THE ROYAL AUSTRALIAN SURVEY CORPS

AERODIST YEARS 1964 – 1975

Peter Jensen[1]

The author and Aerodist: My first involvement with the airborne electromagnetic distance measurement system *Aerodist* was as a Royal Australian Survey Corps School of Military Survey pre-Basic Survey Course trainee MRC2 Remote station operator on equipment trials (Northern Command Field Survey Unit/1 Field Survey Squadron) at Toowoomba QLD in May 1969. In 1970 I was a Sapper topographic surveyor *Aerodist* (MRC2) Remote team leader (1 Field Survey Squadron) and in the *Aerodist* Computing Section in Territory of Papua New Guinea (TPNG) for survey control for scale 1:100,000 military topographic mapping. Early 1972, as a Corporal topographic surveyor, I attended training at School of Military Survey, Bonegilla, VIC, as an *Aerodist* MRB3/201 Master operator and completed the system acceptance trials, before deploying as a Master operator with 1 Field Survey Squadron to Gulf of Carpentaria QLD (Project A6 – 1:100,000 mapping) based at Normanton. Immediately after that project I accompanied the *Aerodist* system to Goroka TPNG to hand-over to 4 Field Survey Squadron (Operation Wine Glass) and to conduct operator and manager continuation training. Early 1973 I was attached to School of Military Survey to train MRB3/201 Master operators and managers. I then deployed with 1 Field Survey Squadron to Cape York QLD (Project A2 – 1:100,000 mapping) based at Cooktown.

Preamble

This story is not a formal history of *Aerodist* (airborne electromagnetic distance measurement system) as used by the Royal Australian Survey Corps (RA Svy) 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 *Aerodist* operation there was a comprehensive report as much covering ‘lessons learnt’ for future planning as reporting what was done. A very good example is the three centimetre thick Operation Sandy Hill 1975 (Cape York and Gulf of Carpentaria) report by 1 Field Survey Squadron Group. It is not intended that this story try and include 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, where and how’ of the Corps’ *Aerodist* years and that what is said is as factual as possible. What this does not cover in any depth is the other associated survey work, such as theodolite and tellurometer traverse and other forms of conventional survey, barometric heighting, heighting by airborne laser terrain profiling in the latter years, and aerial photography in particular station identification photography, all of which were often done at the same time as *Aerodist* and was essential to control surveys for compiling scale 1:100,000 topographic maps from mapping air photography.[2]

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.

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[2] Unit abbreviations used are: Royal Australian Survey Corps – RA Svy; Army Headquarters – AHQ; Survey Regiment – Svy Regt; Topographic Squadron – Topo Sqn; Field Survey Squadron – Fd Svy Sqn; Command Field Survey Unit - Comd Fd Svy Unit

This Version 2022.0 includes comments, corrections and additions to the 'Version 2021.0 of April 2021' from those who were involved in *Aerodist* operations. The main additions in this version are the Operation Mandau 1970 (Kalimantan Barat, Indonesia) horizontal survey control diagram (page 37), a recent story by a RAAF Iroquois pilot about flying in Papua New Guinea in support of the *Aerodist* surveys 1973-74 in weather conditions of temperatures higher than standard for higher altitude, with limited knowledge about degraded aircraft performance in that environment (page 49) and photographs of 1972/73 *Aerodist* operations in northern Queensland (pages 62, 73, 74). There are also minor editorial corrections. One item of interest is that *Aerodist* survey stations in Australia are included in the webpage https://geodesyapps.ga.gov.au/historic-geodetic-benchmarks/ and that many of the Station Summaries are also available from that dataset (select AGD66 in 'layers' on the left and select the station – blue dot over the image background – by putting the cursor/pointer on it. If there is a digitised Station Summary it is a JPEG file or PDF down the bottom of the dataset.)

I am grateful for all of this assistance which is acknowledged in footnotes and at the end of the paper. I am equally grateful for all of the responses from former staff of Division of National Mapping (NatMapper's) who were also involved in *Aerodist* surveys 1963-1974 mainly for the scale 1:100,000 national topographic map series generally in the geographic middle of Australia. This assistance is also acknowledged at the end of the paper. I apologise for any errors or misunderstandings from information provided to me and the fault is all mine.

Please email corrections and additional information to me at: canberrasvycorpsassoc.pres@gmail.com

By far the most common responses which I have received from those involved in *Aerodist* surveys is that the story brings back memories, mostly good, of fifty or more years ago. Some things deposited in that part of the brain need a little stimulation to help us remember. I hope that you enjoy the story.

Introduction

It is not an overstatement to say that without *Aerodist* used by RA Svy from 1964 to 1975, medium scale accurate and complete map coverage by the early-1980s of Papua New Guinea, northern Australia and parts of Indonesia would not have been possible. Reports, some brief and some more detailed, on a few of the *Aerodist* operations were recorded in various public documents, and *Aerodist* was of course mentioned in the Corps history, but to the best of my knowledge there is no one collection of all that was done with that technology along with recollections of those who did the work. Unlike modern Global Positioning System (GPS) enabled technologies for topographic mapping, essentially negating the need for large ground survey networks, *Aerodist* was a system of high interdependency of a survey aircraft and eight to ten ground stations that required a very high level of support in planning, coordination, flexibility and adaptation between the technical, logistic and administrative elements of day-to-day operations sometimes involving all three Services of the Australian Defence Force.

In 1964 the *Aerodist* came with all of the problems of a relatively new technology especially when deployed under harsh environmental conditions such as experienced in the Territory of Papua New Guinea (TPNG)[3]:

[3] Coulthard-Clark CD, Australia's Military Map Makers, The Royal Australian Survey Corps 1915-96, 2000, Oxford University Press, p48

> *'Whereas new technology undoubtedly helped to make these New Guinea operations more manageable and productive, the environment in which personnel and equipment were expected to function remained as demanding as ever. The OC for most of these operations up to 1970 was Major E.U. Anderson, who recalls the extent to which the extreme conditions had to be factored into planning to ensure safety: 'Add to that the effects of high humidity causing failure in the electronics of the equipment, and random bad weather causing flying difficulties, and another set of variables applied to planning. It was under those circumstances of frustration and disappointment owing to the very difficult terrain and weather, and being hampered to a degree by the failure of the technical equipment at the most inopportune times, that the detachment's personnel responded and worked to such a high standard, some well above the normal course of duty'.*[4]

For the next twelve years *Aerodist* was the Corps' major horizontal control survey tool for mainly medium scale topographic mapping (scale 1:100,000 Class A being spatially accurate to within 50 metres) in TPNG (166 maps), northern Northern Territory (103 maps), north-west Western Australia (75 maps), Kalimantan Barat (West) Indonesia (30 maps), Sumatra Indonesia (187 maps), Gulf of Carpentaria and Cape York in Queensland (149 maps). The 327 x 1:100,000 maps produced from *Aerodist* surveys in northern Australia was about 40 percent of the 862 full specification maps produced by the Survey Corps as part of the national program. The series R502 scale 1:250,000 and similar scale maps in Papua New Guinea and Indonesia were then replaced by Joint Operation Graphics derived from the scale 1:100,000 maps.

About 3,050 *Aerodist* lines between survey stations were successfully measured and about 720 of those survey stations were subsequently coordinated by trilateration networks subjected to geodetic adjustments. *Aerodist* was used by Topo Sqn AHQ Svy Regt and all four Australian based field survey units. It was not used by A Section 1 Topographic Survey Troop in Vietnam or 8 Field Survey Squadron based in Papua New Guinea.

By the time *Aerodist* was acquired for 1:100,000 topographic mapping, the Geodetic Survey of Australia had been completed by the members of the National Mapping Council and was soon to be published as the Australian Geodetic Datum 1966/Australian Map Grid 1966. This included the conventional astro-geodetic survey of Papua New Guinea completed primarily by Australia's Division of National Mapping (NatMap) and the Royal Australian Survey Corps (RA Svy) with long distance ties between Australia and Papua New Guinea observed by US Air Force using Hiran[5]. The first national coverage of the general national topographic map series (mainly 1:250,000 series R502) was on program to be completed in four years' time. The second series of the national topographic mapping program at scale 1:100,000 was to be approved by Government/Cabinet in 1965. In this program RA Svy concentrated effort on northern coastal and adjacent inland areas as they were the highest priority for Defence. The survey framework for the initial map series R502 did not satisfy that required for the 1:100,000 program for two reasons. Firstly, much of the survey control for the 1:250,000 mapping was astronomic fixes which were not of suitable spatial accuracy and secondly survey point density and location did not satisfy the aerial photography photogrammetric triangulation which would form the basis of

[4] Major EU (Ed) Anderson's (later Lieutenant-Colonel) service relating to successful *Aerodist* operations (1964-1966) in TPNG was recognised being awarded Member of the Order of British Empire (MBE) (military division) on 1 January 1968

[5] Hiran – high precision Shoran (see footnote 6) developed by the US. RA Svy collaborated with the US Air Force in the 1963 Hiran South West Pacific Survey with Hiran stations in north-eastern Australia connected to the Australian geodetic traverses to extend the Geodetic Survey of Australia to Territory of Papua New Guinea and beyond to the north-east https://www.xnatmap.org/cpng/docs/hiran4web.htm.

map compilation. The geodetic survey provided the fixed framework for lower order surveys, including *Aerodist*, as infil for the mapping control.

The following is from the Officer Commanding Operation Sandy Hill 1975 (1 Fd Svy Sqn Group – Major Bob Skitch), the last *Aerodist* field survey operation which was on Cape York and Gulf of Carpentaria QLD:[6]

> *It was the only major field operation I ever commanded and as it turned out remarkably successful. I would only claim a small amount of credit for its success. My 'foreword' to the Operation Sandy Hill report reads as follows:*
>
> *At the time of preparation of this report it seems likely that the Airborne EDM equipment MRB-3 'Aerodist' will not be deployed again on major field operations in the foreseeable future having been overtaken by Doppler satellite position fixing techniques. Thus an era of field activity spanning more than a decade is brought to an end; an era that drastically changed the nature and concept of field survey operations.*
>
> *Hither-to field survey operations had been mounted almost un-noticed by the Army at large. Personnel in the field rarely numbered more than thirty and were predominantly RA Svy supported by the occasional individual attachment. Although air support for survey operations was not new, it had previously rarely exceeded a single aircraft.*
>
> *The advent of airborne EDM radically changed this concept. Almost overnight 'Survey' operations became 'Army' operations in which RA Survey personnel were confined mainly to their technical duties and at a higher level provided command and control of a group comprising sometimes in excess of 100 personnel spanning many arms and services. Army Aviation and/or RAAF became major partners in survey operations, frequently out-numbering all other Survey and attached personnel…At one point in the planning stage of Op Sandy Hill, 1st Division one senior staff officer recommended to the General Officer Commanding that an operation of this size and complexity should be commanded by a more senior non Survey Corps officer…This never happened after the General was briefed on the detailed planning evident in the Operation Order which was prepared by Survey officers and warrant officers, and other Corps officers, with accumulated expertise acquired over a decade of Aerodist work.*
>
> *Success of such operations became totally dependent on the 'prima donna' of survey equipment, the 'Aerodist'. When functioning well it was capable of great achievements impeded only by the ability of the group to support it logistically. When not functioning the operation would bog down completely and very little could be done to offset the resulting loss of production. Planning and mounting of survey operations became a major activity requiring a greater level of managerial expertise than ever before to coordinate the multitude of activities necessary to effect success. Such expertise was not always available and many lessons were learnt the hard way.,,,,*
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> *Use of network analysis and critical path planning were key techniques to the operation's success.*

Background

From 1913 to the mid-1950s the Australian Survey Corps' primary method of trigonometric surveys for military survey was the centuries old method of triangulation. High accuracy geodetic triangulation established a primary network of geodetic survey stations on which lesser accurate secondary and tertiary frameworks for topographic mapping were based. A very accurate baseline a few kilometres long was measured with calibrated metal tapes and chains of triangulation were established where the angles were observed with theodolites and the distances

[6] Major Bob Skitch (later Lieutenant-Colonel) was the first Officer Commanding A Section 1 Topographic Survey Troop, 1st Australian Task Force Vietnam in 1966

were computed. This was a laborious method requiring inter-visibility between three to five survey stations in the chains and all of the logistics entailed in detailed reconnaissance, establishing, clearing and setting up beacons and targets for the observing teams.

During the intervening years of the Second World War all manner of survey methods were used depending on the nature of the task, access to the area, enemy activity, existing surveys if any and the usual critical time factor. Methods included but were not limited to: astronomical fix, astronomical azimuth, theodolite and chain traverse, intersection, resection, stadia, sub-tense, radiation, compass and chain, compass and pace, compass and time travelled. Wars often drive technological leaps for advanced solutions of complex problems. Such was the case during the Second World War with rapid developments in radar including precision radar based Shoran[7] aircraft navigation (mainly for precision bombing) by radar trilateration with the transmitter/receiver in the aircraft and two radar transponders on surveyed ground stations. This technology was improved after the war with the Hiran system, which when used in triangular networks, could extend geodetic quality surveys by trilateration over distances of 900 kilometres or more and connect hitherto disparate surveys one to another. But these systems were not man-portable for day-to-day survey work.

