the third satellite in the GEOS program commencing in 1965. The satellite 324/162 MHz Doppler package for ground based orbit tracking was tracked by the *Geoceiver*. Other instruments on the satellite were to investigate alternative methods of orbit determination and mapping the ocean surface.

[69] ibid

Transit stations used for GEOS-C Doppler based tracking were the 13 or more fixed TRANET and 12 mobile *Geoceiver*.[70] The station was at RAAF Base Townsville. The program ended in July 1979 but was planned to be longer-term with the DMA operator accompanied by his family with children in school.[71] A small geodetic survey in the Townsville area was also conducted.[72] It is uncertain whether the *Geoceiver* belonged to DMA or RA Svy.

Papua New Guinea, Op ANIA LOLO *Geoceiver* operations were conducted by 8 Fd Svy Sqn on mainland PNG and the Bismarck Archipelago to establish control for future WREMAPS2 Airborne Profile Recorder (APR) operations. Logistic support was AAAvn Nomad aircraft and PNGS Samarai (Patrol boat).

Northern central NSW. For five weeks Det 2 Fd Svy Sqn undertook a collaborative *Geoceiver* project with the Central Mapping Authority in the Collerenebri-Moree area. This was the first time that unit vehicles (Landrovers) were used for the survey teams.

Solomon Islands, Ontong Java (25 June – 2 July 1978) Det 8 Fd Svy Sqn (Wewak PNG) established 4 *Geoceiver* stations on Ontong Java, Solomon Islands. Personnel were: 8 Fd Svy Sqn (6), Syd Wksp Coy (1).

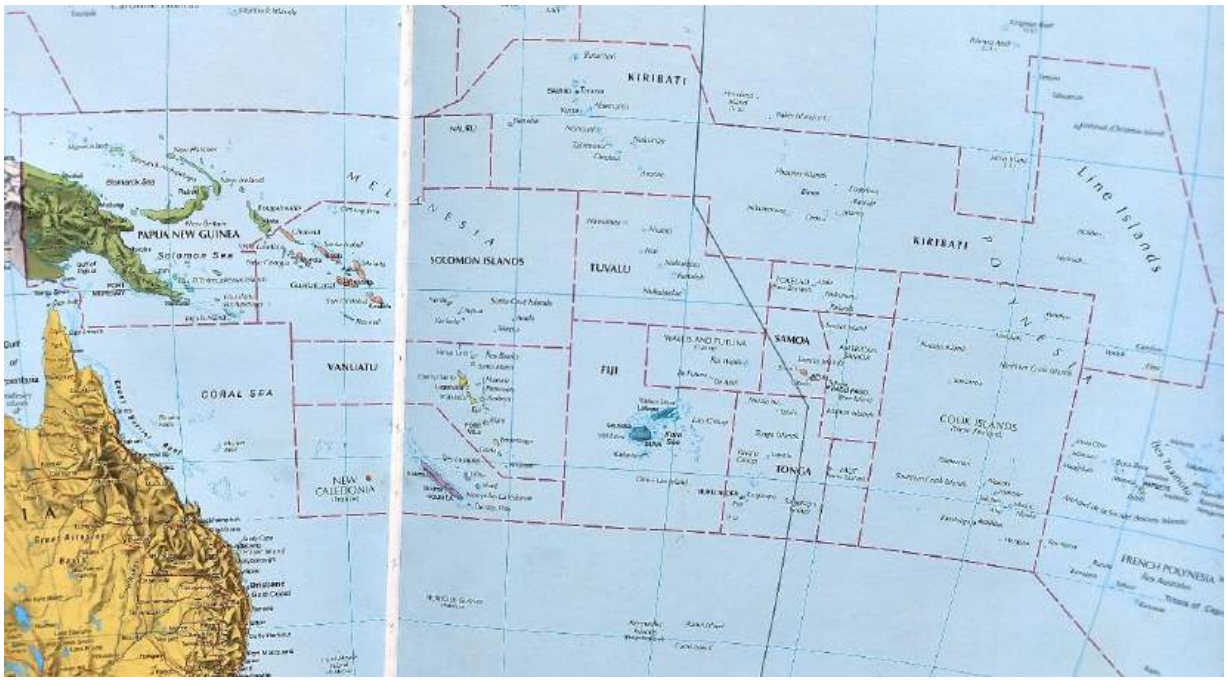

Figure 25. DCP Island Nations South-West Pacific Area (Solomon Islands, Vanuatu, Fiji, Samoa, Tonga, Nauru, Tuvalu, Kiribati) showing the vast extents of the areas of operations and the distances relative to Australia

[70] Anderle RJ, NASA Space Science Coordinated Archive https://nssdc.gsfc.nasa.gov/nmc/experiment/display.action?id=1975-027A-05
[71] Captain Peter Bates-Brownsword (later Lieutenant-Colonel) 1 Fd Svy Sqn
[72] National Bulletin of Survey Corps Associations - 1978

Exmouth area WA, Op NEW BROOM. Det 5 Fd Svy Sqn used *Geoceiver* to establish supplementary topographic survey control for six 1:50,000 maps in the Exmouth area.

1979

Shoalwater Bay Training Area, Townsend Island. Det 1 Fd Svy Sqn used *Geoceiver* to establish WGS72 control for the live naval gunfire and air bombing range.

Townsville, Op Bronze. Det 1 Fd Svy Sqn ……

South Australia, Op DESERT WALK (24 February – 24 March 1979) Det 4 Fd Svy Sqn based at Maralinga Village used *Geoceivers* to establish supplementary mapping control for 1:100,000 mapping in the Maurice, Ooldea, Tallaringa and Barton JOG areas. Five teams observed 20 stations comprising 13 new, 5 existing high order astronomic and 2 existing from an unclosed SA Lands Dept traverse. Twenty five well balanced satellite passes were observed at each station. Terrain profiles of about 100 metres around the station were observed for connection to WREMAPS 2 APR profiles. One *Geoceiver* could not be repaired in the field being replaced from Sydney. 500W generators failed with various problems needing 100 percent backup. *Geoceiver* paper punches frequently jammed from dust ingress. In support was one 171 Command and Liaison Sqn AAAvn Kiowa LOH for reconnaissance and resupply, one 9 Sqn RAAF Iroquois UH-1H for transport of survey teams and to position fuel where vehicles could not access and a charter Queen Air (Brisbane) fitted with Wild RC10 aerial camera for identification photography. Personnel incl: 4 Fd Svy Sqn (20), Syd Wksp Coy Geoceiver Tech (1), AAAvn (2), RAAF (5), civil charter Queen Air (1).[73]

Fiji, Op SPEARLINE 79 (18 April – 21 June 1979) A seven man detachment from 2 Fd Svy Sqn and two Syd Wksp Coy RAEME *Geoceiver* Technicians observed 30 *Geoceiver* stations for Fiji to define baselines for its Exclusive Economic Zone. Each field party consisted of one 2 Fd Svy Sqn soldier, one Fiji Army soldier and one chainman from the Fiji Lands Department. Field parties were transported using one of three Fiji Defence Force ships which were ex US Navy Second World War mine sweepers. In the majority of cases field parties were dropped on shore to then walk/climb the several kilometres to the survey station. Funds were provided to hire local labour. Two stations were occupied with the help of a local charter helicopter for a one way lift from the shore to the top of an existing station on a mountain top. Spot identification photography of all occupied stations was taken using a local charter aircraft with a Fiji Lands Department aerial camera and a 2 Fd Svy Sqn air camera operator. This was the first Pacific operation relying a great deal on local logistic support. [74] [75]

[73] Op Desert Walk 1979, Project Report, 4 Fd Svy Sqn
[74] Captain Kym Weston (later Major) Officer-in-Charge Det 2 Fd Svy Sqn
[75] CD Coulthard-Clarke, *Australia's Military Map-Makers, The Royal Australian Survey Corps 1915-1996*, p170-171, Oxford Press, (2000)

Figure 25a. Op SPEARLINE 79 – Fiji. Officer-in-Charge Captain Kym Weston (wearing a T-shirt) and his team on the beach planning the next phase, to insert the Geoceiver teams on survey stations with the local chartered light helicopter. Sling loads were prepared in the nets. (Photo: Kym Weston)

Maluku Province, Indonesia, Op PATTIMURA 79 (July – December 1979) Det 2 Fd Svy Sqn based at Manado in North Sulawesi established 80 *Geoceiver* stations in the area historically known as the 'Spice Islands' including Morotai and the Halmaheras. This was the first year of a three year DCP project. Support elements included 9 Sqn RAAF Iroquois UH-1H and 38 Sqn RAAF Caribou.

Papua New Guinea. 8 Fd Svy Sqn established 13 *Geoceiver* stations on Manus Is, New Ireland and North Solomons (Bougainville). Support included the Maritime and Air elements of the PNG Defence Force. And like many other survey tasks the trying environmental conditions tested the Survey sappers:

> '*The final field task (8 Fd Svy Sqn – Wewak) was carried out in November 1979 with Doppler satellite observations at three stations to strengthen the survey control of the Admiralty Islands. This task tested the initiative of the members involved as heavy unseasonal rain caused numerous landslides, several massive trees had to be felled to clear stations and to top it all off a tidal wave hit the camp on Papilou Island. Fortunately the equipment had been packed minutes earlier for withdrawl from the point'*.[76]

1980

New South Wales, Op BLACK STUMP (January - February 1980). Det 2 Fd Svy Sqn assisted Central Mapping Authority (CMA) NSW with *Geoceiver* surveys in western NSW. Field parties consisted of three man parties deployed by Landrover. An

[76] National Bulletin of Survey Corps Associations - 1980

AAAvn Kiowa LOH helicopter was deployed for resupply and then subsequent use by NSW CMA for field checking new maps. Stations were located on or near the NSW border from north of Broken Hill to Cameron Corner (junction of NSW, SA, QLD) then east to Burke.[77]

Maluku Province, Indonesia, Op PATTIMURA 80 (20 April – 30 July 1980) Det 2 Fd Svy Sqn established 82 *Geoceiver* stations in Central Maluku Province of islands Beru, Seram, Misool and island groups Banda, Kai and Aru.

Solomon Islands. Op SPEARLINE 80 (15 September – 4 December 1980). Det 2 Fd Svy Sqn assisted the Solomon Island Survey Dept for definition of their EEZ and integration of existing surveys into the world geodetic system. Four *Geoceiver* teams were deployed by two local charter vessels, a 70ft two masted schooner and a 40 foot diesel powered copra boat. Survey points included Ontong Java Atoll 250 km north-east of Santa Isabel Island. Each team was one 2 Fd Svy Sqn soldier and two Solomon Islands Lands Dept chainmen. In support was a charter Queen Air from Australia, with an AAAvn pilot, fitted with a Wild RC10 mapping camera for identification and mapping photography. Australian personnel were: 2 Fd Svy Sqn (7), Syd Wksp Coy (2), AAAvn (1).[78] [79]

Figure 25b. Op SPEARLINE 80 – Solomon Islands. The chartered 70ft two masted schooner (behind the catamaran in the foreground) with the chartered 40ft copra boat alongside for transport and support of the four Geoceiver teams (Photo: Kym Weston)

[77] Captain Kym Weston (later Major) Officer-in-Charge Det 2 Fd Svy Sqn
[78] ibid
[79] Staff Sergeant Brian Partridge (later Warrant Officer Class One)

Figure 26. Op SPEARLINE 1980 – Guadalcanal geodetic station pillar. Warrant Officer Stevo Hinic with the Geoceiver in the white box waiting for the clearing team to finish work (Photos: Brian Partridge)

Figure 27. Op SPEARLINE 1980 – Staff Sergeant Brian Partridge at 11 November 1980 Remembrance Day commemorative service at Honiara, Solomon Islands (Photos: Brian Partridge)

Figure 28. Op SPEARLINE 1980 – Corporal Mark Westbrook trusting the oarsman (Photo: Brian Partridge)

Figure 29. Op SPEARLINE 1980 – Sapper Andy Capp[80] on a log tower, screwing in the Geoceiver antenna ground-plane rods (Photo: Brian Partridge)

[80] Later Warrant Officer Class One

Figure 30. Op SPEARLINE 1980 – Staff Sergeant Brian Partridge in the charter Queen Air at the Wild RC10 air camera NF2 navigation sight. Brian achieved the first mapping photography of Malaita Island a feat much appreciated by the Surveyor-General Solomon Islands who presented Brian with a carton of beer. (Photo and story: Brian Partridge)

1981

Christmas Island, Op NUMBAH (January – February 1981) Det 5 Fd Svy Sqn (3 personnel)

Alice Springs NT, Op CYNTHIA (14 March – 8 April 1981) Det 4 Fd Svy Sqn established 13 *Geoceiver* stations as supplementary control for 1:50,000 topographic line mapping in the six JOG areas: Hermannsburg, Alice Springs, Henbury, Rodinga, Kulgera, Finke. Five *Geoceiver* teams were deployed. *Geoceiver* DHQ054 worked intermittently. Main Base was at Heavitree Gap Caravan Park, Alice Springs. Eighty-five stations including the 13 new stations were panelled and photographed by civil charter Queen Air (Wild RC10). A charter Bell 206 Jetranger helicopter supported the *Geoceiver* teams. Honda generators for *Geoceiver* batteries failed from overloading. Personnel were: 4 Fd Svy Sqn (19); Syd Wksp Coy Geoceiver Tech (2); Adelaide Wksp Coy Vehicle Mechanic (1), civil pilots (Bell 206, Queen Air) (2).[81]

South Maluku Province, Indonesia, Op PATTIMURA 81 (29 April – 10 June 1981) Det 2 Fd Svy Sqn established 40 *Geoceiver* stations. This operation successfully completed the three year DCP project in the Maluku Province including 202 *Geoceiver* stations.