Immediately after the war, the military one-inch-to-one-mile mapping of Australia continued and survey control was predominantly triangulation with theodolite and chain traverses where appropriate. With the commencement of the general purpose (one-inch-to-four-mile and later 1:250,000) national mapping of Australia in the mid-1950s from aerial photography, surveys for photogrammetric control was often astronomic fixes where triangulation did not exist.

This all changed in 1957 with the invention of the Tellurometer (*Tellus* – Latin for earth[8], *meter* – Greek for measure). Similar to radar this man-portable microwave based distance measurement system allowed rapid geodetic quality surveys by trilateration and traverse. But surveyors were still constrained by needing line of sight between network stations or consecutive traverse stations. RA Svy was equipped with Tellurometers in 1958 and soon extended geodetic surveys, mainly by theodolite and Tellurometer traverse, from the east coast of Queensland to northern Northern Territory, along the east coast of Cape York, the Northern Territory coastline and northern Western Australia including the Kimberley region and around much of the coast of Territory of Papua New Guinea. This all contributed to the National Mapping Council's Geodetic Survey of Australia which when completed produced the Australian Geodetic Datum 1966. Early use of the Tellurometer worldwide showed huge gains in efficiency of more than twenty times when compared with triangulation surveys. At the same time as this technological leap in the late-1950s, helicopters were introduced for transport and resupply of survey parties. Logistics were then able to keep up with the potential of rapid projection of field surveys.

The next technological challenge was to extend accurate surveys over-the-horizon and to infil large area existing networks without the constraint of inter-visibility between survey stations. In 1960 the Tellurometer based system was modified for dynamic ship based surveys and ship navigation. This was further adapted for aircraft to accurately measure distances (*Aerodist)*

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[7] Shoran – short range navigation, up to about 500 km, initially developed in the Second World War by the US and developed by Canada 1947-1949 for surveying and mapping

from http://xnatmap.org/adnm/docs/2013/edmhist/ahistedm.htm

[8] Collins dictionary – information provided by Laurie McLean (former NatMap)

between non-intervisible ground survey stations, using the aircraft as an intermediate station, and to accurately determine the position of survey aircraft. Lower order geodetic results could be achieved by survey network trilateration but this system could also be used to accurately position the measuring aircraft by dynamic trilateration to known ground stations. RA Svy was equipped with commercial-off-the-shelf first generation *Aerodist* (MRC2) in 1964 and a second generation system (computer assisted MRB3/201) in 1972. It was quickly put to use in 1964 in the Territory of Papua New Guinea to extend survey control for urgent Defence mapping along the border with Indonesia.

The same year that the Tellurometer was invented, the Soviet Union launched the first artificial earth satellite named *Sputnik 1*. The substantial apparent change of frequencies of radio signals from *Sputnik* as it passed rapidly from horizon to horizon (the Doppler shift) was observed at the Applied Physics Laboratory of Johns Hopkins University in the United States. This observation led to determining the entire satellite orbit with Doppler measurements from a few ground tracking stations and the inverse solution of determining positions on the earth from computed satellite orbits.[9] This led to the US Navy Navigation Satellite System Transit, primarily for navigation of Polaris submarines, but which was available broadly to the US military in 1964 and to civilians for the purpose of geodetic surveying in 1967. In 1975, Transit Doppler satellite geodetic receivers (AN/PRR-14 Geoceivers) replaced *Aerodist* as one of the Corps' major field survey systems.

Summary of Aerodist surveys

The Corps' nineteen *Aerodist* operations 1964-1975 are summarised in Table 1[10]

Year	Area	Unit/Operation	Aircraft	System	Lines	New Survey Stns
1964	Territory Papua New Guine (TPNG) –north west	Topo Sqn AHQ Svy Regt	Hudson VH-AGS	MRC2	64	30
1965	TPNG Western Highlands and Fly River delta	Topo Sqn AHQ Svy Regt	Hudson VH-AGS	MRC2		
1966	TPNG	Topo Sqn AHQ Svy Regt	Hudson VH-AGS	MRC2	186	55
1967	Eastern Arnhem Land NT (Project C4)	Central Comd Fd Svy Unit	Aero Commander VH-EXX	MRC2	317	60
1968	Kimberley WA	Western Comd Fd Svy Unit	Aero Commander VH-EXX	MRC2	193	40
1968	Western Arnhem Land NT	Central Comd Fd Svy Unit	Aero Commander VH-EXX	MRC2	333	60
1969	TPNG (Project C1)	Northern Comd Fd Svy Unit	Queen Air VH-TYV	MRC2	140	47
1970	Kalimantan Barat (West), Indonesia	2 Fd Svy Sqn	Queen Air VH-FWG	MRC2	113	38
1970	TPNG (Project C1)	1 Fd Svy Sqn	Queen Air VH-FWG	MRC2	144	52
1971	Southern Sumatra, Indonesi	2 Fd Svy Sqn – Op Gading 1	Queen Air VH-FWG	MRC2	153	47

[9] Stansell, Thomas A, The Transit Navigation Satellite System

[10] Numbers of lines measured and numbers of survey stations established are mainly from RA Svy annual reports 1964-1976 to the Australian National Mapping Council

1971	Bathurst/Melville Is NT Kimberley WA (Project D3	5 Fd Svy Sqn	Queen Air VH-FWG	MRC2	50	13
					216	53
1972	Southern Sumatra, Indonesi	2 Fd Svy Sqn – Op Gading 2	Queen Air VH-RUU	MRC2	191	46
1972	Gulf Carpentaria QLD (Project A6)	1 Fd Svy Sqn	Queen Air VH-FWG	MRB3/201	156	31
1972	TPNG (Project C1)	4 Fd Svy Sqn – Op Wine Glass	Queen Air VH-FWG	MRB3/201	171	28
1973	Northern Sumatra, Indonesi and Malaysia	5 Fd Svy Sqn Op Gading 3	Queen Air VH-RUU	MRC2	149	30
1973	Cape York QLD (Project A2)	1 Fd Svy Sqn	Queen Air VH-FWG	MRB3/201	162	30
1973	TPNG (Project C1)	4 Fd Svy Sqn – Op Plastic Flagon	Queen Air VH-FWG	MRB3/201	35	10
1974	TPNG (Project C1)	4 Fd Svy Sqn – Op Sea King	Queen Air VH-FWG	MRB3/201	112	10
1975	Gulf of Carpentaria and Cape York	1 Fd Svy Sqn Gp – Op Sandy Hill	Queen Air VH-FWG	MRB3/201	166	41
Total					3051	721

Table 1(above) – summary of RA Svy Aerodist operations 1964-1975 (not including equipment trials and training)

Area of operations	**No of lines measured**	**No. of Aerodist stations (approx.**	**Aerodist system**	**No. of 1:100,000 maps**
Papua New Guinea	852	232	MRC2 & MRB3/201	166
Indonesia – Kalimantan Barat and Sumatra	606	161	MRC2	217
Australia –Arnhem Land Northern Territory	700	133	MRC2	103
Australia – the Kimberley Western Australia	409	93	MRC2	75
Australia – Gulf of Carpentaria and Cape York, Queensland	484	102	MRB3/201	149
Total	3051	721		710

Table 2 – summary of RA Svy Aerodist surveys by areas of operation

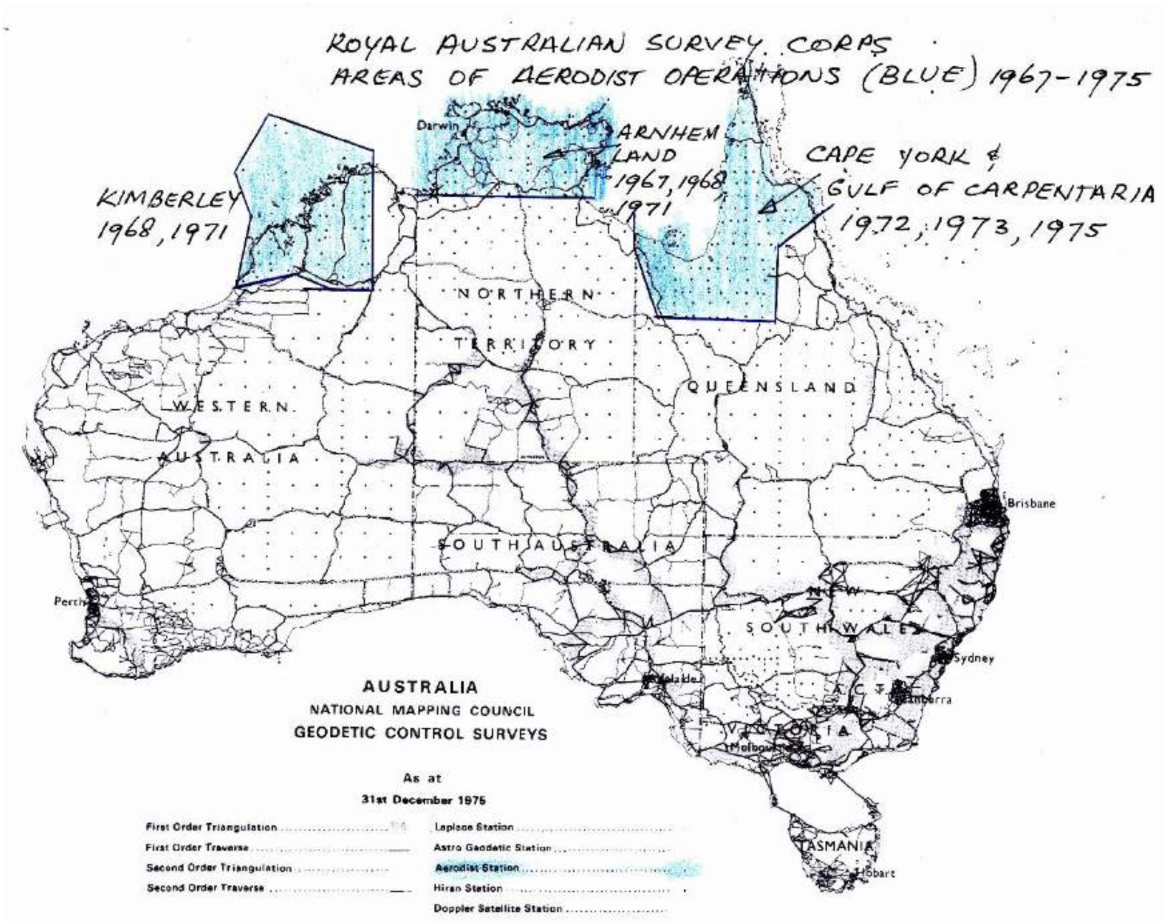

Figure 1. RA Svy areas of Aerodist operations in Australia 1967-1975 – does not include Territory of Papua New Guinea and Indonesia. Aerodist stations are black dots.

Aerodist development from the Tellurometer

In 1954 Colonel H. A. Baumann, Director of the South African Department of Trigonometrical Survey, was familiar with the performance of radar and of the Shoran and Hiran systems but was looking for a system with an accuracy of better than 1 in 100,000 at distances of up to 30 miles and none of the existing systems could provide this. His required system needed to be easily man-portable, work on line of sight and have a resolution of a few inches. This requirement was brought to the attention of the Council for Scientific and Industrial Research (CSIR) in Johannesburg. The CSIR had plenty of other projects on hand and it was well into 1955 before there was an opportunity to give this project to anyone to look at. The person chosen was Trevor Wadley[11]. Wadley soon drew up a design, put together the necessary components into a prototype and was making distance measurements. The first "routine" measurement was made in the field between two beacons some 50km distant to the North of Johannesburg on 14th June, 1955. Two slightly different equipments were involved; one was called the Master and one was the Remote. The Master transmitted frequencies modulated on a continuous carrier wave to the Remote which returned the signal to the Master where the difference in phase between the transmitted and received signals was observed from which the distance between Master and

[11] The History of Tellurometer Brian Sturman and Alan Wright Integrating the Generations FIG Working Week 2008 Stockholm, Sweden 14-19 June 2008

Remote was determined. The production of the first Tellurometer was initiated by an order received for six instruments from the Survey and Mapping Branch of the Department of Mines and Technical Surveys of Canada. These first six production receivers were known as the MRA1 (M = Master. R = Remote. A = Ancilliary equipment.)

By 1959 the system had been modified such that the Master and Remote functions were included in the same instrument, meaning that lines between stations could be readily observed from both ends (to reduce systematic and random errors) without swapping instruments. This was the Tellurometer MRA2 with a cathode ray tube (CRT) which displayed the phase differences in nanoseconds, also known as milli-microseconds, which when multiplied by half the speed of light in metres per milli-microsecond[12] resulted in a distance in metres from the Master to the Remote station.

In 1960 the MRB2 hydrographic variant, known as *Hydrodist,* was developed from the MRA2. A year later US Geological Surveys created the AirBorne Control (ABC) Survey System from the MRB2. MRB2 was installed in a helicopter to measure distances to two Remotes at known survey stations while the helicopter hovered (with the aid of a vertically mounted television camera on the survey station to be coordinated and a television receiver for the pilot to see the underside of his helicopter) high over a survey station. At the same time theodolites mounted at the two known survey stations observed horizontal and vertical angles to a bright strobe light on the helicopter. The unknown ground station could then be coordinated from the resected distances and intersected angles from the known stations. RA Svy trialled this system but it never met the accuracy requirements or indeed the practical aspects of extending large area mapping control over long distances[13].