Fiji, Op AUSSURV 81 (July – September 1981) Det 2 Fd Svy Sqn (8 personnel) conducted *Geoceiver* surveys to assist Fiji with Exclusive Economic Zone (EEZ) baseline points and to strengthen existing triangulation for survey adjustment by Survey

[81] Op Cynthia 1981, Project Report, 4 Fd Svy Sqn

Sect DSVY-A. In support was the Royal Fiji Military Force Maritime Element minesweeper HMFS *Kula* with an embarked civil charter Hiller helicopter for ship-to-shore transport.

Figure 31. Op AUSSURV 81, Fiji – Sail Rock Geoceiver station (Photo: Brian Partridge)

Figure 32. Op AUSSURV 81, Fiji – chartered Hiller helicopter, embarked on HMFS Kula, sling loading a dinghy as safety boat for Geoceiver teams on low lying islands with stations just above sea-level - below (Photos and story: Brian Partridge)

Figure 33. Op AUSSURV 81, Fiji – Round Island Geoceiver station, also next photo – Staff Sergeant Brian Partridge, Corporal Mark Westbrook, Royal Fiji Navy surveyor (Photos: Brian Partridge)

From Brian Murphy[82] : *Many of the Geoceiver stations established by Op SPEARLINE 79 and Op AUSSURV 81 were subsequently re-occupied during 2007 and 2008 with GPS receivers as part of a three-phased field campaign to provide International Terrestrial Reference Frame (ITRF) coordinates for these stations. The ITRF system had been chosen by the Fijian Government's Marine Affairs Coordinating Committee (MACC) as the coordinate reference frame in which Fiji's claim to extended continental shelf (ECS) would be lodged with the UN Commission on the Limits of the Continental Shelf, in accordance with the provisions of Article 76 of the UN Convention on the Law of the Sea.*

Phase 1 of this campaign was observed during the inclusive period 3-10 August 2007. Nine survey sites were occupied in the southern area of the Fijian archipelago and included stations which were adjacent to the ECS claim in the South Fiji Basin. These sites included the following six RA Svy Geoceiver precise ephemeris Doppler sites: Kadavu 10592, Matuku 10596, Vatoa 10603, Ono-i-lau 10604, Tuvana-i-cola 10915, Ceva-i-ra 10918

Phase 2, the Northern Fiji Islands campaign, involved the occupation of twenty sites during the inclusive period 8 July-5 August 2008. Twelve of these sites included the following RA Svy Geoceiver precise ephemeris Doppler sites: Solmea 10589, Seseleka 10593, Nakorowaro 10595, Ului Kamali 10597, Tavuaga 10598, Nggelelevu10599, Vadraulailai 10607, Ekubu 10904, Cikobia Macuata 10908, Mana 10918, Sail Rock 10973, Kia 10988. Phase 2 was a large-scale and logistically complex project. Fijian government vessels "Tovata" and "Rayawa" provided logistic support for this phase. The Fijian Department of Lands office in Suva was closed down for the duration of this phase to enable all staff to assist in the survey of baselines for Fiji's ECS submission.

Phase 3 of the campaign was conducted during the inclusive period 28 July – 2 August 2008 and involved the occupation of two sites on the Fijian island of Rotuma.

Tonga, Op AUSSURV 81 (October – 20 December 1981) After successfully completing the Fiji tasks Det 2 Fd Svy Sqn moved to Tonga for a similar project. Of 169 islands in the Kingdom of Tonga, survey stations on 21 islands and 2 reefs were coordinated by *Geoceiver* for EEZ baseline determinations. Connections to sea level and existing triangulation networks were completed where possible. 'Ata Island being

[82] Formerly Natmap and consultant surveyor and maritime boundary delimitation specialist contracted to the London-based Commonwealth Secretariat to assist the Fijian Government's Marine Affairs Coordinating Committee (MACC) in the preparation of the ECS claim for submission to the UN Commission on the Limits of the Continental Shelf.

the most southern island and essential to defining the EEZ could not be safely landed on by boat to observe with the *Geoceiver*.

Pilbara WA, Op MICROBE 81 (20 July – 19 September 1981) Det 5 Fd Svy Sqn used a leased JMR1 Doppler satellite receiver to supplement and upgrade control for 1:50,000 topographic line mapping in the Pilbara.

1982

Yilgarn, WA, Op MISCAST (February – March 1982) Det 5 Fd Svy Sqn used *Geoceivers* to supplement existing control for topographic mapping of the East Goldfields area

Introduction into service trials of two Magnavox MX-1502 (March 1982). In March 1982, 2 Fd Svy Sqn took delivery of two *MX-1502 Geoceivers* after conducting acceptance trials.

'Ata Island, Tonga (May 1982). The importance of getting accurate coordinates for Ata Island, Tonga, is covered in Op AUSSURV 81 (above).

From Andrew McLeod[83] *'Ata Island, 160km SW of the main island, was unable to be acquired on the 1981 op. After the cyclone in Tonga in Mar 82, HMAS Tobruk was dispatched with relief supplies on 27 May and Det 2 Fd Svy Sqn hitched a ride (a SGT I can't remember and me) in an attempt to get co-ordinates for 'Ata with the MX-1502. However, the voyage was very slow and by the time we reached the launch point for the helo, it was dark and the captain refused to allow flight operations for what to him was a very minor opportunity task. 'Ata remained uncoordinated and Colonel John Hillier, Director of Survey – Army, blamed me for not convincing the captain to drop anchor and wait till morning (I remember that…).*

'Ata Island occupation and observation by Doppler satellite Geoceiver was finally achieved on Op ANON 84, see below.

Kimberley WA, Op MIZMAZE 82 (June – July 1982). Det 5 Fd Svy Sqn observed 24 stations with two *MX-1502* including relative positioning 'translocation' fixes to connect previously established *Geoceiver* stations to the existing high order geodetic network. In addition 200 existing stations were panelled and photographed.

Arnhem Land and North-East NT, Op NERVOSE 82 (4 August – 17 September 1982) 4 Fd Svy Sqn (-) equipped with three *Geoceivers* and two *MX-1502,* established 61 Doppler satellite stations in 44 days by point positioning for upgrade of existing and supplementary control for scale 1:50,000 topographic line mapping of 21 JOG areas north of a line from Darwin to the QLD border near the Barkly Hwy. Of those, 51 were new stations, six were existing stations and four were existing geodetic stations observed for the GMA82 (Geodetic Model of Australia) which was later adopted by the National Mapping Council as the AGD84. Post-orbit precise ephemerides was available

[83] Lieutenant (later Lieutenant-Colonel) 2 Fd Svy Sqn

for five satellites – four Oscar and one Nova. On average one station was completed every 17 hours. Both types of Doppler satellite receivers were very reliable with only 72 hours unserviceability in 4,500 hours of operation (98.4% availability). The 24 hr observing program with five NAVSATS was very tiring for the two man Doppler teams and so were rotated when possible for respite. It was intended to use the *MX-1502* in 'translocation' mode but the requirement of 15 x 3-Dimensional passes[84] meant that about 25 passes be observed. Two 5 Sqn RAAF Iroquois UH-1H supported Doppler teams which were limited to 1540 lbs weight, including two soldiers, for one sortie each station. Precast ground marks and water resupply weighing 550 lbs per station meant that three teams could be resupplied in one sortie. This was an economic use of the UH support. Army Kiowa LOH (161 and 162 Recce Sqns) were tasked with survey reconnaissance/clearing and panelling existing stations but Iroquois were called upon if hoisting was necessary. The *Geoceivers* daily alternate data test on the new Nova satellite (105/30480) failed. This was not a satellite or receiver fault but believed to be caused by the Nova Doppler offset which was 4ppm different to the Oscars. Personnel: 4 Fd Svy Sqn (31) including one ARES; Syd Wksp Coy (3); AAAvn (14); other Army attached (8), Army short-term (15); RAAF (18) on three rotations for each aircraft 1 x 38 Sqn Caribou, 2 x 5 Sqn Iroquois UH-1H.[85]

Figure 34. Op NERVOSE 82, Forward Base Maningrida NT – a community briefing on what we were doing (Photo: author)

[84] A term used by *MX-1502* to ensure 3-Dimensional results
[85] Op Nervose 82, Project Report, 4 Fd Svy Sqn

Figure 35. Op NERVOSE 82, Forward Base Maningrida NT – almost 'glamping' with modesty screens around the canvas bucket showers and the washing machine (Photo: author)

Western Australia (September 1982) Det 5 Fd Svy Sqn observed a *MX-1502* 'translocation' from a previously observed *Geoceiver* 'point position' to the primary geodetic network.

Vanuatu, Op ALGUM 82 (11 September – 10 October 1982) The Corps history notes this operation, but it is unclear the nature of it. It may have been a feasibility reconnaissance and collection of survey intelligence for the Doppler satellite surveys 1984-1986.

Islands south of Singapore, Indonesia, Op NUSA TIMUR 82 (12 November – 17 December 1982). The administrative and technical reconnaissance for the Nusa series of three operations in the islands between Sumatra, Singapore and Kalimantan and west of Sumatra, was conducted by DSVY-A Colonel John Hillier and OC 2 Fd Svy Sqn Major Pat Lilley in March 1982[86]. The operation was to be a mix of Doppler satellite surveys and photo identification of existing survey stations. The first phase in the Riau and Lingga Island groups south of Singapore was then planned for the middle of the year but then cancelled after stores and equipment were positioned at RAAF Base Richmond for transport by RAAF C130 Hercules aircraft. Then in October it was on again with a 'light-scaled' detachment of 20 men and technical equipment with everything else to be purchased locally. Last minute transport was a scheduled Qantas 747 flight for all personnel (Business Class) and technical equipment to Singapore then Indonesian Air Force C130 to Tanjung Pinang. On return it was local civil air from Tanjung Pinang to Singapore then Qantas 747 again to Sydney.

From Peter Clark[87]: *I joined Op Nusa Timur 82 under Major Pat Lilley OC 2 Fd Svy Sqn. I recall we had to go light scales – no lavish survey field camps – no chartered cargo space. We had to source locally in Tanjung Pinang where we were to be based from the local Naval Base. So I spent about a week on the ground there sourcing supplies locally – generators, lights, camping gear etc from the local 'mafia', it was a crazy time. Working through local middle men who knew all the local importers, mostly from Singapore as I recall. Thankfully Pat had a healthy 'imprest' account. As I recall he and WO1 Dennis Duquemin did a lot of wheeling and dealing. As for the Survey Op*

[86] Major Pat Lilley (later Lieutenant-Colonel)
[87] Lieutenant (later Major)

– I have this feeling it was downscaled. I don't think we did any Transit Doppler tracking. I led the survey parties of three teams as we criss-crossed the nearby island groups, putting two man teams ashore to do sea level connections for pre-marked/surveyed points and panelling for air photo identification on some very remote places and rock outcrops. We were based on a small wooden Indonesian Naval Patrol Boat (a former Dutch minesweeper) – armed with an aging 50 cal machine gun up front – more for show than anything serious. I recall SGT Steve Glouster accompanied a charter aircraft for some of the operation as they collected identification pictures once we had panelled all the sites. We also had a Sydney Wksp Coy Geoceiver Tech CPL. I do recall the approach to Mascot late Friday afternoon week or so out from Christmas, sun setting on the Bridge and Opera House, the Harbour looking amazing and thinking this RA Svy life is pretty good – commercial overseas flights, overseas operations and scenic cruises in the South China Sea.