Aerodist MRC2

MRB2 was developed further, initially for the US Army Corps of Engineers, to produce the aircraft based version *Aerodist* MRC2 comprising of two or three identical Master sets (with different carrier wave frequency channels simply named as Red, White and Blue) with selective and steerable antennas. Like the MRA2 the MRC2 electronics were analogue circuitry.

The system of Master and Remote sets was capable of being used in three modes or a combination of these:

- 'line-crossing' - the aircraft flew approximately midway and at near right-angle between two ground stations to measure the distance between the ground stations from the aircraft which acted as an intermediate station
- 'continuous trilateration' - the aircraft position was computed from distances measured to two or three known ground stations, similar to Shoran, and could be used in conjunction with an air camera to determine the camera position at the instant of exposure
- 'height checks' - the aircraft flew directly over a ground station measuring the distance to the ground to check the accuracy of the aircraft height

As the distances between the aircraft Master and the ground Remotes were continuously changing the raw measurement data was recorded on a continuous paper chart for reduction later.

[12] Half the speed of light in a vacuum was then 0.14989625 metres per milli-microsecond (half used as the phase difference of the signal was from the Master to Remote and back to the Master)

[13] Lines, John D, Australia on Paper The Story of Australian Mapping, 1992

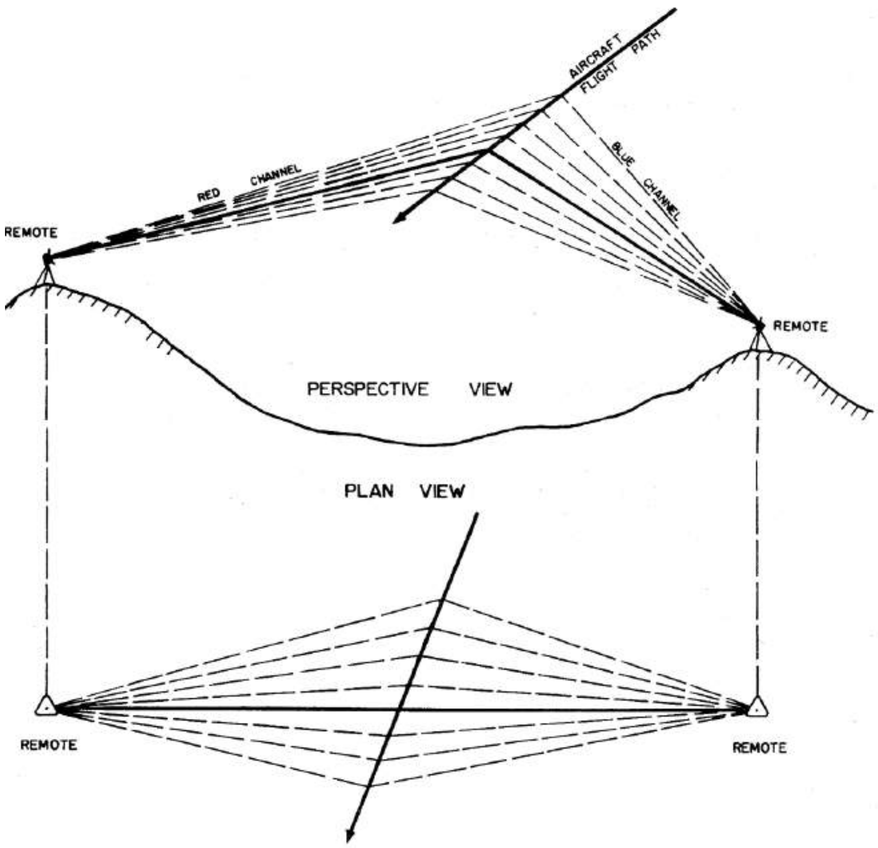

Figure 1a. Aerodist 'line-crossing' method used by RA Svy[14]

Once again Canada led the survey world and acquired *Aerodist* MRC2 systems in 1962 to survey their vast northern territories for geodetic and topographic purposes[15]. Australia's Division of National Mapping purchased MRC2 in 1963. The Division of National Mapping's *Aerodist* story is told in Tech Report 27 (McMaster, 1980 – footnote 13) and in great depth by former NatMap member Laurie McLean.[16]

RA Svy was equipped with *Aerodist* MRC2, as a Corps asset, in 1964 and immediately allocated it to Topo Sqn AHQ Svy Regt (Bendigo VIC) which soon deployed to Territory of Papua New Guinea (TPNG) for survey and medium scale mapping mainly along the land border with Indonesia. Topo Sqn used it in TPNG for the next three survey seasons (the drier seasons) 1964 -1966. The Corps mainly used *Aerodist* in the 'line-crossing' mode. The measured dynamic slant ranges from the Master to each of the Remote ground stations were summed to find the approximate minimum sum. Later a refined minimum sum from about ten measurements either side of the minimum was reduced to account for the varying velocity of the signal through the atmosphere (the refractive index), the aircraft height, the ground station heights, Master antenna separation, Remote eccentric to station and chord-to-arc correction to compute a mean sea level or spheroidal distance between the Remote ground stations. The spheroidal distances were

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[14] McMaster CG, Division National Mapping Aerodist Program, Technical Report 27, 1980, Figure 1 https://www.xnatmap.org/report_tdnm/27_aerodist.pdf

[15] Tuttle AC, Aerodist in Geodetic Surveying in Canada, The Canadian Surveyor, Vol XXI No 2, March 1967

[16] Laurie McLean, The Aerodist Years : Recollections of the Division of National Mapping's Airborne Distance Measuring Program 1963-1974 https://www.xnatmap.org/adnm/ops/prog/aaerod/adist6374/intro/intro.htm
Laurie worked with the NatMap Aerodist ground marking field party in 1969 and with Aerodist measuring field parties from 1970 to 1974.

formed as part of trilateration networks to estimate for each station latitude and longitude from geodetic adjustment and integration into higher order survey frameworks.

Canada, Australia and Tanzania[17] used *Aerodist* as a major part of their national survey networks for large area topographic mapping. A few other countries used *Aerodist* for surveys of various types.

Aerodist MRC2 Measurements and Chart–based Recording

This section draws on Laurie McLean's story as the NatMap and RA Svy measuring and recording systems were similar but not the same.

During an *Aerodist* line measurement, the *A* pattern (modulated frequency on the carrier wave) was the primary measuring signal and was recorded virtually continuously on an analogue paper chart looking similar to a sine curve. The MRC2 operated at the lower carrier frequency range of the Tellurometer family of between 1,200 and 1,500 MHz, frequencies that were allocated by the Australian Post Master General's Department. This frequency range was meant to avoid interference between channels but was not always compatible with environmental conditions where the system was used. The *A* pattern, with a wavelength of 100 metres (and appearing on the chart like a sine curve) indicated the final two digits of the slant range from the aircraft to the remote station on the ground; the ten and units of metres. This was known as the fine measurement. The *A* pattern was switched out for about six second intervals and the three remaining patterns *B*, *C* and *D* were each switched in sequence for two seconds. The *B*, *C* and *D* patterns yielded the coarse distance components, namely the initial digits of the line measurement (the tens of thousands, thousands and hundreds of metres). The top to top peaks of the *A* pattern trace represented a slant range change of 100 metres being 50 metres from top to bottom and bottom to top on the chart. As the *B, C and D* patterns were switched their chart traces were a few millimetres long but were a short part of the pattern trace similar to the A pattern trace. Thus the continuously changing slant ranges represented by changing phase differences could be read from the chart trace values *A-B*, *A-C*, *A-D*, *A* in metres.

Master operation. Topographic Squadron Army Headquarters Survey Regiment based at Bendigo VIC was the first unit to use *Aerodist* and was largely responsible for developing user methodologies and Standing Operating Procedures with continual assessment and modification by other units[18]. Most operations required two Master operators in the aircraft and sometimes a meteorological data recorder. These were normally a survey officer, a warrant officer or sergeant and a sapper.

Line length, local topography and weather conditions determined where the Master aircraft would attempt the 'line-crossing' which optimally was orthogonal to the line bearing and midway between the Remote stations. To reduce errors in the raw slant ranges from errors in aircraft height and meteorologic data it was desirable that the aircraft and ground stations were in

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[17] Ntuwah WM, Analysis and Optimization of the Geodetic Network of Tanzania, Submitted in partial fulfilment of the requirement for the Master of Surveying Science course at the University of New South Wales, August 1984

[18] Warrant Officer Class Two John Harrison BM BEM (later Warrant Officer Class One) – Central Comd Fd Svy Unit (Adelaide) was attached to Topo Sqn AHQ Svy Regt in TPNG 1965, Arnhem Land NT operations with Central Comd Fd Svy Unit in 1967 and 1968 and Svy Sect DSVY AHQ 1969-1971 in charge of the Corps' survey networks adjustments. John was awarded the British Empire Medal in 1963 for services to military survey. In 1978 John was awarded the Bravery Medal for 'removing the source of electricity after a high-voltage accident'.

the same air mass and to fly as low as strong Tellurometer signals and local terrain allowed. As a rule of thumb flying height above the mean terrain was not more than 1,000 feet for each 10 miles of line length. The Topographic and Geodetic Survey of Canada established *Aerodist* observation specifications for 1st Order trilateration networks (10 parts per million – ppm) in the mid-1960s[19]. These included: lines not shorter than 75km, distance between master aircraft and a remote station not less than 30km, two groups on different days at least 12 hours apart of at least 6 acceptable line-crossings in pairs with different altitude pairs not less than 1,000 ft apart. This specification was also used by a Canadian company to extend/densify the geodetic survey of Tanzania[20] (results reported later). These requirements were more than that required by RA Svy for survey control for 1:100,000 topographic mapping but higher order observation specifications are instructive.

As the aircraft approached the first 'line-crossing' the Master operator contacted the Remote stations by High Frequency (HF) radio. After the Master – Remote signals were established the *Aerodist* voice channel was used to direction find the Master and Remote antennas to optomise the signal strength. The signals from each Master channel (Red, White, Blue) were transmitted and received from one of the three steerable antennas mounted under the wings and fuselage of the aircraft. To avoid signal interference the antenna closest the Remote station was the antenna used. As the aircraft turned onto a reciprocal heading for another 'line-crossing' the Master operator switched the Master channel to antenna connection from one wing antenna to the other. The Master operator then maximised the signal strengths to each Remote by small changes to the antenna direction. At least ten groups of *B, C and D* switchings were needed from both Master-Remote channels either side of the line to ensure a reliable estimation of the minimum sum (the shortest summed slant range).

The Master operator checked the peaks on the two *A* traces to make sure that the wavelengths were increasing indicating that a 'line-crossing' had been observed with more than a minute either side. After a 'line-crossing' the Master operators checked charts to make sure that pens for each channel were recording well defined *A* patterns and the short traces of the *B, C and D* patterns. Aircraft height and meteorological data of atmospheric pressure, dry and dew point temperatures were recorded on the observation form for the later calculation of refractive index for atmospheric correction of the observed slant ranges.

Figure 2. Sergeant Stan Campbell[21] (left) and Lieutenant George Gruszka (right) operating the Master MRC2 system in the Hudson VH-AGS[22].

[19] Tuttle AC, Aerodist in Geodetic Surveying in Canada, The Canadian Surveyor, Vol XXI No 2, March 1967

[20] Ntuwah WM, Analysis and Optimization of the Geodetic Network of Tanzania, Submitted in partial fulfilment of the requirement for the Master of Surveying Science course at the University of New South Wales, August 1984

[21] Sergeant Stan Campbell (later Major)

[22] *Australian Aerial Survey Review, 1965, p2*

Lieutenant Gruszka[23] was a Master operator in TPNG 1965 and 1966. The three similar instruments are the Red, White, Blue channels.

Remote operation. Remote stations were normally operated by two topographic surveyor soldiers, a corporal and a sapper. On direction from the aircraft Master operator, via HF radio and *Aerodist* voice communications, the Remote operator would move the Remote in elevation and azimuth to maximise signal strength. The atmospheric pressure by survey barometer or altimeter, and the dry and wet temperatures by psychrometer were recorded for each 'line-crossing'. The large 24 inch circular dish and dipole antenna could be placed on a tower connected to the Remote by coaxial cable.

Figure 3. N Comd Fd Svy Unit (Brisbane) pre-deployment to TPNG (based at Goroka) Aerodist MRC2 trials May 1969 at Toowoomba QLD (Mt Rubieslaw eccentric adjacent to the survey mark with pole, disc and cairn). A large 24 inch circular reflector dish and dipole antenna are on the Remote instrument powered by the 12VDC battery. The green 'cube' in front of the vehicle is the Remote thickly padded transport bag. On the yellow box is a HF radio Motorola MTR1 for communications to the Master aircraft Beechcraft Queen Air VH-TYV. The vehicle is a Landrover Series 2 short wheel base ideal for steep rocky terrain.[24] (Photo: Author)

Data reduction

To ensure that each line measured met the data quality specifications the raw data paper charts had to be reduced quickly, ideally on the same day, before the Remote parties were moved from the survey stations. To do otherwise might mean that a station had to be reoccupied. As Topographic Squadron of AHQ Survey Regiment was the first unit to use *Aerodist* that unit developed the first standing operating procedures for data reduction. Later, other units modified or refined those procedures to account for revised methods and to suit the specific operation. In general, reduction of the measured slant ranges (aircraft to the ground Remotes) recorded on the charts was done in the field normally at the base where the aircraft was operating from, or the operation's Main Base, by a Survey Computations Section (warrant officer or senior non-commissioned officer and four to six topographic surveyor corporals and sappers). The two chart A pattern traces were firstly examined to make sure that a long enough 'line crossing' was achieved by looking for the longest distances between the 100 metre peaks indicating that the minimum distance to each Remote was observed, taking the mid-point between those two points and then looking for ten sets of *B, C* and *D* patterns each side of the approximate 'line-crossing'.