Much of what was done in the last month of 1982 was survey intelligence and reconnaissance information for the follow-on Op Nusa Timur 1983.

Western Samoa, Op AUSSURV 82 (5-21 December 1982) Det 2 Fd Svy Sqn of two *MX-1502* teams established 6 Doppler satellite stations on the two main islands of Western Samoa.…extract from an article by Al Hancox[88] posted on Facebook[89]:

On the tarmac at Sydney's Mascot International Airport, LT Andrew McLeod had no idea that in just a few minutes time how lucky he would be. He was expecting to deliver a Christmas present to the Government of Western Samoa (since 1997, just called Samoa). The plane was shortly to depart for Fiji, and then onto a weekly connection service to Samoa.

Through Australian Government assistance via OP AUSSURV 82, on board his commercial flight today, he had the capability to enable Samoa to transform its geodetic framework onto a world geodetic system. This would allow Samoa to determine its 200 nautical mile Exclusive Economic Zone (EEZ).

With Andrew on the flight were recently Magnavox vendor-trained SGT Nev Stone[90], and me, WO2 Al Hancox, along with our camping stores, technical equipment, and two Magnavox MX1502 satellite tracking kits. Could you imagine the commercial checked baggage cost these days for two fully fitted out survey camp stores and equipment?

Andrew was probably thinking about the 2½ week project ahead of him. The operation was expected to:

- *occupy **six existing survey stations** on the coastal limits of Samoa's two main islands using Doppler satellite receivers,*
- *determine **geoidal heights** through connections to sea level,*
- *carry out **PCP (photo control point)** connections on existing mapping photography, and*
- *retrieve any obtainable **survey information** relevant to this and future*

[88] Warrant Officer Class Two (later Class One)
[89] Provided by Andrew McLeod
[90] Later Captain

operations.

- *Rather than working in the middle of nowhere as was the case with most survey operations, Samoa is a must-see tourist destination complete with tropical rain forests, marine parks, food markets, rock pools and waterfalls, native villages, the Robert Louis Stevenson Museum, and very friendly inhabitants.*

***Disaster loomed**. Still on the tarmac with passengers settled in and soon about to take off, blind luck played a critical role in rescuing the operation from ruin before it even began. Andrew happened to be on the side of the plane facing the terminal buildings, sitting in a window seat, of which he just chanced to be idly gazing through. It was then he had a major 'WTF' moment! He'd recognised two white transit boxes containing his satellite tracking receivers sitting on a baggage cart being driven back to the terminal! If he did nothing about it, he'd arrive in Samoa unable to do any work.*
In an understandably concerned state, he immediately jumped out of his seat and spoke with aircrew staff. He explained the situation - accommodation stores could stay but not the boxes. Ground crew were consulted and a solution was found. Fortunately, the flight was not full of passengers on this trip. A fix was arrived at by the ground and air crew - some of our stores were retrieved from the cargo hold and strapped into spare seats making room for the satellite equipment boxes. With the crisis averted, he could now sit back, relax, and thank his lucky stars.

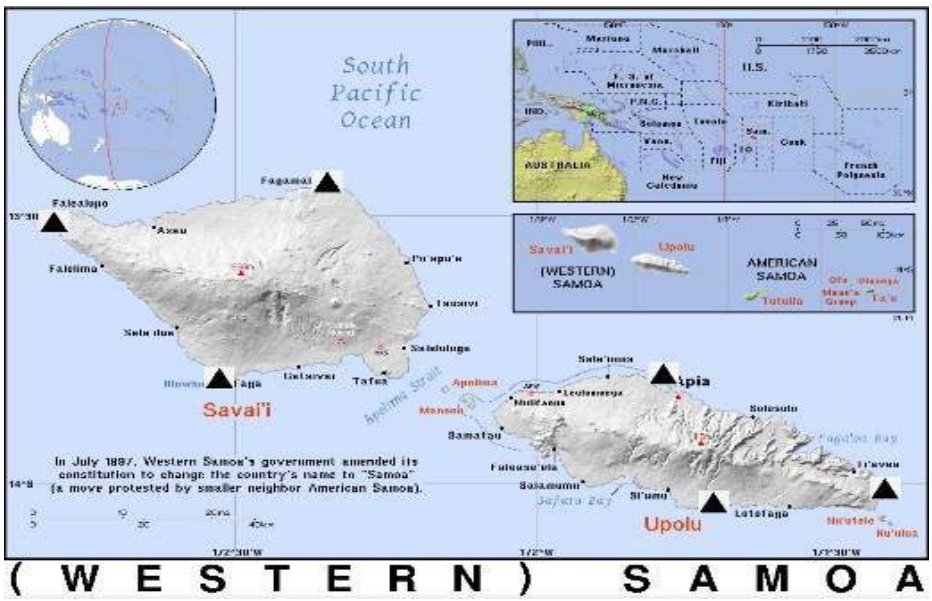

Figure 36. Op AUSSURV 82 - 6 survey control points (black triangles) on the two major islands: Savaii and Upolu. Neville surveyed Savai'i, and I, Upolu. Andrew shared himself between both islands and sorted out admin requirements.

*I noted four interesting things about Samoans. Firstly, they had a characteristic **style of traditional house** called a fale (fah – lay). The construction is distinctive - oval or oblong shaped domed roofs of palm fronds are supported by wooden posts set in an elevated platform consisting generally of small stones or timber. There are no walls.*

The next *thing of interest was the **mat**; the type consisting of woven palm fronds. They have many uses, one being for weather protection and privacy as temporary fale walls – they hang folded up from the roof eaves when not needed. Another important use is*

as a combination floor and sleeping mat which was put to use in my tent. My assistant Samoan Lands Department surveyors Joseph and Peter, and driver Sio brought them along with them and as uncomfortable as it was, I joined my co-workers in using the mats for sleeping instead of my stretcher – one in, all in. (photo below)

*A rectangular piece of cloth wrapped around the waist, known as a **lavalava**, is an article of daily clothing traditionally worn by Polynesians and other Oceanic peoples. We bought these and wore them after hours. They were quite a comfortable form of casual attire, although when seated cross-legged, the custom for another use of the mat is to cover your knees – who knows what lurking underneath on display could be!*

Figure 37. Op AUSSURV 82 – the team in the accommodation and work tent with the MX-1502 in the corner (Photo: Al Hancox)

*The last surprise was an interesting situation. Some Samoans like to socialise into the late hours and their preferred setting is **sitting on a tarmac road**, with the warmth of the day still radiating from the road's surface. They are a dangerous traffic hazard, and at 0030 on the Sunday morning after our arrival to Samoa, we encountered quite a few dashing out of the vehicle's path on the 30km trip from the airport to our accommodation at Apia.*

We stayed at Aggie Grey's Hotel at both the beginning and end of our stay in Samoa. Built in 1900, this internationally renowned hotel was founded by Aggie Grey in 1933 as the old British Club. In the 1940's it became a renowned club for American servicemen stationed in Samoa during World War II. Soon after the war, the location became a popular holiday spot for celebrities including Marlon Brando and author James A Michener. In 1982, the style reflected a 1950's vintage construction with an old-world tropical feeling to it. Its tariff of $42.70 a night offered the guest gardens with bungalows, a pool and a large dining hall, as well as a main building for more accommodation. The hotels original form is mostly unrecognisable today having had major overhauls over the years. It is now known as the Sheraton Samoa Aggie Grey's Hotel.

Downtown Apia had a quiet colonial feel about it. We wandered about on the first day being a Sunday (when not much officially happens), visited the yacht club for drinks, and at Aggies we had meals and swam.

The first of my three stations on Upolu Island was at the Mulinu'u Peninsula Observatory which is located on the northern tip of Mulinu'u Point and the western entrance to Apia Harbour. The observatory had an outside basic shower and ablution facility which was very handy (the first and last time I ever encountered this at a survey site). I went shopping for food with Joseph in the local markets and shops, and Peter cooked our meals. He prepared a range of local dishes using a variety of cooking methods, which even included a shredded raw fish meal which tasted surprisingly good. I was also introduced to some local customs during my time spent with them.

My second survey site lay on the south-central coastline in the village of Poutasi which lies in a tropical paradise setting. (Unfortunately, it would be later extensively damaged by the 2009 Samoa earthquake and tsunami.) We had previously carried out a recce here for a suitable tracking site with good elevation prospects; none could easily be found, but our driver, who comes from Poutasi, put us in touch with the village chief – he would let us use a breadfruit tree as a tower. This was just the start of his generosity to us.

It appeared that the chief had at least two residences. One was a traditional Samoan fale. Nearby were smaller fales which were set up for food preparation and cooking. All the fales were sited close to the ocean shoreline, and a short distance offshore, a small tree-covered island (Nuusafee) could be seen. It was a picture-perfect tropical scene.

The chief would not hear of us refusing to use his other house, a rectangular building set on a concrete slab floor, with roof and walls constructed in corrugated iron sheeting, and glass louvered windows. Again, woven palm fronds were used extensively as floor matting. This was the house he personally used, and Andrew and I were expected to sleep in his and his wife's bed - they slept on the floor. The MX1502 receiver was conveniently set up in the corner between the bed ends, with the antenna lead running through the open louvres and up into the breadfruit tree to the antenna.

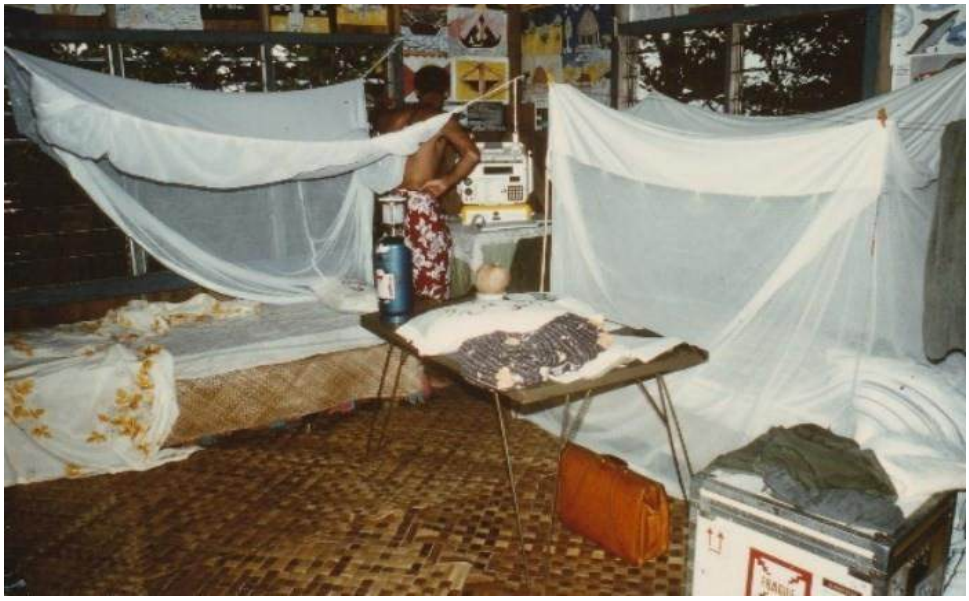

Figure 38. Op AUSSURV 82 – the Poutasi Village Chief insisted the team take over his house while he and his wife slept on the floor. Al and the MX-1502 are between the beds. The MX-1502 transit box is in the foreground. The table is the Army small folding table. (Photo: Al Hancox)

Figure 39. Op AUSSURV 82 – the Poutasi site with MX-1502 antenna atop the breadfruit tree (Photo: Al Hancox)

Figure 40. Op AUSSURV 82 – 'On the night of our final day at Poutasi, the chief provided a feast for us. Andrew and I were seated at one end of the fale as guests of honour, while the family and our assistants sat at the other. It is customary to be seated cross-legged. Later, Andrew presented our hosts with a gift in appreciation for all their support during our stay, and our time spent here was a unique experience' (Photo and story Al Hancox).

.

Figure 41. Op AUSSURV 82 – the Poutasi Village Chief next to Andrew and his family (Photo: Al Hancox)

We were also honoured as guests of a dinner graciously provided for us by Joe, the Director of the Samoan Lands Department. His garden and house were more along the lines of colonial influence and in total contrast to our Poutasi village experience.