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[23] Lieutenant George Gruszka (later Lieutenant-Colonel)

[24] Author: I was a driver under instruction of Corporal Bob Morrow, a geologist national serviceman. At the bottom of Mt Rubieslaw I stopped, asking Bob if we walked from there. He said 'I don't walk anywhere, especially carrying that lot in the back. If you can drive to the top and down without wrecking the Land Rover, and us, I will recommend to Garney Cook (the Transport Sergeant) that you get your licence.' I got my licence.

The change in the summed measured slant ranges over time was a parabolic function. The twenty-one data points were graphed manually to plot a curve to identify any outliers to be rejected and to ensure that a minimum sum slant range from the two Remotes to the Master could be reliably interpolated.

The minimum sum slant range was then separated into its two parts to compute the refractive index to account for the delay in the velocity of propagation of the signals through the atmosphere from the Master to both Remotes. The refractive index was a function of atmospheric pressures, dry and wet bulb temperatures recorded at the Remotes and Master stations. The A frequency gave a direct chart readout in metres using a reference refractive index of 1.000330. The estimated corrected path length L was then given by: L = 1.000330 / n * d , where 'n' = the calculated refractive index and 'd' = the minimum sum slant range extracted from the chart.

In most cases the minimum sum slant range for each 'line-crossing' was as far as the computations went in the field. From 1964 to 1968 all further data reduction up to the stage of preparing the trilateration network geodetic adjustment was conducted by AHQ Svy Regt (Bendigo). Later it was done by the field survey units, either at a deployed base or at unit headquarters (Brisbane, Sydney, Adelaide, Perth) after the operation, using Lincross 2 and 3 computer programs on Hewlett Packard 9100 series desktop programmable calculators/computers.

The geodetic adjustment using the new (1967) computer program 'variation of coordinates' or VARYCORD[25] was conducted by the Svy Sect DSVY AHQ (Canberra) using a CSIRO Division of Computing Research mainframe CYBER computer until 1976 when that function was transferred to a Defence UNIVAC computer.[26]

Sources of error

The main sources of error were: chart readout and estimation of the minimum sum slant ranges, aircraft height, computation of refractive index, ground-swing, modulation frequency, instrument zero error and antenna to station eccentrics (both Master and Remotes):

- The effect of errors in the aircraft height were more prominent on shorter lines and higher flying heights. On a 60 km line flown mid-point and a flying height of 5,000 feet a 20 m error in aircraft height, introduced an error in distance of 2.2 m or 30 ppm (1:30,000). Whereas on a 200 km line and a flying height of 10,000 feet a 20 m error in aircraft height introduced an error of 2.4 m or 12 ppm (1:80,000).
- Errors in the refractive index were a function of errors in the meteorologic data at the Master and Remotes and that the observed data was at the terminals only and not representative of conditions along the signal path. This was more problematic in the tropical weather conditions of New Guinea and Indonesia than in northern-Australia where the surveys were in the winter dry season with more stable and extensive air columns. There were a few formula for refractive index of radio waves with different

[25] Bomford AG, Division of National Mapping (NatMap) Technical Report No. 6 https://www.xnatmap.org/report_tdnm/6_VARYCORD.pdf
[26] John Harrison

terms and coefficients which gave different results but which rarely differed by more than 10 ppm (1:100,000).

- Ground-swing (error from reflected signals) depended on the terrain along the line, local Remote terrain and aircraft flying height. This was reduced by flying as low as the terrain and strong signal strength allowed and by varying flying height of the line-crossings.
- The modulation frequency, controlled by the crystal oscillator in the Master, and the zero error were negligible.
- The aircraft eccentric to centre (wing antenna separation) was known to better than 10 cm. The effects of the aircraft line-crossing bearing not being orthogonal to the line and of crabbing across the line was reduced by the pilots' skills and experience. Remote eccentrics to station centre were reduced to better than 0.5 m. Remote on-line eccentrics were used where possible.
- **Combined error**. Considering the Canadian experience and the Corps' operating environments and procedures, a reasonable theoretical estimation of errors (standard deviation in ppm) in *Aerodist* distances were: Instrumental and estimation of minimum sum – 3.5 ppm; aircraft height – 20 ppm; refractive index – 12 ppm; ground swing – 2 ppm; Combined standard deviation – 24 ppm (1:42,000) or 3.6 m on a 150 km line.

System accuracies

- **Aerodist distances compared with geodetic surveys**. The Canadian experience with MRC2 *Aerodist* observations to their 1st Order specifications compared with known geodetic distances over 21 lines of lengths between 71 km and 210 km (mean 138 km) was a mean difference of 10 ppm (1:100,000). This story does not include any comparison of the Corps' MRC2 observations with tellurometer surveys or geodetic survey adjustments. *Aerodist* MRB3/201 comparisons are in Table 2.
- The accuracy of an *Aerodist* trilateration network was a function of how accurately scale and azimuth were maintained in the network. This depended on the precision of the distances measured and the geometric configuration of the network. As most of the Corps' *Aerodist* stations were positioned for photogrammetric triangulation purposes for map compilation, these were rarely in positions of optimal network strength, especially in coastal regions where all of the lines into a station may have been in two or one quadrants. This notwithstanding, typical line residuals (MRC2 *Aerodist* spheroidal distances – geodetic adjusted spheroidal distances) were better than 5 metres which was satisfactory for 1:100,000 mapping[27]. The 1975 composite VARYCORD adjustment of the 1972, 1973 and 1975 *Aerodist* MRB3/201 networks in Gulf of Carpentaria and Cape York, resulted in a mean line residual (479 lines) of 2.8 metres and a standard deviation of 3.8 metres[28].
- This empirical result was consistent, at the accuracy level required for 1:100,000 mapping, with a School of Military Survey investigation in 1976 (page 82). Major

[27] John Harrison

[28] Operation Report Op Sandy Hill 1975 – 1 Fd Svy Sqn Gp (courtesy Captain Paul Pearson – later Lieutenant Colonel)

Dave Hebblethwaite concluded that: *VARYCORD adjustment and individual line crossing data was analysed in respect of RA Svy Aerodist measuring procedure and a value of 3.7m was determined as the standard error of an Aerodist measure regardless of line length or number of crossings in the line measure.*

- And NatMap reported[29]: *From all the Aerodist Varycord adjustments, the average difference between the observed and the adjusted distances is 1.49 metres, for an average line length of around 100 km. On the twenty-nine adjustments, the average maximum residual was 6.3 metres. Subsequent Tellurometer traverses or JMR (Doppler satellite) fixes at a number of Aerodist stations verify that the Aerodist coordinates are accurate to better than 5 metres.* The NatMap networks were generally well braced quadralaterals with lines 50-70 km.
- The Tanzania *Aerodist* experience with a grid of stations about 100 km apart was that the Canadian 1st Order observation specifications produced a 2nd Order (1:50,000) network accuracy if only *Aerodist* was used. As expected azimuth was the most difficult to manage. The network was greatly improved when Transit Doppler observations were made at *Aerodist* stations about 400 km apart.

Maintenance

The *Aerodist* MRC2 system was installed and maintained by Royal Australian Electrical and Mechanical Engineers (RAEME) radar mechanics nominally posted at that time to AHQ Svy Regt (Bendigo). Base level maintenance was conducted by those soldiers in workshops who also deployed on all field survey operations.

On many occasions a large part of the success of the survey was due to the quality of the RAEME soldiers who ensured a high level of system serviceability. It was normally the case that the RAEME soldiers could also double as Master and Remote operators. There is no complete list of those technicians but noteworthy soldiers were: Corporal Graeme Thorn, Sergeant Mick Skinner (later worked with NatMap *Aerodist*), Staff-Sergeant Duane Hicks.

Aerodist MRC2 Operations

As there was no suitable service aircraft for the RA Svy Aerodist MRC2 system, Adastra Aerial Surveys based in Sydney was contracted to provide Lockheed Hudson VH-AGS, for three years 1964 – 1966, including flight and maintenance crew. Originally this Hudson was a Second World War medium bomber A16-112 delivered to the Royal Australian Air Force (RAAF) in December 1941[30] . That aircraft now registered as VH-KOY is owned by the RAAF (100 Squadron) and operated by the Temora Aviation Museum NSW. It is now painted in a wartime pattern and fitted with an upper gun turret. It is the only flying Hudson in Australia, and possibly the world.

[29] McMaster CG, Division National Mapping Aerodist Program, Technical Report 27, 1980, p15 https://www.xnatmap.org/report_tdnm/27_aerodist.pdf

[30] https://aviationmuseum.com.au/lockheed-hudson/ 14 Sqn RAAF anti-submarine patrols off Western Australia, 32 Sqn RAAF anti-submarine patrols off East Coast Australia, 6 Sqn RAAF Milne Bay New Guinea bombing and armed reconnaissance, RAAF Survey Flight

Two other Adastra Hudsons were contracted for Survey Corps aerial survey work at the time. One was fitted with a radar based Airborne Profile Recorder and the other for aerial survey photography.

Figure 4. VH-AGS in the original Aerodist configuration outside Hangar 13 at Mascot Airport (Sydney NSW) circa 1964. One antenna pod is on top of the fuselage and two are under the belly one in front of the other. The forward belly antenna is partially obscured. (Photo by Ken Watson – Adastra).

After deployment in 1964 other methods of employment were trialled in 1965. One plan for the use of *Aerodist* was to use it with an air camera to provide ground coordinates of photo control points for mapping.[31]

> *The original plan was to have all three measuring units operating simultaneously; with Survey Parties on known fixed stations the aircraft recording continuous distances and then photographing a remote point which would then be used to densify Mapping Control. As AHQ Survey Regt Topographic Squadron surveyors had borne the brunt of two long field seasons in TPNG it was decided to supplement the Squadron with personnel from the Command Field Survey Units giving the Regiment members a break and time to catch up on promotion courses. Members from the Command Field Survey Units marched in to AHQ Survey Regt in Feb 1965 and moved on to Puckapunyal to commence Aerodist trials with the Lockheed Hudson under command of Lionel Von Praag[32] operating from Mangalore Airport. Day one the remote party operators set up in three positions around the Airport and the Hudson loaded up with the crew including Director of Survey for the big in inaugural flight. The aircraft had hardly cleared the runway when the port engine emitted a loud bang and flames and great clouds of smoke. On immediate landing, the pilot having activated the on board fire extinguishers, the crew and their VIP guests, very shaken and ashen disembarked very quickly.*
>
> *After the inaugural "flight" we then commuted from Puckapunyal to Mangalore on a daily basis while our electronic "experts"* Royal Australian Electrical and Mechanical Engineers (RAEME) *Techs investigated the system. After thorough operational trials it was discovered that the Aerodist System would not successfully operate with all three Master Units measuring simultaneously. We (the Field Parties) occupied various existing (Trig) Survey Stations around Southern Victoria, testing and developing the different ways this new system could be used.*

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[31] Sapper Alex Cairney (later Warrant Officer Class One) Eastern Comd Fd Svy Unit (Sydney) was attached to Topo Sqn AHQ Svy Regt in TPNG 1965

[32] Lionel Van Praag was Adastra Aerial Surveys chief pilot. In 1936 he won the Motorcycle Speedway World Championship. During the Second World War he enlisted in the RAAF and trained as a Wireless Air Gunner. In January 1942 his transport plane was shot down over the Sunda Strait and for thirty hours, while subject to shark attacks, he supported one of the crew, an act for which he was subsequently awarded the George Medal.

Figure 5. VH-AGS in the final Aerodist configuration, believed to be landing at Albury NSW. Photographed by Dave Aitchison (Adastra)

1964 -1966 in New Guinea

When *Aerodist* was acquired in July 1964 it was immediately deployed to Territory of Papua New Guinea with Topo Sqn AHQ Svy Regt (Major Ed Anderson) from August to October working in the north-west region from Vanimo on the coast to Telefomin in the mountains to commence a high priority three year program for medium scale mapping in a three degree wide longitude band along the Indonesian border. The *Aerodist* trilateration network was to supplement control for mapping that was established by theodolite and Tellurometer traverse at the same time.[33]

The early years of 1964 and 1965 were spent trialling how best to employ and deploy the *Aerodist* in New Guinea measuring ‘line-crossings’ totalling 3,760 line miles and learning from equipment malfunctions. In 1965 two additional Remote sets were purchased to make a total of eight Remotes and three Master sets. One technical problem was the close proximity of the carrier wave frequencies of the three channels. The Australian agency then responsible for spectrum management, the Post Master Generals Department, allocated more suitable frequencies.

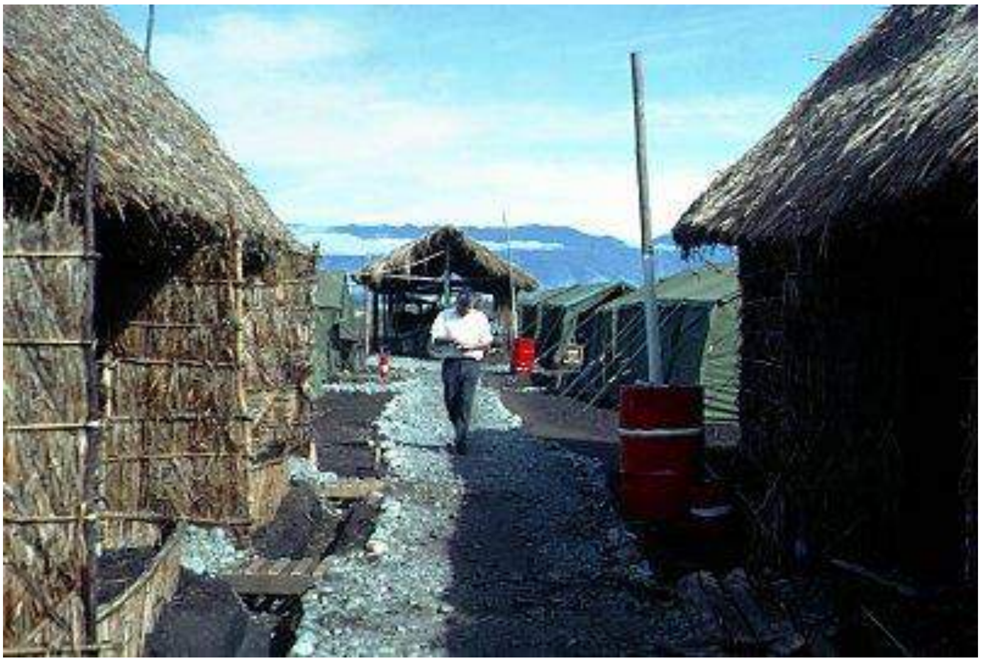
The 1965 survey season in New Guinea, again in the north-west, and again conducted by Topo Sqn AHQ Svy Regt (Major Ed Anderson) was July to October with main base in Mount Hagen and forward operating bases in Wewak, Ambunti, Angoram, Lake Kopiago and Telefomin. Also established was a 1st Order Traverse connection from the north coast to the Highlands (Central Spine) traverse established by Division of National Mapping in 1963.

Primary *Aerodist* stations, with more than four lines connecting, established on a notional 30 minute (mile) grid were assigned the station prefix AA continuing the convention commenced in 1962 with the first order traverse around the coastline. The three digits commencing with ‘4’ following the prefix eg AA400, indicated an *Aerodist* station. The photo control points with three lines from the primary stations were allocated the nomenclature ACP1 etc.

[33] Coulthard-Clark CD, Australia’s Military Map Makers, The Royal Australian Survey Corps 1915-96, 2000, Oxford University Press, p148

Figure 6. 1965 - Lockheed Hudson VH-AGS at Mount Hagen, TPNG, (attached to Topo Sqn AHQ Svy Regt) carries the final Aerodist fit with under-wingtip and belly antenna pods. Note the minimal ground clearance of the belly antenna pod. (Photo: Dave Aitchison, Adastra website)

Figure 7. 1965 - Keith Cooper (Adastra) walking through Main base Mount Hagen in 1965. The camp was constructed by the Army with the hut on the right being allocated to the Adastra crew. (Photo: Dave Aitchison, Adastra website)



In 1965 the command field survey unit personnel attached to Topo Sqn were used mainly in support roles such as station clearing, tower operations, station monumenting, *Aerodist* computations, forward base operations, geodetic observations on the north-south traverse and logistic support for Remote teams.[34]

> *The aircraft used was a WW2 Hudson bomber fitted with a plywood floor in the decommissioned bomb-bay, and flown/piloted by Mr Lionel van Praag. The Aerodist crew were from Topographic Squadron. The photographer/navigator was Lionel's son (name forgotten). Corporal Graeme*

[34] John Harrison

Thorn, (RAEME), was the attached radar mechanic whose skills were called upon often and regularly to get/keep the system running. Graeme was particularly adept in using the Aerodist spares building audio amplifiers for the various mess's entertainment. More the pity though, when the Aerodist required repairs, the locally built amplifiers had to be cannibalized for parts.

Our accommodation was of 'local pattern' grass huts with 32v lighting from military 240v generators, and step-down transformers. I was somewhat surprised that the Survey Regiment's Main Base camp design had separate ablution, and messing arrangements for officers, sergeants, and OR's. This was at odds with Field Survey Units where we were all in together.

My working role at Mount Hagen gradually morphed into the role of camp Sergeant Major, camp administration and logistics - coordination of air movements, disciplinary paperwork, local labour-line hiring/firing and officer-in-charge fire-fighting following a hut fire and the loss of our initial generators on night one or two, building/hut maintenance etc.

But I did manage to be involved in some interesting technical tasks. I was to relieve a person who had to be evacuated from a mountain top because of a diagnosed bout of 'snow blindness', where I sat for about six weeks to observe one 1st order vertical and horizontal angle as part of the north-south Tellurometer traverse. That accomplished it was another two weeks for the weather to clear for our extraction by helicopter. In my absence from the main camp the Aerodist still continued operating under the direct control of Survey Regiment personnel. Another interesting task for me was star prediction/s for a short-notice LaPlace observation in the western highlands. An FK4 (Fundamental Places of Stars), chronometer and chronograph were sent from Australia, and both myself and Warrant Officer Len Davies carried out the required prediction computations from memorised basic principles, and on completion the/our results were compared and found to be complete and accurate for the task required.

And other recollections:[35]

In early June 1965 we (the attached Svy personnel) were returned to our home Units, to return to AHQ Svy Regt in late June to prepare for movement to TPNG. On 1 July we moved to RAAF Base Laverton to load Hercules C130 aircraft and move to TPNG. Main Base Mount Hagen Aerodist Aircraft returned with data and Aerodist Tapes (distance measurements) were analysed and reduced to distance measurements for trilateration calculations. (I was in that Computing Section September - October) Return to Australia personnel back to their Field Survey Units.

In addition to the Hudson Aerodist aircraft other air support (all charter) was one Piper Aztec from Crowley Airways at Lae TPNG for moving and resupply of bases and two Helicopters Bell 47G (VH-UTG, VH-UTX) from Helicopter Utilities, Mascot NSW. Six civilians crewed and maintained these aircraft. The forward Base at Telefomin had grown considerably and our aircraft support was not really up to large cargo movements. A request was made for RAAF support. A large white aircraft bearing United Nations signage arrived. The extraction of the Telefomin forward base to Mt Hagen was apparently one of the first operational sorties in New Guinea, of the RAAF Caribou short-take-off-and landing aircraft.

Personnel on the 1965 project were: AHQ Survey Regiment - four officers, eighteen other ranks; command field survey units – fourteen other ranks; six civilians (air support).

In 1965 the Indonesian confrontation with Malaysia was active with Australian forces supporting Malaysia. For this reason there was sensitivity around any Indonesian and Australian military activity near the TPNG – Indonesian border. On at least one occasion one of the aircraft landed to refuel in Hollandia the former Dutch capital of West Irian. On the return flight the aircraft was ordered to land at Wutung Village, on the coast near the border, to be interviewed by the Pacific Island Regiment personnel who were guarding the border for any intrusion by Indonesian Forces.

1966 (again Topo Sqn AHQ Svy Regt – Major Ed Anderson) was the first year when good equipment serviceability meant that the *Aerodist* survey was completed as planned in TPNG.

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[35] Alex Cairney

The *Aerodist* control continued down the three degree longitude band adjacent to the Indonesian border and lines connecting the Geodetic Survey of Australia and TPNG supplemented the US Air Force Hiran network established three years earlier. A total of 186 lines (8,813 line miles) were successfully completed over days of long flights, exhilarating at times, across the north-south extent of the territory adjacent to the western border. Captain Noel Sproles was officer-in-charge of the northern section operating in the Sepik Valley out of Green River, Imonda and Nuku.[36]

> *If you were any way involved, then you will remember the Adastra call signs of Alfa Golf Sierra (AGS), Alfa Golf Juliet (AGJ), and Alfa Golf Xray (AGX) with mixed emotions. Regardless of how sweet or otherwise your memories are of these venerable aircraft, they became a part of the Corps' history and their call signs were an addition to our vocabulary for many years.*
>
> *Memories are dimming as time passes but, if I am correct, I believe that all three were capable of aerial photography and were employed by the Corps at various times in that capacity. Because of the extensive modifications to the airframe and electrical system needed to install aerodist and APR, AGS alone was fitted with aerodist and AGJ likewise with APR. The longest of the several associations that I had with Adastra was in 1966 when Topo Sqn was operating in PNG in a broad band along the entire length of the border with Irian Jaya. The main base was on Horn Island, next to Thursday Island, and a typical day's work was to fly from Horn Island to Wewak or Vanimo on the PNG north coast then back again to Horn Island. In that time, they would be measuring to ground stations positioned on both sides of the mountain spine running the length of PNG. It was noisy and smelly and uncomfortable work and the physical and mental pressures at times were great. Fortunately for me I only did a few trips but some, such as George Gruzka and Eddie Anderson, did it day after grinding day.*
>
> *The Hudson was a pre-war medium bomber, and of the several hundred that were purchased for the RAAF some were eventually acquired by Adastra. By the 60s they were getting a bit long in the tooth and were much the worse for wear. Signs of age could be seen in things such as the amount of oil consumed on a long flight. AGS for one had a long thick band of heavy oily sludge on its wing behind the engine nacelles as a result of its excessive oil consumption. I observed at Wewak that it took longer to replenish the engine oil used on the trip north from Horn Island than it did to fill the fuel tanks!*
>
> *One of the nice things about operating out of Horn Island was the scenery as you came home south across Torres Strait. It was peppered with reefs surrounded by lovely turquoise water that turned to the rich blue of deep water as the reef edge plunged into the depths. Dead ahead was Cape York. The tip was plainly visible and the triangular shape was quite evident as the eastern and western coastlines gradually moved to the left and to the right to eventually span the width of the windscreen. One beautiful evening, coming home to Horn Island, Lionel decided to skip the scenic tour and reverted to his motor bike racing days. He flew AGS so close to the sea that the propellers were drenching the aircraft in the spume that they whipped up. I thought at the time, as I gripped my seat tightly with both hands, that the aircraft was decrepit enough as it was without giving it a coating of corrosive salt water, but Ross McMillan expressed it more succinctly. "What am I doing flying at dot feet across Torres Strait", he said with clenched teeth, "in an aircraft built before I was born and flown by a pilot older than my grandfather". Good question.*

[36] Captain Noel Sproles (later Lieutenant-Colonel) served in TPNG with Topo Sqn AHQ Svy Regt on Aerodist operations in 1965 and 1966 and then in 1971 as Operations Officer 5 Fd Svy Sqn on Aerodist survey operations in west-Arnhem Land NT and Kimberley WA

Figure 8. Main Base Horn Island QLD, TPNG Aerodist survey 1966, photograph probably from Hudson VH-AGS. The roads are probably Second World War taxiways - Horn Island was a major air base for Australian and US air units. (Photo: Noel Sproles)

Figure 9. 1966 TPNG - an Aerodist tower being hook-carried by Bell 47G helicopter to a survey station (Photo: Noel Sproles)

And more about Remote meteorologic data from a sapper topographic surveyor at Nomad River (TPNG) base[37]:

> *………you mention a problem re feet/metres readings on the Wallace & Tiernan Altimeters which reminded me of an issue with them in 1966.*
>
> *We were at Nomad River (South Base) and (Cpl) Peter Davis noticed that the recorded altimeter readings from some stations were not varying through-out the day.*
>
> *Turned out that in some of the altimeters the "travel" plugs in the face had not been changed for the "operational" plugs and they were still sealed to atmospheric variation.*
>
> *If I recall correctly the instruction to the relevant parties was to unscrew the "travel" plug VERY slowly before exchanging to avoid sudden/violent movement of the mechanism.*
>
> *I then spent a couple of days seated at the bottom of the tower taking readings every 15mins to establish the diurnal wave to use in the mets corrections.*

[37] Sapper William (Bill) Black (later Corporal)