He was proud of his extensive garden, showing us beans 6' long, a variety of fruit trees and veges, as well as his menagerie of pigs and fruit bats. The house was large as he had 11 kids, and it also included a room set up as a chapel. Even his marital situation was special - his wife had been killed (possibly in a protest insurrection), and he then married her sister. Joe had put on a feast for us which included beer, coral eggs, chicken, smoked fish, pig, wild passion fruit (soft orange shell type), taro leaves in coconut sauce, potato, and taro etc. The coral eggs were from the annual coral spawning event that happened that month – a rare treat.

He had shown us most generous hospitality. This survey project would make a significant upgrade to Samoa's geodetic positioning data which Joe would have greatly appreciated.

Figure 42. Op AUSSURV 82 – one of Nev Stone's sites on Savai'I, MX-1502 antenna on the right (Photo: Al Hancox)

Work results?

The Magnavox MX1502 Satellite Surveyor instrument was fairly recently introduced into RASVY as an upgrade replacement for the AN/PRR-14 Geoceiver. Neville and I were trained by Magnavox vendors in its use, and the equipment worked well.

We marked and established some new stations, carried out spirit level connections to sea level to determine geoidal heights, observed sun azimuths and theodolite angles etc for eccentric and photo control point connections, did the usual calculations and station notes in triplicate. I cast my mind back to basic course training - I never thought that there would ever be a requirement for PCP connections.

Andrew determined that the poor state of the existing Samoan coastal survey traverse records, and the fact that most ground marks had been destroyed, meant that no network data was extracted. New Zealand aid was expected to work on a new control survey which would incorporate the RASVY coordinates.

OP AUSSURV 82 Western Samoa was successful and a most enjoyable experience. Include Samoa on your bucket list for places to visit; Andrew, Neville and I can guarantee that you would enjoy it.

1983

Central/Western NSW, Op ATAVIC 83 (16 February – 19 March 1983) As South-East Australia suffered one of the worst droughts in the 20th century and the devastating and deadly (75 lives lost) Ash Wednesday fires in South Australia and Victoria on 16 February 83, a Det 2 Fd Svy Sqn of two three-man *MX-1502* teams and headquarters of two, headed west from Sydney in unit Land Rovers with trailers. The task was to establish control for 1:50,000 topographic mapping of a potential Army training area bounded by West Wyalong-Griffith-Hay-Ivanhoe-Wilcannia-Nyngan-Narromine-West Wyalong. Extreme and changing environmental conditions were very trying for everyone and everything with seemingly never ending cycles of: 43 deg temperatures, dust storms, rain storms, mud, 43 deg temps and on and on. Each team observed about 9 'point position' stations, all with a minimum of 30 acceptable passes over an average of 58 hours observing per station.[91]

If the conditions weren't trying enough, one of the Land Rover's gear selector played up with being stuck in reverse at one stage. Notwithstanding the conditions, the Doppler survey productivity rate remained high. As long as the antenna was vertical, and securely connected to the receiver, the observations were assured from the tent – the *MX-1502* was designed to be left unattended.

> From the detachment Officer-in-Charge Peter (Blue) Blaskett[92]: *The operation included levelling connections on the WREMAP 2 Laser Airborne Profile Recorder network in far-western NSW. This was at the end of the '82-'83 drought. Conditions were so bad that most properties were de-stocked and the owners had shut the doors and left. The extremely hot conditions were very hard on men and vehicles. To boot, bush-fires, smoky air, and horrendous dust-storms were frequent. On two (might even have been three) occasions the Queen-Air suffered engine fire while on photo missions, caused by dust in the air/fuel intake systems, and made emergency landings on one engine (Jim Miller was the pilot). All on board were safe, but the nerve of all suffered too. We were all very pleased to get back to Randwick.*

[91] Al Hancox
[92] Captain (later Major) 2IC 2 Fd Svy Sqn

Figure 43. Op ATAVIC 83 – dust storm rising (Photo: Al Hancox)

Figure 44. Op ATAVIC 83 – some stations had to be revisited to clear dust/dirt off the panels before the identification photography (Photo: Al Hancox)

Figure 45. Op ATAVIC 83 – after the 40 degree temps, the dust storms, the rain storms, came the mud (Photo: Al Hancox)

Defence Main Supply Routes NT, Op NEURATION 83 (21 March -12 June 1983)
Det 4 Fd Svy Sqn established supplementary control for 348 x 1:50,000 topographic line maps and orthophotomaps (total 270,000 sq km) of the Defence Main Supply Routes corridors of the Barkly Highway, the highway from the Stuart Highway to the WA border and the Stuart Highway from 25 km north of Daly Waters to 100 km north of Alice Springs. Main base was Tennant Creek, Outback Caravan Park[93] [94]. Five *Geoceivers* were deployed for 'point positioning' and one *MX1502* (loan from SA Lands Dept) was used for navigation to new stations and to locate existing survey stations. 73 *Geoceiver* stations were completed in 65 days or average one station completed every 22 hours. Five NAVSATS were available with precise ephemerides - four Oscars (NSWC 59, 60, 68, 77) and one Nova (NSWC 105). Observation requirements were minimum of 25 passes balanced one north going one south going within 10 degrees elevation. Teams were two soldiers. Some observed 30-35 passes if 25 passes were completed early in the night. This was not required if the team needed a rest from 24 hour work. The observation program was about 50 hours over three nights and two days. Two HP9863A paper tape readers to convert to magnetic cassette tape on HP9815A went unserviceable from dust ingress. Paper tapes were copied on the rear-link communications signals telex. Personnel: 4 Fd Svy Sqn (27) including one ARES; AAAvn Kiowa LOH (9) and Pilatus Porter (2); other Army attached (13). The original plan was to use RAAF Iroquois UH-1H helicopters for *Geoceiver* team support, but after the administrative reconnaissance in Dec 82 it was decided to use a mix of AAAvn Kiowa LOH and Landrovers with trailers to reduce the air support

[93] https://www.rasvy.org/wp-content/uploads/2024/03/ACT-CanbSvyCorpsAssocNewsletter63_Sep23.pdf
[94] https://www.rasvy.org/wp-content/uploads/2024/03/ACT-CanberraSvyCorpsAssocNewsletter64_Dec23-compressed.pdf

logistics. AAAvn pers rotated three times for operational experience. The operation was timed between the end of the wet season for vehicle access and the start of *Geoceiver* Op ARIGHT (Cape York) committed to start 1 July with 1 Fd Svy Sqn – a higher priority area.[95]

Figure 46. Op NEURATION 1983. A RA Sigs Signaler copying AN/PRR-14 Geoceiver punch paper tapes on the messaging Telex machine. Two HP9863A tape readers to convert paper tape to magnetic cassette tape on HP9815A went unserviceable from dust ingress. The small white items on the table bottom left are the Geoceiver rolled paper tapes being one for each Transit satellite pass. The round tins next to the Telex were used to store the tapes in the field. They were 'tobacco' tins with a screw-tight seal. The supply battalion questioned why we were buying 'tobacco' tins (empty). They were more mystified being told they were for data recorded from observations of satellites. (Photo: Mark Heinrich)

[95] Op Neuration 83, Project Report, 4 Fd Svy Sqn

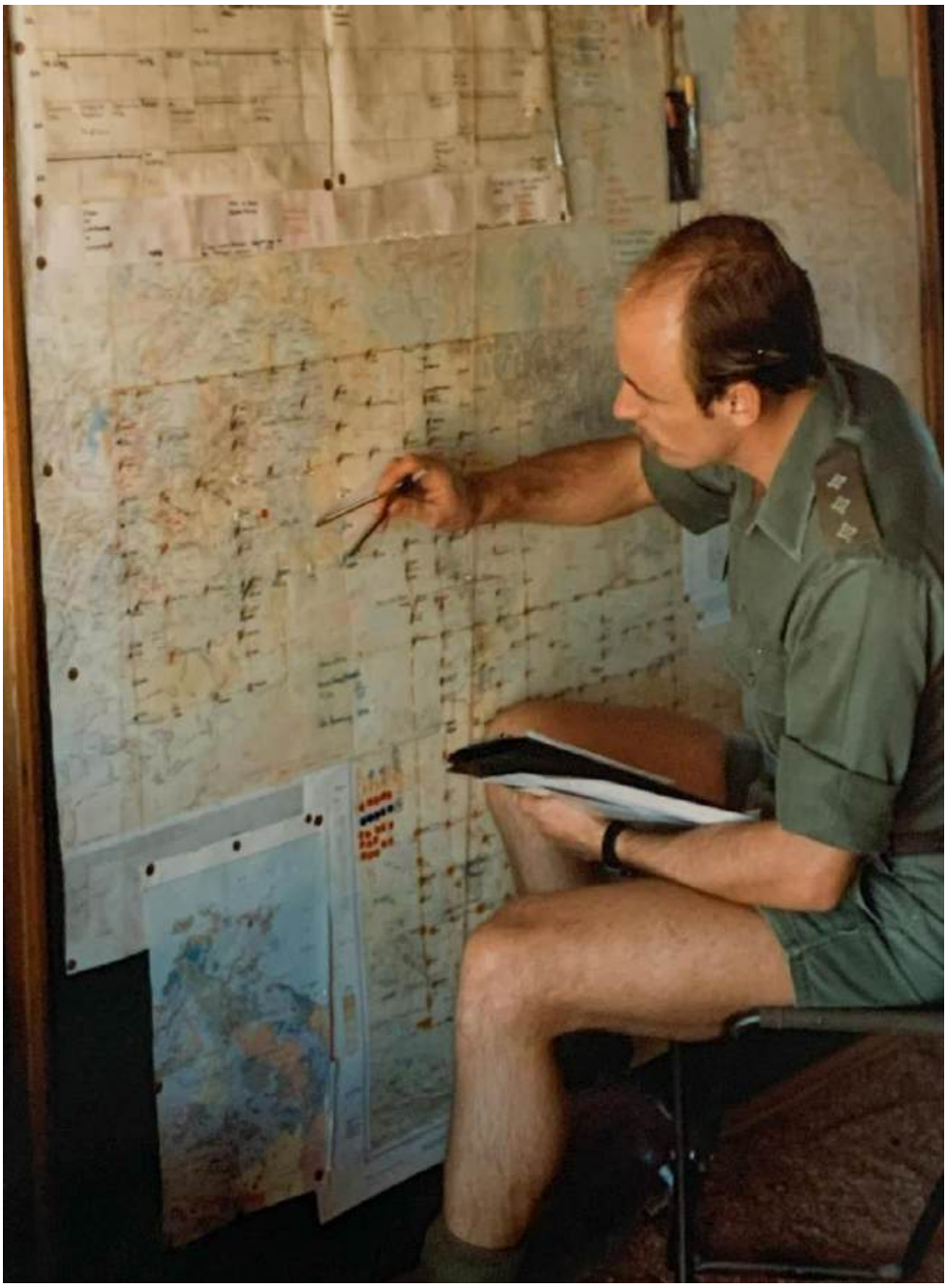

Figure 46. Op NEURATION 1983. Captain Mark Heinrich[96], 2IC/Operations Officer, at the situation map board in the Main Base operations tent. The Operations Officer planned daily and longer-term tasking by continuously monitoring everything about people, equipment, aircraft, vehicles, technical progress, weather, road and off-road driving conditions, bush fires, floods, forward base, fuels, water, rations etc to make sure that the operation was completed on time and on budget given the resources allocated. Early morning 'radio schedules' and mid-afternoon SITREPS (situation reports) from all elements were essential inputs for the daily late-afternoon planning meeting. Most of the direct support of the field survey teams was from Forward Base. Detailed technical, administrative and logistic planning commenced about twelve months prior to the operation. (Photo: Mark Heinrich)

[96] Later Lieutenant-Colonel

Kalimantan, Indonesia, Op NUSA TIMUR 83 (9 May – 14 August 1983) Det 2 Fd Svy Sqn equipped with *MX-1502s* (four teams) established control in the islands of the Riau Archipelago between Kalimantan and Sumatra. Main base was Pontianak, Kalimantan Barat, which was the main base for *Aerodist* survey Op MANDAU 1970 (2 Fd Svy Sqn). Forward support bases were Sinkawang, Tambelan, Karimata, Matak Oil Base and Tanjung Pinang.