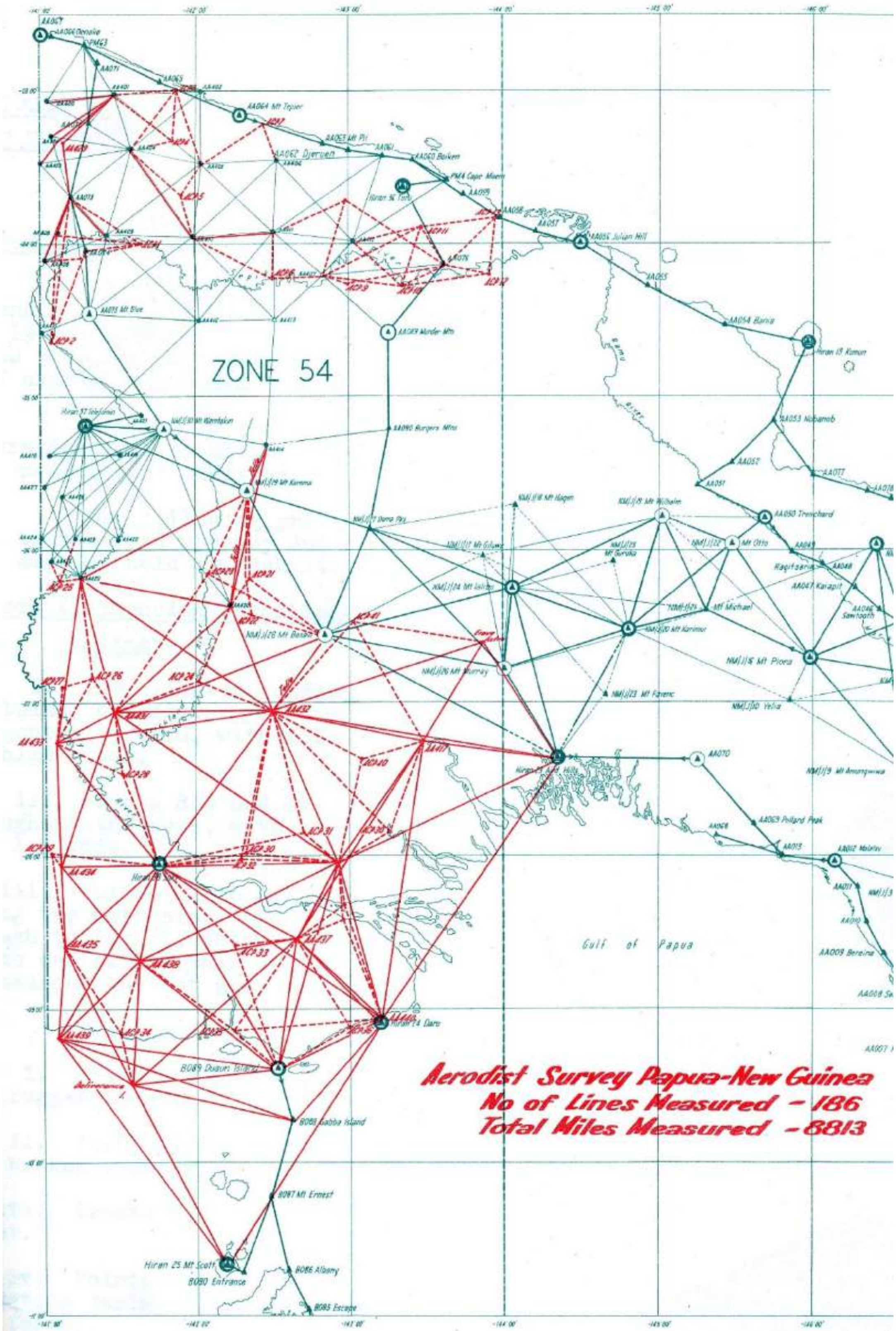

Figure 10. 1966 – RA Svy Aerodist network TPNG, Lambert, B.P. (1967), The Use of Aerodist for filling in between Tellurometer Traverse Loops, in Proceedings of Conference of Commonwealth Survey Officers, Cambridge, Paper B3, pp.93-106. Full and dotted red lines and red stations are 1966 and thin blue lines into blue dot stations are 1964 and 1965. Thick blue lines and blue triangle stations are the Hiran/NatMap/RASvy geodetic survey 1962 – 1965. http://www.xnatmap.org/adnm/ops/prog/aaerod/bpl67/bpl67aerodist4web.htm

1967

In 1967 the *Aerodist* aircraft contract changed to Executive Air Services of Essendon VIC and the MRC2 Master equipment was installed in Grand Aero Commander VH-EXX. This was the same aircraft type and company contracted to Division of National Mapping for *Aerodist* MRC2 surveys. From July to October 1967 the aircraft was attached to Central Comd Fd Svy Unit (Adelaide - Major Don Ridge) on Project C4 eastern-Arnhem Land NT, where 317 *Aerodist* lines measuring 17,300 line miles were successfully completed. This was the most productive *Aerodist* project thus far.

This was the first of major Australian projects for mapping control as part of the Corps' contribution to the 1965 Government approved scale 1:100,000 national topographic mapping program. The location of survey stations was chosen to satisfy the requirements of photogrammetric triangulation (done by AHQ Svy Regt) of the aerial mapping photography in blocks based where practicable on the standard 1:250,000 sheetlines. Irregular coastlines and offshore islands meant that the number of stations required within these blocks increased significantly from about 11 to up to 25.

Figure 11. 1967 – Aero Commander VH-EXX at Gove NT. Aerodist antenna pods in the rotated raised position are on the aircraft fuselage. (Photo: 4 Fd Svy Sqn[38])

Most Remote survey teams were moved from station to station by charter Bell 47G helicopter.

Remote station heights were surveyed by helicopter barometric heighting traverses.

[38] All 4 Fd Svy Sqn photographs were provided by John Harrison who rescued them from a unit garbage bin in the 1970s

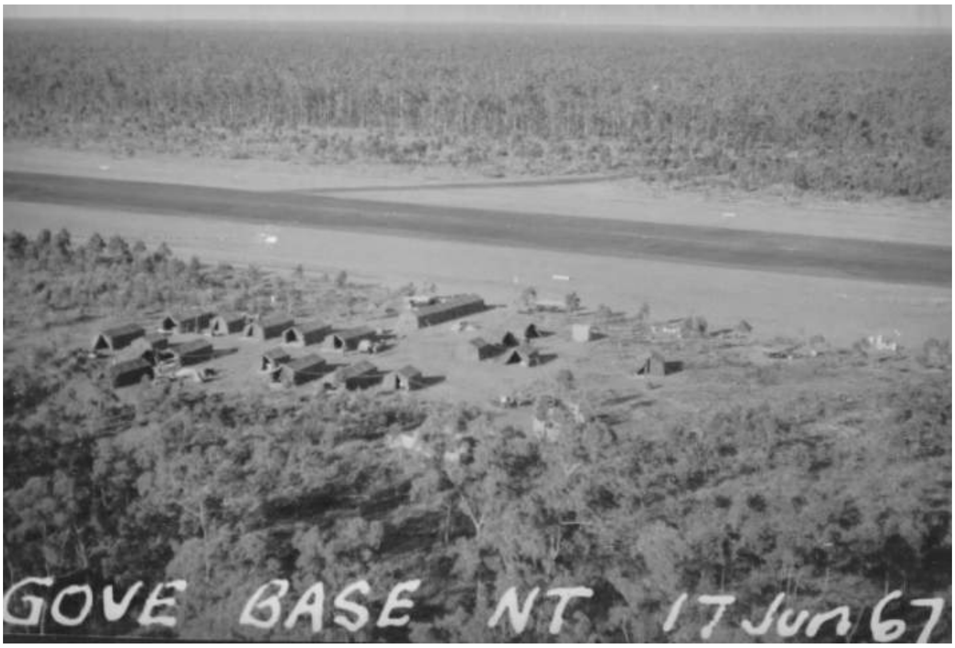

Figure 12. 1967 – Main Base Gove NT, Project C4 (Photo: 4 Fd Svy Sqn)

Figure 13. 1967 - the Aerodist MRC2 Remote (on the tripod) antenna could be mounted on a 20 foot pole tower. The antenna direction was controlled by wires/ropes to the two arms under the dish at right angles. The antenna elevation could be changed to the vertical for aircraft height checks (right photo). (Photos: 4 Fd Svy Sqn)

Figure 14. Main Base Gove (Nhulunbuy) NT 1967 (Central Comd Fd Svy Unit) – Warrant Officer Class One Pat Wood BEM[39] *(right) and Sapper Harry Dunn in the Operations Section tent (Photo: 4 Fd Svy Sqn)*

From the Computing Section: [40]

> *Working with the 'Aerodist', both in the field, office, and in Svy Sect DSVY AHQ (Canberra) computing and 'massaging' the data for an acceptable result, I came to realise that it was never going to be of a standard required for large-scale mapping. Better than astro fixes, but would never be of a geodetic accuracy. In brief - good enough for 1:250k, 1:100k at a stretch mapping. There were just too many variables with associated errors that could never be controlled, including: aircraft height, ground elevations, eccentric station corrections sometimes based on magnetic bearings with poorly known variation (I did suggest taking magnetic bearings to the rising or setting sun to enable the calculation of magnetic declination at the station), sash-cord operated tower stations, sometimes 'guessed' atmospheric meteorological conditions, aircraft yaw (variations in inter-aerial distances) and suppositions on the required skill/s of aircrew to maintain constant a/c elevation, and fly with some precision over a known point.*
>
> *Existing field techniques inherited from the survey Regt' were adopted - aircraft height checks, fly whenever, and where-ever with only little consideration of weather or meteorological condition. My field role during 1967 was the management of a small Computing Section of personnel working from a temporary office within Larrakeyah Barracks in Darwin. Raw slant ranges were reduced in the field at Main Base Gove and sent to Darwin. Data reduction forms were designed on the principals dictated by the Regiment and modified to reflect errors/techniques identified during the equipment's initial appraisal by the Unit in the Northern Territory. Needless to say reams of data*

[39] Warrant Officer Class One Pat Wood (later Major) was awarded the British Empire Medal (military division) BEM in June 1961 for services to military survey

[40] John Harrison

reduction paperwork were generated which needed to be microfilmed on a 'flow camera' by Kodak, Adelaide before being sent to AHQ Survey Regiment for final reduction to spheroidal distances. Routinely original charts, and reduced data were stored overnight in fire-resistant, lockable metal, boxes.

The Darwin working hours for RA Svy personnel were dictated by the amount of data received and requiring data extraction. Working within the camp routine, messing, etc, regular after-camp-hours office work was necessary. These arrangements were of concern, particularly to the newer/younger soldiers who, from their office, could see the other Unit's members recreating on the camp sports field, (or in the adjacent 'Ratty' Club) after hours and or/on weekends.

From an impressionable young sapper topographic surveyor on his first survey operation: [41]

The survey operation in the Northern Territory in 1967 covered the area east of the Stuart Highway to the Gulf of Carpentaria and north of the Roper River. My 'Five Ways' (13°00'S – 133°30'E) survey point was north-west of Bulman Airstrip (an old World War 2 strip) from where a major part of the survey was controlled. My experience included being a driver and member of a party that tried to retrace a very old survey from Bulman to Gove. My final survey point was on top of Nimbuwar Tor, east of Oenpelli (below), on to which we were dropped there by helicopter. Being a topographic surveyor was a wonderful experience and is part of my 'odyssey'. We could consider ourselves as explorer surveyors.

Figure 15. Left – Nimbuwar Tor 1967 (Bob Williams) and Right – Nimbuwar Tor 1943 (from a RAAF biplane)

Lieutenant Dave Hebblethwaite's first major field survey was with Central Comd Fd Svy Unit using *Aerodist* in eastern-Arnhem Land NT in 1967. Dave went on to be one of the Corps' most experienced *Aerodist* officers being involved in the planning and conduct of

[41] Sapper Bob Williams (later Major Ph D and Defence Science and Technology Organisation geospatial scientist)

operations in Australia and Indonesia and system test and evaluation over the next eight years[42]:

> *This operation was based at Gove (as it was then) with the airstrip and Main camp sitting on top of a bauxite deposit. We started off with two civilian Bell G47 helicopters and one Army Bell G47. I can remember trudging up a hill with a couple of Sappers and axes with the intent of clearing a helicopter pad on the top. The helicopter had dropped us off at the bottom of the hill. We had a number of hours in which to clear the pad at which time the helicopter would appear overhead and hopefully land to pick us up. We discovered that Army pilot landing pad requirements weren't quite as rigorous as those for the civilian pilots. We also discovered that it was unwise to try and chop a tree down without first giving it a good shake to dislodge as many green ants as possible. They can bite!*
>
> *We also had a Haflinger for initial transport around Main camp. I can remember helping to load this little vehicle through cargo doors into a DC3 at Darwin. It's a small 4 wheel drive vehicle powered by 643 cc flat twin horizontally opposed, rear mounted, air-cooled engine. It can literally go anywhere and when the going gets tough the driver can set the throttle, hop out and walk alongside to help it over the really tough spots. I can still see the image of it chugging south in the evening absolutely loaded to the gunnels and beyond with bodies going to watch a movie at the nearby ELDO establishment.*
>
> *With regard to the Aerodist it struck me almost straight away that one major flaw in the system was the determination of the Aerodist aircraft's altitude. This was being determined by a survey altimeter in the aircraft cabin. I managed to convince the OC, Maj Don Ridge, to allow me to take the aircraft for a morning and/or afternoon at various intervals to do some tests. This involved setting up an Aerodist remote with the dish pointing vertically and flying the aircraft vertically above it at various altitudes while measuring the electronic distance between the Aerodist Master and Remote. At Gove a Wild vertical collimator and a siting device made from helio parts was set up alongside the Aerodist remote. The aircraft was guided over the remote by radio instructions from an observer using the sighting device. The collimator was used to estimate the aircraft's deviation from the remote zenith so that the true aircraft altitude could be determined. The altitude error was then calculated by subtracting the true altitude from that obtained by the altimeter in the aircraft. This process was done for a number of different altitudes between 1 and 3 km. The end result was that an error of 100m could occur at an altitude of 3km (10,000 feet). Lines measured at this altitude were usually around 100+ km and the altitude error could result in a line error of around 10m.*
>
> *My time at the Regiment in 1969 was spent looking into various devices to improve Aerodist accuracy. One of these investigations was looking into the feasibility of mounting a gyro-stabilised mirror mounted just outside the co-pilot's side window so that he could see a vertical*

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[42] Lieutenant Dave Hebblethwaite (later Lieutenant-Colonel) served in Central Comd Fd Svy Unit (Adelaide) on Aerodist operations in Eastern Arnhem Land in 1967 and the following year in Western Arnhem Land. In 1969 Dave undertook investigations relating to improving aspects of the Aerodist operation while he was posted to AHQ Svy Regt. In 1970 while posted to B Section, 1 Topo Svy Troop (reinforcement section for A Section in South Vietnam) at Randwick in Sydney, Dave was assigned as Second-in-Command and Operations Officer on Operation Mandau (2 Fd Svy Sqn (Sydney)) in Indonesian Kalimantan Barat (West) as part of the Defence Cooperation Program between Australia and Indonesia. In 1971 Dave served again on Aerodist operations in Indonesia, this time as Second-in-Command Operation Gading 1 (2 Fd Svy Sqn) in Southern Sumatra. In early 1974 Dave was promoted to Major and posted to the School of Military Survey at Bonegilla VIC as Senior Instructor. There he undertook various investigative projects to do with Aerodist and WREMAPSII – the laser airborne terrain profiler developed by the Weapons Research Establishment at Salisbury in South Australia – more detail on these investigations is at page 82.

view of the terrain underneath the aircraft and thereby more easily guide the pilot over a particular point on the ground such as was required for aircraft altitude checks. The device was never fully developed and was abandoned.

1968

After the northern-Australia wet season in 1968, the survey season commenced in late-April in the Kimberley WA, with *Aerodist* operations conducted by Western Comd Fd Svy Unit (Perth - Major Clem Sargent). In just seven weeks, ending mid-July, 193 lines were successfully completed over 11,900 line miles. The longest line measured was 178 miles (285 km). Once again mapping control for coastal regions and offshore islands meant that there were more stations established than on standard 1:250,000 blocks.

On completion of the Kimberley project the *Aerodist* system in VH-EXX was immediately deployed to western-Arnhem Land NT for Central Comd Fd Svy Unit (Adelaide - Major Don Ridge) to complete the mapping control across northern NT from mid-July to October. Main bases were established at Oenpelli, Daly River and ……..Once again there were only minor equipment faults and 333 lines were completed over 19,513 line miles. This was the most lines measured on any operation to date and indeed was the record for any *Aerodist* campaign 1964-1975. There was no official competition between units for number of *Aerodist* lines measured but this record was rightly celebrated by those involved. After five years of rigourous use of the *Aerodist* system in hostile (to electronic equipment) tropical conditions it was still performing well. Good equipment serviceability was testament to the maintenance skills of the RAEME radar mechanics and the RA Svy Master and Remote operators use of it.

This was the first of three years (1968-70-71) when a British Army Royal Engineer (Survey) Troop was attached to RA Svy units for a few months. From July to December 1968 one officer and fourteen other ranks were attached to the Fd Svy Units firstly in the Kimberley WA and then western-Arnhem Land NT.

Figure 16. 1968 - the Aerodist Computation Section at Main Base Oenpelli NT ...Les Magar (RE Svy?), Aussie…, Joe Brennan, Dave Collins, Alex Cairney (Photo: 4 Fd Svy Sqn)

Systematic error sources were identified and reduced by sound operating procedures. But unexpected problems did occur. One VARYCORD adjusted trilateration network seemed to be internally satisfactory but would not fit when integrated into the higher order geodetic survey. Data was checked many times until the Svy Sect DSVY AHQ queried the Wallace and Tiernan precision altimeters used for heighting. Altimeter readings were in feet but at some stage an incorrect systematic conversion to metres introduced a significant scale error in parts of the network. With the field data corrected the network adjustment fitted.[43]

> *During this season my role/activity in the operation was of the tape/chart breakout, and the investigation and implementation of barometric/and visual protocols for the determination of measuring a/c height indication at cruising/measuring speed over a known point. This established I moved out of the main-base environment to select and take charge of the various 'forward bases' at places closer to the action. These revised taskings were essentially logistical, helicopter movements, resupply of remote stations/parties, etc.*
>
> *The same checking, security and transfer of data was adhered to as was the previous season. The only change was that I was then posted to Survey Section Directorate of Survey as the senior computer where I would be responsible for geodetic adjustments including the Aerodist networks for use in aero-triangulation to be done by AHQ Svy Regt*

1969

After an absence of three years, the Corps returned to TPNG to work on priority scale 1:100,000 mapping working east from the earlier priority of the western border with Indonesia. *Aerodist* would go on to provide mapping control of the mainland based on the geodetic surveys. Later control for the many offshore islands was to be a mix of geodetic traverse linking New Ireland, New Britain and New Guinea (1972-1974) and Doppler satellite from 1975.

In 1969 the aircraft contract changed to Union Air, Toowoomba QLD for two survey aircraft. This contract lasted for the next seven years with Union Air providing all of the *Aerodist* aircraft in Australia, Papua New Guinea and Indonesia, until the capability was withdrawn in 1975. In the final report on the last *Aerodist* operation ‘Sandy Hill 1975’ (Cape York and Gulf of Carpentaria) the Officer Commanding 1 Fd Svy Sqn Group (Major Bob Skitch) said what was true of all of the operations:

> *It should be recorded that Union Air have again shown themselves to be an excellent contractor. The vast experience of the aircraft captain Kev Sullivan was of inestimable value to the Aerodist operation, and his ability to fit into the forward base operation and accept the vicissitudes of service life under these conditions is fully appreciated.*

Other Union Air pilots worthy of the same mention included Kelvin Grady and Vince Russell.

The *Aerodist* MRC2 was installed in Beechcraft A65-8200 Queen Air VH-TYV. Equipment trials were conducted in the Toowoomba area in June 1969 before the aircraft was attached to Northern Comd Fd Svy Unit (Brisbane - Major Ed Anderson MBE) temporarily based at Goroka in Territory Papua New Guinea (TPNG) from July to November 1969.

140 *Aerodist* lines established 47 new survey stations for mapping control in an area on the main island south of Wewak to Madang south to a line at about the latitude of Lae, Army Sioux helicopter mounted barometric heighting traverses established heights for not only the *Aerodist* stations but 400 vertical control points for aerotriangulation of the mapping photography.

[43] John Harrison

Figure 17. 1969 Computing Section Northern Comd Fd Svy Unit, Goroka TPNG – back row from left Warrant Officer Class Two Noel Ticehurst, Sapper Kevin Kennedy, Sapper Dave Johnston, Sapper Frank Yates; front row from left Sapper Bill Griggs, Sapper Dave Conrad, Sapper Alan Shepheard, Sergeant John Willis is absent (Photo: Kev Kennedy[44])

Figure 18. 1969 Main Base Goroka TPNG – Computing Section tent - Sergeant Bob Mason (Aerodist Master operator) instructing Sapper Patrick Miller on the 'mystery' of extracting the raw slant ranges from the Aerodist charts. Patrick preferred the duty of mets recorder in the aircraft. (Photo: Facebook P. Miller)

A few weeks after returning from TPNG, Queen Air VH-TYV crashed on 30 November 1969 near Shepparton VIC, tragically killing all six people on board. Those killed were the Army pilot and five civilians. The aircraft was attached to the School of Military Survey, Bonegilla VIC (aircraft based at Albury airport, NSW) at the time, but the fatal flight occurred on a 'rest day' from *Aerodist* work and was not under control of the School on the day of the crash. The civilians killed were all Shepparton area residents.

[44] Sapper Kevin Kennedy (later Warrant Officer Class Two)

Figure 19. Beechcraft A65-8200 Queen Air VH-TYV with Aerodist MRC2 under-wing and under belly antenna pods. This photograph was taken at Essendon, Melbourne VIC on 29 November 1969 the day before the aircraft crashed near Shepparton VIC, (http://www.adf-gallery.com.au/gallery/Queen Air-VH-TYV/Queen_Air_VH_TYV_Essendon_29th_November_1969_Photo_Peter_Kelly?full=1)

1970

In early-1970 an *Aerodist* MRC2 Master system was installed in Union Air Beechcraft A65-8200 Queen Air VH-FWG. This aircraft was attached for *Aerodist* surveys to the Sydney based Detachment 2 Fd Svy Sqn (Major Clem Sargent attached from 5 Field Survey Squadron – Perth WA) on Operation Mandau in Kalimantan Barat (West), Indonesian West Borneo, from May to early-August 1970. It was then attached to 1 Fd Svy Sqn (Brisbane - Major Ed Anderson MBE) based at Goroka TPNG from August to November 1970.

Operation Mandau[45] was part of the Military Assistance to Indonesia program and was a tri-nation collaborative field survey operation also involving the British Army Royal Engineers (Survey). Based at Pontianak in the south of Kalimantan Barat, 2 Fd Svy Sqn worked with the Indonesian Army Corps of Topografi (JANTOP) from mid- May to early-August 1970, to establish an *Aerodist* based network for medium scale mapping. At the same time 84 Sqn Royal Engineers (Survey) established a geodetic framework on which to base the *Aerodist* network (the control diagram is at *Figure 20a* page 37). Thirty-eight survey stations were established for mapping control from 113 *Aerodist* line measured. A very good account of that operation is in

[45] 'Mandau' meaning the 'traditional knife weapon of the local Dayak people of Borneo'

the Survey Corps Associations Bulletin September 1971 page 35 http://www.rasurvey.org/actindex.html .[46]

> *…aerial photography missions flown by the Royal Air Force……The contingent had with it a small fleet of aircraft including three Army Sioux helicopters and an Army Pilatus Porter, a RAAF Caribou, and a chartered Beechcraft Queen Air in which the aerodist and barometric equipment was installed. Because of the varied equipment and administrative needs of a field operation of this size and duration, a considerable component of support staff was added. As a result the base camp established at Supiado, the airfield serving the town of Pontianak some 20 kilometres away, containing a total of seventy-two Australian personnel including nine members of the RAAF, two civilians, and members of a range of Army Corps, including aviation, signals electrical and mechanical engineers, ordnance, medical, service, pay and catering. Five loads by RAAF C-130 Hercules transports were needed to bring in the Australian contingent.*

From Captain Dave Hebblethwaite (Second-in-Command):

> *The Main camp was situated on swampy ground which became a quagmire after heavy rain. To alleviate the situation, we dug drains to try and drop the water table and we were spraying to try to keep the mosquitos at bay. The drains must have ended up in a local creek as sometime later we were approached by some of the nearby villagers saying that the DDT we were spraying was killing their chickens. I can't remember how that issue was resolved.*

> *We initially set up a movie projector in the camp from which movies were projected on to a couple of sheets draped vertically from poles. It wasn't long before we noticed small shadows flitting across behind the screen – the local kids were sneaking into the camp (verboten!) to watch the movies. We eventually moved the screen to one of the boundary fences near the road. We watched from inside and the locals watched from outside – they didn't seem to mind watching the movie in mirror image!*

> *At least once we were unable to get additional helicopter support for a few days as there was a French oil exploration company in the area which was also relying on the Indonesians for helicopter support and since they apparently had hard cash they got first dibs sometimes.*

> *On one memorable occasion the OC Maj Clem Sargeant went off with some of the Indonesian Survey officers to visit one of the outlying villages in an Indonesian helicopter with a return to Main camp due before dusk. Well, dusk came and went with no returned helicopter and no communications. Now a number of factors came into play. I knew that the Indonesian helicopter maintenance was a bit iffy (we had seen some examples repair on the airstrip) and at the best they had reached their destination safely and couldn't restart the helicopter or at the worst – they had crashed somewhere. As the Vietnam War was in full swing (we could occasionally hear bits of radio transmissions from Vietnam) we believed journalists were monitoring military communications looking for stories to print. So what to do? Since we had heard nothing from the OC my initial thought was that they were safely at the village and would turn up next morning. But if that was not the case and they had crashed? At about midnight I got the signaller to send a coded warning message to Singapore explaining what had happened and that I felt they would turn up in the morning but if they didn't then a search would have to be mounted. Well, the s##t hit the fan – we received a reply in the clear (not a coded message) asking for more details. I found out later that they had organised somebody in Perth to inform Maj Sargent's wife that he was missing – I thought this was a knee jerk reaction and totally wrong. After a few more back and forth signals it was agreed to wait any further action till the morning. After breakfast we heard a helicopter land at the airfield and who should hop out – Maj Clem Sargeant all bright and cheery! They had indeed had a*

[46] Coulthard-Clark CD, Australia's Military Map Makers, The Royal Australian Survey Corps 1915-96, 2000, Oxford University Press, p161

problem restarting the helicopter and the crew were able to eventually fix the problem sufficiently enough to get the helicopter going again.