> From Peter (Blue) Blaskett[97]: *Early '83 was a turbulent time in 2 Fd Svy Sqn. There was a 100 percent turnover of the five officers with me (Admin Commander/2IC) arriving in early-January for a few days handover with the outgoing OC Major Pat Lilley. Hand-over was understandably a schemozzle with the lack of continuity in manning and no overlap in postings. We had a few days deliberation together about the previous years recce and thoughts for the '83 operation, and I recall making many notes about the recce photos that they took of the sites and islands to be occupied.*
>
> *When the OC Major Harry Hansen arrived in late-January (two weeks before I departed on Op ATAVIC) I had to bring him up to speed on the situation as I understood it. For sure a lot must have been missed or jumbled in all the telling and re-telling.*
>
> *Unsatisfactory as the situation was, nevertheless the operation was planned well and executed successfully and on schedule.*
>
> *The extraction return to Australia was planned to be by RAAF C130 entirely. However the opportunity arose to get personnel home on a chartered Ansett flight from Singapore during the ferrying of 'Exercise Long Look' British Servicemen to Australia. This short notice change meant a rush at the end in packing stores, and extracting all people and stores from Pontianak to Support Base at Tanjung Pinang, and then getting the people to Singapore by RAAF C130 in time for the flight home with just an overnight in Singapore to spare. Stores and equipment were returned to RAAF Base Richmond by RAAF C130 later.*

Mt Ovens, Bathurst NSW (mid-1983) Det 2 Fd Svy Sqn

From Al Hancox[98] *'It was during mid-winter in 1983 that we spent eight days, 18 kms due east of Bathurst, NSW, on the top of Mount Ovens. A trial was being conducted using the Magnavox MX1502 satellite receiver in conjunction with other agencies for reasons I can't recall. Our party consisted of three people – LT Arnold Simpson, PTE Wolfgang Hofbauer, and me, WO2 Al Hancox. The priority was to set up the MX1502 and start tracking, but there was a reason for mild panic – there was no 'lock' on the expected satellite passes. Metal close to the antenna can cause interference, but we had tracked near fences etc previously without issue. Even though the steel post and vanes were placed part way down the slope from the plinth, removing it much further away*

[97] Captain (later Major) 2IC 2 Fd Svy Sqn
[98] From Al Hancox article posted on Facebook, provided by Andrew McLeod

down the hill immediately fixed the problem, and satellite passes were now collected as normal. With technical concerns now alleviated, we could finalise our camp set up.

Seeing that we were expecting to be on-station for a longer than usual tracking time needed to suit the requirements of the trial, a bit of extra effort was made with toilet ablutions. Two logs set over a hole dug next to a dead tree trunk, and sited with some thought, provided a very pleasant outlook over the plains below when used in the seated position.

The surveying equipment and our generator operated without fault during the eight days that we tracked.'

As might be expected in a Bathurst winter, the weather changed to test both the *MX-1502* and the team. Both passed the test.

Figure 47. Mt Ovens, Bathurst NSW. Det 2 Fd Svy Sqn - the MX-1502 antenna is barely visible on the survey pillar in the snowy background (Photo: Al Hancox)

Figure 48. Mt Ovens, Bathurst NSW – winter 1983, Det 2 Fd Svy Sqn (Photo: Al Hancox)

Cape York and Gulf of Carpentaria QLD, Op ARIGHT 83 (1 Jul – xxx) Based in Normanton Det 1 Fd Svy Sqn completed 96 *Geoceiver* stations as supplementary control for scale 1:50,000 topographic line mapping of Cape York and Gulf of Carpentaria. Personnel included members of the unit's ARES Troop and 1 Div Svy Sect. This was the unit's largest field survey operation since Op SUNBIRD 76.

Murchison and Gascoyne WA, Op GOLDEN FLEECE (1 September – October 1983) Det 5 Fd Svy Sqn completed 45 Doppler satellite stations using *Geoceiver* and a rented JMR1 receiver for supplementary control for scale 1:50,000 topographic line mapping. In addition 220 existing stations were panelled and photographed.

1984

Dundas region Eastern Goldfields, Op NUYTSLAND Det 5 Fd Svy Sqn completed xx *Geoceiver* stations as supplementary control for scale 1:50,000 topographic line mapping.

Pilbara WA, Op MICROBE 84 (April – June 1984) Det 5 Fd Svy Sqn of 15 personnel established 49 Doppler stations including observation by 'translocation' and 'simultaneous point positioning' as supplementary control for scale 1:50,000 topographic line mapping Total Doppler stations observed on Op MICROBE 1981 and 1984 in the Pilbara was 74 new and 16 existing stations upgraded.[99]

Islands west of Sumatra, Indonesia, Op NUSA BARAT 84 (2 June – 2 August 1984) Based in Padang on Sumatra, Det 2 Fd Svy Sqn of 43 personnel plus Indonesian forces with support of charter civilian Sikorsky S58 helicopter from Airfast, an AAAvn 173 Gen Spt Sqn Nomad fitted with a Wild RC10 mapping camera and Indonesian

[99] Major Pat Wood, Westlink magazine of WA Survey Corps Assoc, no 4, 1992

Navy LCU Andri XXXIV, established 54 Doppler satellite stations (*MX-1502*) and two stations by azimuth and distance. The successfully completed operation was reported in the Army Newspaper September 20, 1984.[100] This was the last of the three NUSA series of operations (1982-1984) and the last of the DCP Doppler satellite field survey operations with Indonesia – GADING Sumatra 1974-1975, CENDERAWASIH Irian Jaya 1976-1977, PATTIMURRA Maluku 1979-1981, NUSA Islands between Sumatra, Singapore and Kalimantan Barat and west of Sumatra 1982-1984.

Tonga, Tuvalu, Kiribati, Nauru, Op ANON 84 (18 June – 30 October 1984) The importance of national declarations of EEZs was recognised and supported by all South Pacific nations. Fiji supported other nations by assigning the Royal Fiji Military Force Maritime Element minesweeper HMFS Kula[101] acting as a mobile forward operating base having a helideck and an embarked charter Bell 206 Jetranger from Fiji. Det 2 Fd Svy Sqn of 20 personnel established 35 Doppler satellite (three *MX-1502* 100% serviceability) stations selected to define baseline for EEZs. Doppler stations were: Tonga (Ata Is) -1, Tuvalu – 13, Kiribati (including Banaba Is) – 19, Nauru – 2. One of the stations observed in Tuvalu was US Air Force HIRAN 55 Niulakita 1965 Eccentric. Ninety-one new and existing stations were panelled and photographed – a charter Beech B80 Queen Air fitted with a Wild RC10 mapping camera for mapping and station identification spot photography. Force insertion and extraction to Suva Fiji as a staging base was by scheduled civil air Qantas 747. Movement between bases was by light civil air charter. Main bases were the national capitals of Funafuti in Tuvalu and Tarawa in Kiribati. Two inflatable Zodiac boats, with outboard motors, were available for ship-to-shore transfer and as utility boats. These were only partially successful being damaged by coral and rocks – recommended future operations use aluminium boats. The Army force comprised personnel from: 2 Fd Svy Sqn (13), Syd Wksp Coy (1), 2 Sig Regt (3), HQ 2MD (1), 6 RAA Pay Corps Unit (1), 1 and 2 Mil Hosp (1) medical officer. In Tarawa the Det provided a 'door opener' party (2 x RA Sigs CPLs) during a visit by the Governor-General of Australia Sir Ninian Stephen to open the new Australian Embassy in Kiribati. Detachment members were introduced to the Governor-General who showed great interest in the EEZ surveys. Rear-link communications was HF radio Morse-code (RA Sigs operators) through Naval Communications Station Canberra (HMAS Harman). The operations network including main base, HMFS Kula, Queen Air and survey teams was HF radio. [102]

'Ata Island in Tonga, which had not been able to be landed on by boat in 1981, or from HMAS Tobruk helicopters in 1982, was finally accessed and observed. This completed the survey for Tonga to be able to finalise its EEZ declaration.

[100] Army Newspaper https://trove.nla.gov.au/newspaper/article/267036238/29901600 (Brendan Whyte NLA)
[101] Commanding Officer was Lieutenant Frank Bainimarama, later Commander Republic of Fiji Military Forces, 2006 coup leader and Prime Minister
[102] Op ANON 84, Project Report, 2 Fd Svy Sqn, Dec 84

Detachment Officer-in-Charge Captain Peter (Blue) Blaskett and Lieutenant-Colonel Don Swiney SO1 Survey Land Command conducted the reconnaissance for Op ANON 85[103].

Vanuatu, Op ALGUM 84 (30 June – 22 September 1984) A five man Det 4 Fd Svy Sqn (Adelaide) provided support to the Vanuatu Survey Department (lead agency) for a Doppler satellite survey (*MX-1502* all point positioning) to help define baselines for their EEZ, to upgrade existing Dept Overseas Surveys (UK) and IGN French surveys to establish one integrated homogeneous survey network for 1:50,000 topographic mapping of the entire country. DSVY-A performed the national geodetic adjustment. This was the first of three phases of Doppler satellite surveys over three years (1984 in the south, 1985 central, 1986 in the north). The Det provided technical advice, the technical equipment (funded by DCP) and air photography. Two *MX-1502* (Nos 344 and 351) were hired with spare parts. Eighteen new stations were established (20 well balanced satellite passes) and 3 existing network stations observed (40 well balanced passes). Two existing 512 STRE (Specialist Team Royal Engineers) Doppler satellite stations (31329 and 31330) were connected to sea level, 31330 being adjacent to a RAN Hydro tide gauge. Twenty-nine existing stations were panelled and all 50 stations were photographed (Queen Air Wild RC10). Some EEZ base points were to be coordinated photogrammetrically from line photography flown by Queen Air Wild RC10 (scale 1:30,000). DCP purchased stores were: 2 x pneumatic telescopic Hilomast NL21 for *MX-1502* (21 metre, 7 sections, 4.2m retracted); 2 x AGA Geodimetre Model 16 short range infra-red EDM, 2 x Yamaha EF2000 generators. The two survey teams were three people from Vanuatu Survey Dept and one Australian. Personnel were: 4 Fd Svy Sqn (4), Syd Wksp Coy Geoceiver Tech (1), civil pilot Queen Air (1), civil aircraft engineer Queen Air (1). Transport for the two *MX-1502* teams was two boats provided by Vanuatu.[104]

Northern Territory, Darwin Area. Sergeants Roger Rees and Neil Jones (4 Fd Svy Sqn) established Doppler stations (*MX-1502* on loan from NT Lands Dept) in the Darwin area to support development of the over-the-horizon radar surveillance and tracking system now known as the RAAF operated Jindalee Operational Radar Network.

> From Roger Rees[105] *Stations were at Cox Peninsula to the west, Point Stuart to the east, Adelaide River to the south, and on the tarmac of Darwin airport. This point near the junction of the runways, was to be used as the initialisation of equipment prior to take-off and on return. At the time of acquiring our observations at Darwin airport, there had been a major incident with one of the RAAF jets crashing during an exercise in the area, necessitating all similar aircraft in the region to have engine tests not far from our control point. The noise from these engine tests was intense. At Point Stuart, a buffalo came too*

[103] Survey Corps Magazine Parare, Vol 2 Issue 1, Dec 84
[104] Op ALGUM 84 Project Report, 4 Fd Svy Sqn
[105] Later Warrant Officer Class Two

close to our equipment and we were required to use our SLR 7.62mm to stop its advances. The weapon had been issued for protection from crocodiles we may have encountered in the area whilst carrying out observations.

1985

Northern Territory, Op NERVOSE 85 (30 May – 25 Aug 85) Phase 1 of a four phase operation established 52 new Doppler satellite stations across northern Arnhem Land, Bathurst and Melville Islands and a large area south-west of Katherine to the WA border as survey control for scale 1:50,000 mapping. Phases 2-4 were panelling existing stations, field checking of new maps, APR and vertical survey connections from APR profiles to AHD (Australian Height Datum) network.. The Doppler satellite survey method was Simultaneous Point Positioning using precise ephemerides - one base station and three remote stations of four *Geoceivers* (*DHQ 053, 056, 057, 058*) and *MX-1502s (2 x RA Svy nos. 307,335); 2 x loan Australian Survey Office Darwin 12 Jul – 6 Aug nos. 539, 546; 3 x loan SA Lands Dept 7 Aug – 30 Sep nos.312,341,343).* SPP required a minimum of 18 common balanced passes which at times required 40 passes observed. Five NAVSATs were available with precise ephemerides – three Oscars (NSWC 59, 77, 93) and two Nova (NSWC 105, 115). Positioning of Doppler teams of two soldiers was by a mix of Landrovers with trailers and AAAvn LOH (161 and 162 Recce Sqns and 171 Comd and Liaison Sqn). The 3 x LOH were also used for reconnaissance, panelling existing survey stations and field checking new maps. Other aircraft in support were 1 x RAAF Squirrel helicopter and 1 x RAAF Caribou (Darwin Search and Rescue Flight), 1 x AAAvn Porter (173 Gen Spt Sqn - air photography Wild RC10, general support) and 1 x charter Queen Air equipped with WREMAP2 laser APR (Airborne Profile Recorder) and Wild RC10 mapping camera. Of the 103 personnel on the operation, 56 were from AAAvn units on two week rotations and the remaining 47 were 4 Fd Svy Sqn (33) and attached (14).[106]

Cape York, Op ARIGHT 85 (20 May– 8 Aug 85) From Main Base at Weipa Airport, Det 1 Fd Svy Sqn completed seven stations using *MX-1502* amongst other tasks of Airborne Profile Recorder (APR), APR level connections and field annotation of mapping photography. QLD Lands Dept loaned *MX-1502* for this survey.

[106] Op NERVOSE 85, Project Report, 4 Fd Svy Sqn

Figure 49. Op ARIGHT 85. Det 1 Fd Svy Sqn MX-1502 believed to being tested at Weipa Airport Main Base. The antenna and tripod on the left is a loan MX-1502 from QLD Lands Dept (Photo: Mick McConnell)

Figure 50. Op ARIGHT 85. A MX-1502 'light scale' team camping stores under-slung net load on AAAvn Kiowa LOH. The technical stores are in the cabin (Photo: Mick McConnell)

Figure 51. Op ARIGHT 85, Det 1 Fd Svy Sqn, Staff Sergeant Cameron Chapman – Topographic Surveyor, unloading his MX-1502 team stores from the Kiowa LOH under-slung net load. (Photo and information: Mick McConnell)

From Mick McConnell[107]*: Op ARIGHT 1985 in Cape York QLD was only my second deployment on a 1 Fd Svy Sqn operation. The Detachment HQ was based at the Weipa airport. As a young Sapper it was an excellent opportunity to gain more experience conducting ground and aerial (AAAvn Kiowa LOH) field verification annotation, levelling using the Kern automatic level, and operating the Magnavox MX-1502. I do remember the several weeks of static MX-1502 operation to be quite tedious compared to the other more active tasks, as we operated in two man teams with continuous rotating 6 hour shifts for 4 to 6 days before relocating to start the whole process again.*

Having to spend days on the same site with the MX-1502 in/near crocodile infested swamps/rivers, teams were issued an SLR 7.62mm and ammunition for self-protection. We were under strict instructions from the Quarter Master (QM) to at all times keep the rifle, bolt and ammunition hidden separately in the vehicle, and under no circumstances was the ammunition box seal to be broken unless we could justify a self-protection incident in writing. I think all teams ignored the QM direction; especially, the CPL I was teamed with who placed the SLR at the full magazine load condition in the tent on the first evening we set up on station within a swamp area. We definitely sighted and heard a lot of

[107] Sapper (later Warrant Officer Class One)

crocodiles, most likely because we had an excellent device for attracting them (the generator) vibrating the ground to make them all curious about our presence.

Figure 52. Op ARIGHT 85, Det 1 Fd Svy Sqn, Northern Cape York near Weipa (Photo: Mick McConnell)

From Mick McConnell: *Just as we finished setting up the station near the homestead (on left of photo) you can see in the photos with antenna with panel markers, vehicle and tent, we heard a noise right behind us and turned to see a large King Brown snake less than 2m behind us under the tripod. I seem to remember both of us saying "don't move" at the same time and we waited until it slithered away.*

Kiribati, Op ANON 85 (20 Jun-12 Sep 85). Det 2 Fd Svy Sqn of 57 personnel, including support, established 35 *Geoceiver* stations with connections to 14 scale and azimuth points for EEZ definition. Phase 1 covered nine islands in the Line Island group spread over 2,200 km with logistic support from the Royal New Zealand Navy hydrographic ship HMNZS Monowai with a RNZN Wasp helicopter embarked. The initial Main Base was Penrhyn Island in the neighbouring Cook Islands. Phase 2 of eight islands in the Phoenix Islands was from a staging base at Apia in Western Samoa. This phase was supported by Royal Fiji Military Force Maritime Element minesweeper HMFS *Kula* fitted with the helideck and the same charter Bell 206 Jetranger and pilot from Fiji as Op ANON 84. Other air support included RAAF C130 Hercules, AAAvn Nomad, scheduled civil air 707 and scheduled civil air Qantas 747. At Malden Island the *Geoceiver* team had to wear Nuclear Biological and Chemical protective gear until

nuclear radiation levels were monitored to be safe (British nuclear tests 1957/58). A report is in the National Bulletin of Survey Corps Associations - 1986[108].

Vanuatu, Op ALGUM 85 (15 Jun - 29 Sep 85) Op ALGUM 85 was year two of the three year project conducted by 4 Fd Svy Sqn. This operation covered the central part of the archipelago. Det 4 Fd Svy Sqn insertion and extraction was by civilian air. Main base was Port Vila with a Forward Base established at Luganville. Like 1984, the Det acted in an advisory role to Vanuatu Survey Dept with the exception of acquiring the identification and line photography. *MX-1502* teams were manned by the Vanuatu Survey Dept, two of whom had attended the School of Mil Svy Control Survey Course. Twenty-three new stations were observed by point positioning along with 6 existing stations chosen for their network value. Minimum acceptable passes were 20 for new stations and 40 for existing stations. All new stations were connected to sea level. Four new stations had to be re-observed in 1986 as it was found later that DMA could not provide precise ephemerides for that short period. DCP hired two *MX-1502* (Nos 284 and 551) for the survey. Both operated well. Two MEMTEC5000 and MAL5450 tape duplicators faulted having to be replaced. Transport for the *MX-1502* teams was by two chartered boats each equipped with 4.2m aluminium boats with 40HP Evinrude outboard motors for beach landings. Fifty-five existing stations were panelled and all 84 new and existing stations were photographed by Queen Air RC10. Other survey equipment purchased for Phase 1 (1984) was used for this phase. Personnel: 4 Fd Svy Sqn (3); Syd Wksp Coy (1); civil pilot Queen Air (1); civil aircraft engineer Queen Air (1); Vanuatu Survey Dept 2 surveyors and 14 assistants for various periods.[109]

Project GEOSAT, 5 Fd Svy Sqn. US Navy launched GEOdetic SATellite (GEOSAT) on 12 Mar 85. One mission was to improve earth gravitation models. On board was a radar altimeter capable of measuring the distance from the satellite to the ocean surface with an accuracy of less than 10cm. In support of the mission US DMA established a global network of temporary tracking stations with one at Swanbourne Barracks in Perth using a modified *MX-1502DS (Dual Satellite – Transit 400/150MHz and GEOSAT 324/162MHz)* including an automatic weather station. 5 Fd Svy Sqn supported the program by providing Corporal Jeff Ruiz to assist the DMA operator Mr Stephen Vereb. GEOSAT and Transit satellites were observed full-time over three months to contribute to precise orbit solutions for GEOSAT. In August the GEOSAT program became a hot national media topic when Australia's participation in the program appeared to some to be contrary to the Government's decision earlier in the year to not support US trials of the MX multiple nuclear warhead missile system. There were calls of misleading the parliament. Early 1985 the Hawke Labour government had bowed to internal party and public protest pressure reversing an earlier decision to support the tests. This was reported as testing the ANZUS treaty something which was a first and very sensitive with the Australian and US Governments. In the media the GEOSAT argument about its relevance and value to US missile test

[108] https://www.rasvy.org/wp-content/uploads/2024/04/National-Bulletin-22-1986.pdf
[109] Op ALGUM 85 Project Report, 4 Fd Svy Sqn

programs became a tit-for-tat debate amongst Canberra academics. The media reported 'The Army' (5 Fd Svy Sqn) use of a *MX-1502* to be part of the MX missile test program.[110] It was coincidental that the prefix MX stood for the geodetic receiver built by MagnavoX and Missile EXperimental for the missile.

The National Bulletin of Survey Corps Associations – 1986, notes Op CASTEBELLA and Sergeant N McNamara (2 Fd Svy Sqn) being attached to a US DMA survey team. This may have been for a GEOSAT tracking site on Norfolk Island, the existence of which was confirmed in a Minister of Defence media release on 9 August 1985[111].

Kimberley WA, Op MIZMAZE 85. Det 5 Fd Svy Sqn completed the survey control for the 1:50,000 topographic mapping of the Kimberley WA using *Geoceiver*.

Figure 53. Op MIZMAZE 85, Det 5 Fd Svy Sqn, Main Base Mitchell Plateau (Photo: Greg Tolcher)

[110] Captain Rob McHenry (later Lieutenant-Colonel) 2IC 5 Fd Svy Sqn
[111] Aust-US Cooperation on Trial, Aust Foreign Affairs Record, vol 56, No 8, August 1985, p 764

Figure 54. Op MIZMAZE 85 Kimberleys WA – should have brought the Astromasts (Canberra Newsletter 2/2013 story and photo Captain Greg Tolcher – Officer in Charge. That is Greg up the tree, boots off. Never one to ask his soldiers to do something that he wouldn't do himself.)

Figure 55. Op MIZMAZE 85, Det 5 Fd Svy Sqn, Main Base Halls Creek Caravan Park – tents and vehicles in the middle of the photo. Also helicopter landing area in the camp (Photo: Greg Tolcher)

From Greg Tolcher[112]. *Deployment to Main Base Mitchell Plateau in the Kimberley was a combination of road from Perth and three C-130 Hercules sorties from RAAF Pearce Perth.*

In order to achieve preparatory training for a possible operation to Malaysia in 1986, we sent several personnel and three loaded vehicles and trailers by C-130 to Mitchell Plateau. Three sorties were allocated and loading was conducted at RAAF Pearce.

As Conducting Officer, I waited at Pearce while sorties one and two were carried out. During my wait, an enormous roar enveloped the old WW2 building that housed the Movements Office. As I recovered from audio shock, RAAF staff gleefully declared "They've arrived", their enthusiasm directed at the arrival of two "new" FA-18 Hornets that zipped over to WA to participate in a military capability exercise being hosted by Commander 5 Military District (MD), Brigadier Townley. Watching FA-18's conduct vertical ascents later that day was a buzz; watching ace pilot egos in the Officers' Mess that afternoon was also entertaining!

The Mitchell Plateau airstrip is a dirt strip, so, during the drop-offs, the RAAF pilots kept their C-130 engines running rather than risk getting stranded there. Such precaution was probably justified; while returning on their second sortie, one engine failed and a replacement engine had to be called forward from RAAF Richmond NSW. RAAF Movements staff apologised for the unfortunate delay and advised that a planning meeting was being conducted to determine how they would execute our last sortie.

In the meantime, a C-130 sat nearby on the Pearce tarmac, complete with a fresh coat of camouflage paint. A 4WD Land Rover was strapped to honeycomb packaging and several parachutes were attached. Movements staff had already advised that SAS

[112] https://www.rasvy.org/wp-content/uploads/2024/03/ACT-3-19.pdf

soldiers would jump from the aircraft and the vehicle would be air-dropped as part of Commander 5 MD's military capability exercise.

After their planning meeting, RAAF Movements staff explained their solution for our last sortie. With the view that military survey operations had a status superior to exercises, they would cancel the camouflaged C-130 sortie from the military capability show and reassign it to OPERATION MIZMAZE 85. While they were most comfortable with this reasonable logic, I mentally fast-forwarded my thoughts to a possible one-way conversation that might arise when Brigadier Townley learned I had seconded his aircraft with RAAF blessing; that scenario could only be considered as 'not good'. So, I graciously thanked the Movements staff for their kind proposal and suggested that minimal operational impact would arise by delaying our last sortie for 24 hours to allow the Commander's sortie to proceed first, and then ours could follow the next day. With this compromise amicably agreed, I side-stepped that certain difficult 'one-way conversation' ~ and all other ramifications!

We had one electrician and one mechanic assigned to support the operation. At Mitchell Plateau, we were well and truly on our own and dependent on two 10 KVA generators to power the camp, fridges, survey kit, etc. After a couple of weeks, the electrics on one generator failed and the engine failed on the other. When our RAEME team advised that we were in trouble, I asked if they could build one generator that might last the final week. They baulked on the grounds that they were not authorised to undertake such a task. It took some strong immunity promises to convince them to bail us out of trouble, but, to their full credit, they tinkered away and got one generator working.

1986

Cape York, Op B 300 (1 May – 15 May 86) Det 1 Fd Svy Sqn re-observed station B 300 with *MX-1502* and 'translocation' from 1st Order station Mt White.

Vanuatu, Op ALGUM 86 (22 June-14 November 86) Op ALGUM 86 was the final phase for this project being mainly in the northern part of the archipelago. This operation by Det 4 Fd Svy Sqn was in two phases: Phase 1 – line and station identification photography, 22 Jun -14 Nov; Phase 2 – Doppler and other control surveys, 22 Jun – 27 Aug. Insertion and extraction was a mix of civilian air and RAAF C130 Hercules. Main base was at Port Vila. In the period 4 Jul – 6 Aug, 15 new *MX-1502* stations and 1 existing station were observed with 20 acceptable satellite passes for new stations and 40 for the existing station. Three *MX-1502* were used by three teams (2 x Det, 1 x Vanuatu Survey Dept). *MX-1502* serial numbers 003, 004 and 005 were noted in the project report (ownership uncertain). Five satellites observed with precise ephemerides were three Oscars and two Novas. All new stations were connected to sea-level. Personnel: 4 Fd Svy Sqn (7); Syd Wksp Coy (1); civil pilot Bell 206 (1); civil engineer Bell 206 (1); civil pilot Queen Air (1); civil aircraft engineer Queen Air (1); Vanuatu Survey Dept (2)

The Royal Fiji Military Force Maritime Force minesweeper HMFS Kula supported the Doppler satellite phase acting as a mobile Forward Base having a helideck and an embarked charter Bell 206 Jetranger from Fiji. The pilot was familiar with Doppler satellite surveys having worked with Det 2 Fd Svy Sqn on Operations ANON 84 and

ANON 85. He played a big part in the success of the operation being able to position survey teams on difficult sites and operating from the Kula helideck in unfavourable weather and sea state conditions. The Kula crew also contributed significantly being very keen to be actively involved in all aspects of the surveys. The surveyors thought they had the 'rugby scrum' won until the stokers appeared from the ships engine room.

At the end of the operation 93 percent of the planned line photography (scale 1:30,000), 3,960 km of the required 4,260 km, had been completed. The main constraint was low cloud.[113]

Carteret Islands SA, Op CARTERET 86 (11-14 March 86) An eight man Det 4 Fd Svy Sqn, including one ARES, established two Doppler satellite stations (one each on Rocky and Greenly Islands in the Port Lincoln SA area), using three *MX-1502* and 'translocation' from Mt Gawler. The 'translocations' were observed at the three stations simultaneously. Two teams were two soldiers and the third team three. Over about 60 hours of operation an average of 55 passes were observed to achieve 30 of 3-Dimensional passes required by the specifications. The *MX-1502s* were on loan from SA Lands Dept as were two HP3805 short range EDM to establish azimuth/scale points on each island. A charter Bell 206 Jetranger helicopter was used to support the teams on the two islands.[114]

Lake Hume Advanced Survey System Test Range (29 September – 8 October 1986). Det 2 Fd Svy Sqn observed supplementary control, by *MX-1502* translocation, at the Lake Hume Advanced Survey System Test Range within the Lake Hume Photogrammetric Test Range for the acceptance trials of the GPS TI4100 Geodetic Receivers in February 1987. The GPS TI4100 survey[115] was in turn used to upgrade the test range for the acceptance trials of the Ferranti Inertial Land Surveyor 3 (FILS 3) Inertial Positioning System in mid-1987.

Sydney Test Range. In 1987, 2 Fd Svy Sqn used the GPS TI4100 Geodetic Receivers to establish a Sydney test range between 2 Fd Svy Sqn (Randwick) and Syd Wksp Coy (Mascot) for field and maintenance testing of the Geoceivers, the nine GPS TI4100s and the two FILS3 IPS.

1987-1989

8 Fd Svy Sqn (Port Moresby) staff advised PNG Central Mapping Bureau in extending the central Doppler network east to Alotau, Milne Bay to support planning for construction of a sealed road from Port Moresby to Alotau.

[113] Op ALGUM 86 Project Report, 4 Fd Svy Sqn
[114] Op CARTARET 86 Project Report, 4 Fd Svy Sqn
[115] Captains P Clarke, P Jensen, J Mobbs, *The RA Svy GPS Experience 1987/88*, The Australian Surveyor, Vol34, No6 (1989)

End of the Corps' Geoceiver era

The Doppler satellite Geoceivers were kept in reserve but not deployed after 1986 as GPS TI4100 geodetic receivers were introduced into service in RA Svy in early 1987 including a relative positioning field computing capability. Initially GPS point positions from precise ephemerides were computed by DMA. This transitioned to Army Survey Regiment in 1992. The Corps' Doppler satellite Geoceiver capability was then retired. The Smithfield SA TRANET station was retired 30 September 1993 along with the other stations in the global TRANET network. DMA retired their *MX-1502DS* capability on 30 June 1993.[116]
The Transit program was closed 1996.

Conclusion

The Survey Corps' Doppler satellite Geoceiver capability was a unique high value contributor to Australia's military survey and national defence and development of its two nearest neighbours and eight regional island nations in the South West Pacific area of Australia's primary area of strategic interest. Transit and the Geoceivers gave the Corps an all-weather, anywhere in the world reliable geodetic survey capability not had before to support the policies, objectives and intentions of the Australian Government and the directives and orders of the Australian Defence Force.

The simple statistics of 66 survey operations mounted by all five Field Survey Squadrons over thirteen years (1974-1986), 37 being in Australia and 29 in foreign nations, to accurately coordinate about 2,000 survey stations, says it all.

Operations were everything from two or three men with camping and technical equipment on a civil aircraft flight to half way across the Pacific or Indian Oceans for a week or so, to large tri-service ADF and multinational combined operations over many months. The common element was always that the Corps' deployment and employment of the Geoceivers made sure that the assigned tasks were completed. Essential to the capability was the support of the US Defense Mapping Agency, in the first instance with the release of the AN/PRR-14 *Geoceivers* to Australia, the satellite predictions, the satellite precise ephemerides and the Doppler data processing software.

Operating environments included high mountains, island beaches, dense jungle, swamps, deserts, tropical high humidity, rain storms, snow storms, dust storms, high temperatures, low temperatures, tsunamis, inquisitive crocodiles, snakes, terrorist threats and the need for survey team protection, aircraft attracting ground fire and vast and remote areas of operation. Because the Geoceivers were so reliable it was normal for the supporting logistics to be the biggest challenge, to keep up with the constant high rate of survey effort, and at times over very long and demanding lines of communication.

[116] Physical Science Laboratory, New Mexico State Univ, Las Cruces, New Mexico, *The History of the Satellite Ground Instrumentation Section 1958-1993* (December 1993)

But like all survey operations it was the people who made it work under all of these conditions and circumstances. Of course that was not only the Geoceiver operators and maintenance technicians but the thousands of people in Army, Navy and Air Force support elements, the military and civilian survey agencies of other countries, military logistic support of other countries, survey agencies in the then National Mapping Council, civilian aircraft and equipment charter and the data processing centres.

It was not uncommon for members of the support forces to ask how they could volunteer to be part of the next operation. Such was the nature of being involved in doing something worthwhile, but also challenging at times, for the national interests of Australia and its regional neighbours.

Acknowledgements

Sources are generally acknowledged in footnotes as close to the reference as possible. Apart from those references I have received other comments, editorial notes and encouragement since I distributed the previous versions of the paper.

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Appendix

1. Op CENDERAWASIH 1977 – Force security incidents

Appendix 1
to RA Svy Doppler Satellite Years

Operation CENDERAWASIH 1977 - Force security incidents

TIMIKA. For thirteen days, 21 June – 3 July, the *Geoceiver* reconnaissance team (author[117], Corporal Danny Galbraith[118], Sapper Jamie Lyle and two JANTOP soldiers) was based at TIMIKA, near the south-coast. The team also acted as Advanced Forward Operating Base in direct support of the *Geoceiver* teams while Forward Base was at ENAROTALI about 80 km west. TIMIKA was a sealed airstrip, on the flat coastal plain, built to support the construction and operation of the PT Freeport Copper Mine containing the largest reserve of gold and the second-largest reserve of copper in the world**,** high in the mountains near the Grasberg Glacier at nearly 14,000 ft and the highest mountain in Indonesia and the island of New Guinea, Puncak Jaya at 16,024 ft.

Figure A1. TIMIKA international airport 1977 (Photo: author)

In 1977 the airport was a shed near a couple of villages. Now it has a very modern terminal with multiple aero-bridges for a nearby modern Freeport built city (Kuala Kencana) of population 142,000 people.

The lifeline for the mine and the adjacent town TEMBAGAPURA is a precipitous road from TIMIKA about 100 km away. The road is a gruelling climb from TIMIKA at near sea-level to nearly 10,000 feet[119] then down to TEMBAGAPURA at 6,500 feet.

Security elements of TNI-AD (Indonesian Army) were posted at TIMIKA to guard the airstrip, at the Freeport de-watering plant and export shipping port (PORTSIDE) on the coast south of TIMIKA and at TEMBAGAPURA. The mined ore is watered into a sluice at TEMBAGAPURA and then piped over the 10,000 foot mountain down past TIMIKA to the coastal de-watering plant for export.

[117] Then Sergeant
[118] Later Major
[119] Mt Kosciuszko height 7,310 ft above sea level

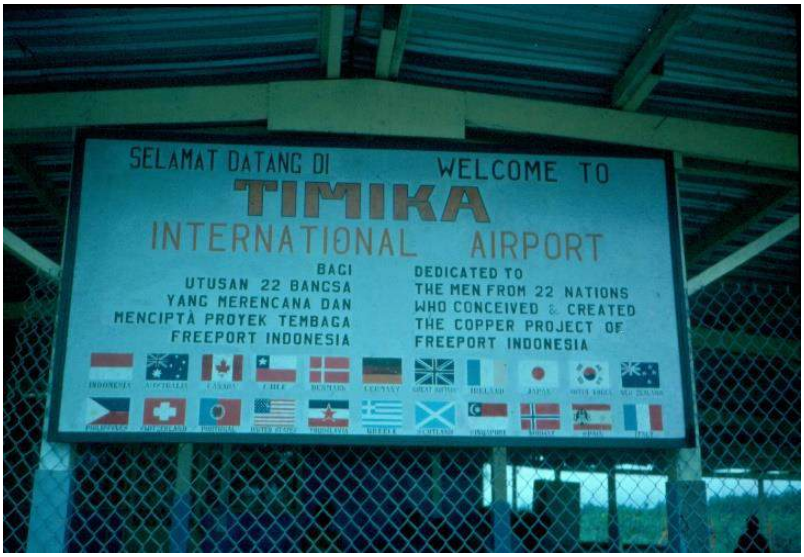

Figure A2. TIMIKA international airport 1977 (Photo: author)

An armed group of OPM (Organisation for Free Papua Movement) was in the area against the existence of the Freeport mine, how it dispossessed them of their land and destroyed the culture of the local Papuan people, was not benefiting the local communities or the province and the environmental damage without any compensation. The mine opened in 1973 but until 1977 the group had not directly attacked the mine, its associated infrastructure or its people. That changed in mid-1977 when attacks did occur from June to September. That was the time that we were in the area. We Australians were unarmed. JANTOP members did carry small arms but that was standard practice wherever they were. Since 1977, and particularly the last two decades, there have been many attacks against the mine and people related to it. Traffic on the TIMIKA – TEMBAGAPURA road and the sluice pipeline have been attacked many times. There are reports that dozens of people have been killed and many more injured, including foreigners, over the past twenty years. And there are many reports of Indonesian forces and police attacking local inhabitants and villages.

The two RAAF Iroquois and Caribou were based at Forward Base ENAROTALI. Each day the Iroquois flew to TIMIKA where we reviewed the proposed daily tasking considering local weather conditions, changes to *Geoceiver* teams status, security reports and fuel states of the 315 drums (80 Avgas for Caribou and 235 Avtur for Iroquois and Porter) ferried in by five RAAF C130 Hercules sorties, mid-May, from BIAK having been positioned there by RAN LCH (Landing Craft Heavy). Iroquois used two drums of Avtur an hour. The Caribou were busy shuffling fuel and *Geoceiver* teams around airstrips, moving Forward Base stores and Iroquois doing survey reconnaissance, moving *Geoceiver* teams and repositioning fuel. The Iroquois and Caribou pilots worked very closely with us on detailed planning of sorties to optomise use of the aircraft to keep progressing the survey work in the most economic way often in trying and changing operational conditions. *Geoceiver* stations reconnaissance was not always an easy task with aborted and amended sorties. The only navigation aid was a Tactical Pilotage Chart (TPC scale 1:500,000) with the overprinted *Geoceiver* station

site preferred location. In the swampy areas east of TIMIKA navigation was very difficult with the TPC, as map detail, mostly rivers and jungle, was incomplete and generalised and low cloud was often everywhere. Often it was the co-pilot navigating from dead reckoning (DR) and the TPC and me TPC map reading. Sometimes we were unsure where we were exactly, adjusting where we had been based on our DR misclosure on return to TIMIKA.

The following is from a contemporaneous journal (the author) mainly about security issues in the area at the time:

***21 June**. Recce D84 and D85 (problem) by Porter. Aerial recce D91 MULIA by Porter (no longer sec risk). To TIMIKA by Porter and two Caribou sorties as Geoceiver recce team and Adv Fwd Base. Set up next to the Indonesian Army Sec Pl on the only dry area around the airstrip. Pl Comd thought we should be inside his compound for our protection. Fwd Base to relocate to here from ENAROTALI. Requested Land Rover to cart water from potable water point to camp. Recce D78 at Freeport Copper Wharf PORTSIDE. Arranged accommodation and meals for Geoceiver Team at Freeport and requested approval from Capt Cash (Paymaster) BIAK. Travel Allowance to be paid rather than invoicing Op. Reported fuel state in SITREP.*

Figure A3. TNI-AD Sec Pl at TIMIKA – afternoon siesta for picquet with leg over his bipod mounted automatic rifle. This was the day before the attack on the Freeport copper sluice pipeline nearby.

***22 June**. Caribou delivered the Land Rover. Caribou overnight here due to bad weather – own emergency ration packs, our stove, slept in aircraft. Sec Pl stood-to all night as OPM had attacked (axe) the copper sluice pipeline in the river bed. Pl Comd warned us not to move around. Employed Alfions 750 rupiah/day local labour.*

***23 June**. Caribou early departure to ENAROTALI and return TIMIKA with Fwd Base stores. Two Iroquois inserted Rusty W Geoceiver D78. Two Iroquois inserted Wally C Geoceiver D77. Loan of a bulldozer to clear a dry site for Fwd Base. Employed Sule 750 rupiah/day local labour.*

***24 June**. Attempted to drive (with two JANTOP soldiers) to TEMBAGAPURA to visit Survey Office for survey intel. Aborted attempt with Landrover smelling badly on very long very steep high grade. Mine use Ford F100/150 utes. Fwd Base no longer coming TIMIKA but going to SENGGO about 250 km south-east. Paid-off Sule 1,500 rupiah.*

Figure A4. Turn around point for the Landrover attempt to drive TIMIKA to TEMBAGAPURA. Road drop offs were 1,500 – 2,500 ft. My JANTOP colleagues waited for me to turn around before getting back in. Traffic is targeted by OPM on this road. Mine vehicles are now armoured. The Landrover is stripped down to load into the Caribou – the windscreen folds down. (Photo: author)

***25 June**. Caribou ferried fuel TIMIKA to SENGGO on recce of SENGGO (me) then returned TIMIKA for fuel to ENAROTALI. Danny and Jamie profile (by level) survey TIMIKA airstrip centreline and connection to D79 for APR.*

***26 June.** Iroquois recce D87, D92, D96. D87 requires 2 hrs clearing. Arranged locals at D92 to build a low pad to stop Iroquois skids sinking in wet ground. Agreed to pay them later. Returned via D86 flypast recce (sec?)*

***27 June.** Danny, Jamie, Suzion, Sudiman cleared D87, ready for occupation.*

Danny to ENAROTALI by Caribou to join Geoceiver Team 4 tomorrow. Sec Pl requested an Iroquois take a section to AKIMUGA to investigate a report that the terrorists had murdered the Indonesian school teacher who has not been able to be contacted by radio for nine days. Local Govt representative and local mission station have had no contact with the teacher. Said that I would pass on the request but to expect a no (confirmed).

***28 June**. Jamie to TEMBAGAPURA with Freeport surveyor Bob. Caribou with resup for us and two Geoceiver teams. Caribou overnight here 3 crew – own rations, our stove, slept in aircraft.*

***29 June**. Two sorties Caribou with fuel TIMIKA to SENGGO. Two sorties each Iroquois insertion Geoceiver teams D87 and D96.*

***30 June**. Iroquois to Pad 11 with me and LT Franz (JANTOP) to meet with Police Colonel from FAK FAK about security. The Colonel said 'The terrorist training camp is three rivers east of here.' Visited Kodim Major at Freeport PORTSIDE about Army ops - 'AKIMUGA should be safe in three days.' Informed Fwd Base. (Later note: I was told that two TNI-AD Infantry Sect went in two outboard boats to investigate the situation at AKIMUGA. At the up river boat landing point the matter of which Sect would guard the boats and which would patrol the few kilometres into AKIMUGA wasn't resolved so the pl(-) returned to PORTSIDE.) We never went to AKIMUGA.*

***1 July**. At 0900 hrs local villagers arrived at our tent very anxious to report terrorists just south of the airstrip in a village on the road. Sec Pl patrol checked it out, nothing found but unknown foot prints in the garden confirmed the villagers story. Informed Fwd Base. Planned Porter five nights basing here cancelled because of sec situation – Porter RAEME Tech and fly-away stores returned to ENAROTALI. Change of plans from Ops BIAK – us to move tomorrow as adv party Fwd Base to SENGGO 250 km south-east, away from OPM activity.*

***2 July**. Caribou ENAROTALI - Geoceiver team from D91 MULIA – TIMIKA with Jamie and 2,000 lb stores to SENNGO. Planned second sortie thwarted by poor weather and light.*

***3 July**. Caribou move TIMIKA to SENGGO including me and three JANTOP. Left Landrover at TIMIKA for later Caribou pickup - rotor button removed and given to Caribou co-pilot. Resup Geoceiver team 2 at TIMIKA enroute to D92. Set up Adv Fwd Base at the abandoned oil exploration camp SENGGO, airstrip slippery. 20 pers overnight including Caribou, two Iroquois and Porter air and ground crews. Fwd Base planned relocate to SENGGO tomorrow.*

***4 July.** Commenced recce sorties from SENGGO. Morning - attempted D109, D115 and D122. Bad weather prevented getting anywhere near D109 and D115. Chose a site for D122 but our navigation was suspect on return to SENGGO. Completed Fwd Base move ENAROTALI-SENGGO. Fwd Base resumed control and spt of Geoceiver teams.*

AAAvn Pilatus Porter hit by ground fire – early August. The AAAvn Porter (air photography Wild RC10) was tasked to acquire low level air photography of the Iroquois crash site near WAMENA. After the flight, damage was found to a 'gust lock'

(to lock flight control surfaces when the aircraft is on the ground). A bullet, having been fired from the ground, had passed through the aircraft skin, through the 'gust lock' which was stored just behind the air camera operator's feet (Corporal Bruce Hammond[120] – 2 Fd Svy Sqn), through the back of the seat, marked an oxygen bottle and was found lodged in a thick roll of white survey station panelling plastic stored behind the operator's seat. The 'gust lock' is now in the AAAvn Museum.[121]

D108 APALAPSILI – early August. Kevin O'Halloran's *Geoceiver* team (see above mention of Iroquois crash) did get to D108 APALAPSILI from WAMENA, along with a protective force of a TNI-AD infantry platoon (-). Major Swiney (Aust Force Commander) and Major Soetrisnoe (Indonesian JANTOP Officer-in-Charge) had earlier visited the APALAPSILI airstrip but the fact that the AAAvn Porter had been shot at in that area indicated that that site was a higher security risk. The Sec Pl fired a few 3 inch mortar rounds into the local river a few times each day as a warning for all to stay away.

D97 KARUBAGA – early August. D97 KARUBAGA, about 60 km north-west of WAMENA (Baliem Valley), was another security risk station avoided earlier in the operation. Pro-independence OPM elements had planted poles on the airstrip to stop aircraft landing. The grass airstrip was one way, uphill and no go-around. An Indonesian Air Transport Piper Navajo (Figure A5 below) was committed to land before seeing the poles. Luckily it landed safely with no injuries. KARUBAGA was a Christian mission school and hospital of Regions Beyond Missionary Union.

Figure A5. Damaged aircraft at KARUBAGA – major damage to both wings (Photo: author)

[120] Later Warrant Officer Class Two
[121] https://www.rasvy.org/wp-content/uploads/2024/03/ACT-9-11.pdf

Figure A6. D97 KARUBAGA Geoceiver station (Photo: author)

Figure A7. D97 KARUBAGA – the Geoceiver team stayed in this house as the missionary was on leave in UK. It was much appreciated after a couple of months in a tent (Photo: author)

The author: *Major Swiney and Major Soetrisnoe conducted the reconnaissance of KARUBAGA by AAAvn Pilatus Porter after the airstrip incident. Geoceiver operations from WAMENA recommenced about a week after the Iroquois crash. The Geoceiver*

team (author, Corporal Tim Allanson[122], Sapper Paul Leskovec[123] plus two Indonesian soldiers) was inserted into D97 KARUBAGA by two Iroquois from Forward Base (-) WAMENA. Early on the third night the missionary in charge knocked on the door with the not good news that there was a credible report, through the missionary radio network, that a small group of OPM from BOKONDINI (about six hours walk away) were on their way to KARUBAGA intending to capture the weapons of the two Indonesian soldiers with us and possibly hold us Australians as hostages. He didn't know if they were armed. The mission bible school boys had gone down the track and were confident that they would know of anyone coming. The missionary offered for us to move to the mission but I didn't want to involve them. He said he would let us know immediately if anyone was coming. I said that I would ask for an evacuation early next morning (terrain, weather and no navigation aids meant that night flying was not possible). The radio call to Fwd Base WAMENA was very noisy on both frequencies (night and day) but I was sure that the emergency message was acknowledged. I encouraged the two Indonesian soldiers to mount a picquet outside the house but they weren't keen on that. The favourite weapon in local-on-local conflict was to burn the house. One soldier was JANTOP but I was not sure about the other as I hadn't met him before and he had a rifle (named a SP I recall – looked like a M16 variant) which I had seen with the TNI-AD infantry units at TIMIKA and WAMENA. They readied their weapons and gave me a 9 mm pistol and two loaded magazines. We had no briefing about 'rules of engagement' I suppose because we weren't armed but I assumed that we had the right of reasonable force for self- protection – maybe not in a foreign country! I told them that if it got to the point of being in imminent danger that we would move across the airstrip with survival essentials to wait for the helicopters early in the morning. We busied ourselves packing the things in the house then packed the Geoceiver and the tent. At that stage we had fifteen good satellite passes which was enough for 1:100,000 mapping control. At first light the missionary came to say that two men from BOKONDINI had been apprehended by the bible school boys. Then came the familiar, distinctive and welcome 'wocka-wocka' sound in the cool thin mountain air of the two Iroquois approaching. They must have departed WAMENA in very marginal light. I made radio contact with the Albatross (Iroquois radio call-sign) to confirm that all was okay and that it was safe to land. Before we left, the missionaries insisted that we (nine of us including the two Iroquois crew) be their guests for a very enjoyable hot pancake and South American coffee breakfast with them. Our two Indonesian team members opted to be safe in the two Iroquois which were guarded by the bible school boys.

One of the missionaries at KARUBAGA, Phyllis Masters, was the widow of one of the three missionaries, Phil Masters from the US, Stan Dale from Tasmania and a local missionary Ndenggen, killed (not by OPM) and cannibalised in 1968 for their preaching Christianity in the Seng River valley of the central highlands east of the

[122] Later Sergeant
[123] Later Warrant Officer Class Two CSM

Baliem Valley[124]*. Three Dutch missionary families suffered the same fate at Christmas 1974 and allegedly thirteen local missionaries in 1976 all in the central highlands.*

OPM elements had not taken hostages prior to 1977, but did so in 1978 and have done so to the present time. In February 2023 New Zealand pilot Phillip Mehrtens was taken hostage at PARO between WAMENA and TIMIKA and his Pilatus PC-6 Porter destroyed by fire. He was held hostage for 19 months and finally safely released on 21 September 2024. His captors said his release was on humanitarian grounds.

On 4 August 2024 New Zealand helicopter pilot Glen Conning was shot dead when he landed at a remote village ALAMA between WAMENA and TIMIKA and his body and helicopter then burnt. His four passengers, three Indonesian health workers and a child were not harmed.

[124] Manning, Helen, *To Perish for Their Saving*, Victory Press, 1969