We were all aware that the Indonesians were still having problems with communist terrorists along the border with Sarawak. We did see a World War 2 B25 Mitchell bomber take off/land at the airstrip from time to time. Rumour had it that the Indonesians had dragged it out of the sea from somewhere, refurbished it and were using it in operations against the communists.

The terrain was pretty rough and I remember visiting one Dyak mountain village to discuss Aerodist remote sites with the village chief. As soon as we landed, we were surrounded by a gaggle of enthusiastic kids – even before the rotors had stopped turning. This was a common occurrence wherever we went with helicopter village visits. As we were escorted to the Chief's hut, we passed a muddy looking pond with a few pigs standing there in. When we sat down with the Chief and his entourage, we were offered glasses of orange cordial. My mind immediately went to the pond and the possible nasties within it. As there was no option but to drink, it was down the hatch and thank goodness we have a doctor back at the camp! Luckily, I am not aware of anyone getting sick after that visit.

Aircraft altitude error checks were done at Pontianak. The method was different to previous checks. True aircraft altitude was established by setting up two vertically oriented remotes, one at each end of a measured base line (measured by Tellurometer normally along the length of the Main camp airstrip). Normal line crossing procedures were carried out. This method eliminated the problem of guiding the aircraft over a point that was experienced in 1968. At the instant of line crossing, the three sides of the triangle formed by the aircraft and the remote stations were known and the aircraft altitude was calculated by trigonometric methods. Four passes at each of four different altitudes between 1km (3,000 feet) and 3km (10,000 feet) were done on 5 different days. On two of these days altitude checks were done in the morning and in the afternoon.

Figure 20. 1970 Operation Mandau – Officer Commanding Major Clem Sargent (standing on the white plastic) demonstrating the Aerodist MRC2 Remote instrument to Indonesian Army surveyors at Main Base Pontianak, Kalimantan Barat, Indonesia (Photo: Survey Corps Assocs Bulletin)

Six Eastern Comd Fd Svy Unit/ 2 Fd Svy Sqn topographic surveyors (Corporals Clive Craddon, Dave Anderson, Greg Buckenham, Mario Zappula, Rod Offer and Leon Griffiths) were *Aerodist* Remote team leaders serving in that capacity for the entire operation. Mario Zappula spent the longest on one *Aerodist* station – 30 days. The other member of the two man teams was an Indonesian Army JANTOP surveyor. Leon Griffiths valued that experience as a young surveyor but says much has not been said of that operation[47]

> *On one high survey station near the Malaysia (Sarawak) border (south-west of Kuching, Sarawak) my Indonesian partner was evacuated suffering from yellow fever. I was there by myself for a week as the weather had closed in. Rations were meager and I was on my last radio (AN/PRC F1) battery. But I did have a Tellurometer. The nearest Aerodist station (Greg Buckenham) was nearly 80km away and the small scale map that we had showed two high mountain ranges between us. Nevertheless we pointed the Tellurometers at each other and somehow received a signal, established voice communications which we could use to relay messages. We managed to measure the line about 78 km.*
>
> *At that time in that area there was an active revival of the Malaysian communist insurgency of 1948-1960. Insurgents were using Indonesia as a place of concentration and infiltration into Malaysia and the Indonesians were pursuing them[48]. I could hear a fire-fight going on around the base of my mountain. There were rumours of communist bodies being brought into military camps in the area.*

[47] Corporal Leon Griffiths (later Captain) 2 Fd Svy Sqn, telephone conversation with author January 2021
[48] New York Times newspaper 7 Oct 1970 – Malaysia estimated 200 insurgents but there may have been 500 with half of them operating in Indonesia

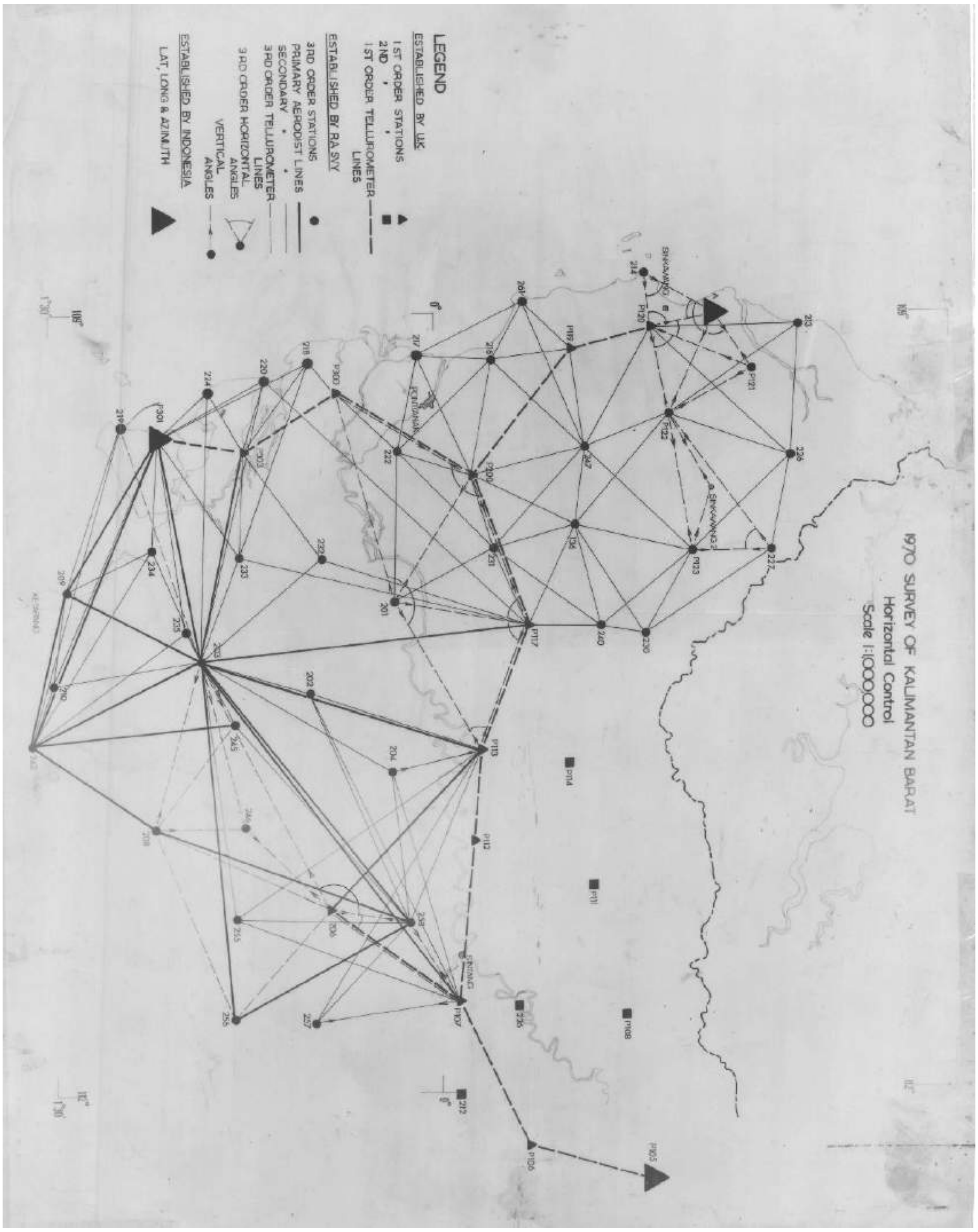


Figure 20a. 1970 Operation Mandau – Kalimantan Barat (Borneo), Indonesia, horizontal survey control diagram showing the integration of the three nation JANTOP, RE (Svy) and RA Svy surveys (courtesy Leon Griffiths)

Along with mapping assistance to northern neighbours, work continued on the remainder of 1:100,000 mapping of TPNG as a high Defence priority. Once again Goroka in the eastern highlands was the main base for 1 Fd Svy Sqn (Brisbane – Major Ed Anderson MBE). This base camp was used for *Aerodist* surveys over five years 1969-70-72-73-1974. Forward operating bases at Bulolo, Kokoda, Kikori and Daru supported the operation east and south of Goroka including to the Torres Strait to connect with the Australian Geodetic Survey. 144 completed *Aerodist* lines established 52 new ground survey stations.

Figure 21. 1970 – N Comd Fd Svy Unit/1 Fd Svy Sqn (Brisbane) Main Base Goroka, Eastern Highlands, TPNG, between the main runway and the road (Lae to Mt Hagen) looking north through the 'bubble' of an Army Sioux helicopter. The mainly tented camp with some semi-permanent structures such as showers/toilets was used by N Comd Fd Svy Unit/1 Fd Svy Sqn 1969-1970 and 4 Fd Svy Sqn (Adelaide) 1972-73-1974 (Photo: Author)

Below – the enlarged Main Base Goroka 1972-1974 (Photo: Bob Dikkenberg[49])

Figure 22. 1970 - British Army Royal Engineer (Survey) soldiers Corporal Ian Brown and Sapper Mark Johnson on familiarisation training with Army Sioux helicopters near Goroka TPNG (Photo: Author)

[49] Sapper Bob Dikkenberg (later Staff-Sergeant) 4 Fd Svy Sqn

Figure 23. 1970 - Army Sioux helicopter departing a survey station near Goroka TPNG in the Eastern Highlands. NM/J/21 Mt Michael 11,965 ft is probably the mountain in the centre distant background (Photo: Author - enhanced by Laurie McLean)

Figure 24. 1970 – Forward Operating Base Bulolo TPNG, No 38 Squadron RAAF Caribou Tactical Transport - Short Range (aircraft on the right is reversing into the parking bay). RAAF Caribous were used to move and resupply forward operating bases and Aerodist teams (Photo: Author - enhanced by Laurie McLean)

Figure 25. 1970 – Forward Operating Base Bulolo TPNG, locals in the shade of the Aerodist aircraft while a RAEME radar mechanic does some work (Photo: Author)

Figure 26. 1970 – Forward Operating Base Kokoda TPNG, unloading Aerodist team stores from RAAF Caribou (Photo: Author)

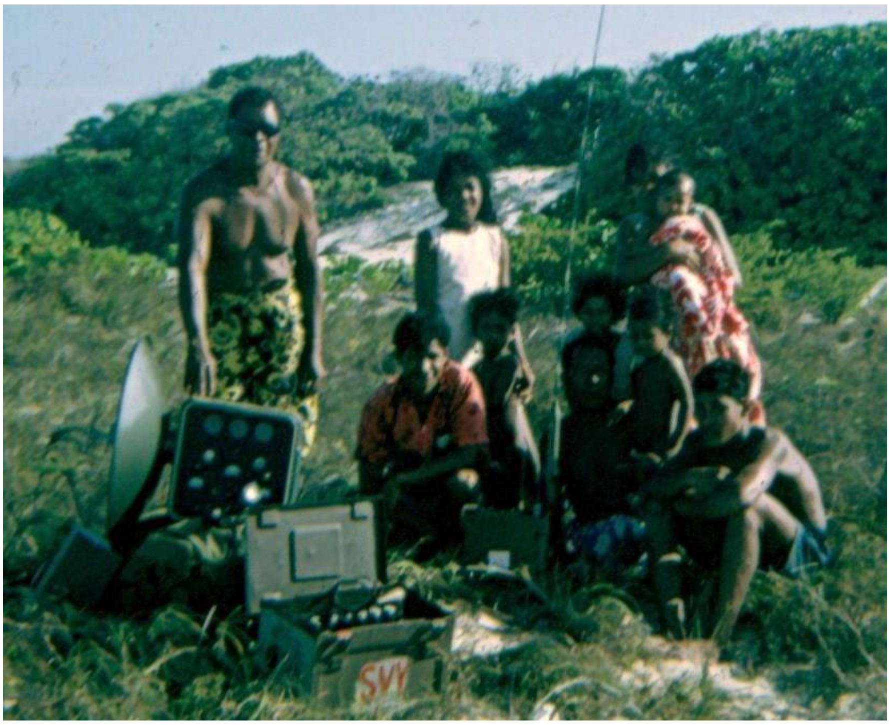


Figure 27. 1970 – Torres Strait Island family helping with an Aerodist station – the family was on a fishing trip and camping on the otherwise uninhabited small island. Helicopter weight restrictions meant only one Remote operator and light scale equipment of Remote (without tripod), Baromec, psychrometer, survival backpack with three days water, three one man combat rations, hexamine stove, dixies, inflatable mattress, bed sheet, mosquito net, waterproof cover, machete, Remote 12V wet cell battery; AN/PRC F1 HF radio. The Remote instrument resting on the survival pack on the station ground mark is measuring a line. Not using a tripod helped to minimise 'ground swing' reflections off the adjacent ocean water. (Photo: Author)

Figure 28. 1970 – Aerodist station (photo control point) at white plastic 'T' on small uninhabited Torres Strait island (Figure 27) 80km south of Daru Is TPNG (Photo: Author)

Figure 29. 1970 – Torres Strait Aerodist survey, charter Bell 47GB1 helicopter fitted with floats to transport and resupply Remote teams (Photo: Author)

1971

After the success of Operation Mandau in Kalimantan Barat (West) in 1970, the Indonesian Government requested a similar military assistance project in southern-Sumatra, the entire area being swampland. This became Operation Gading 1[50] mounted again by 2 Fd Svy Sqn (Sydney - Major Ted Laker MBE) with main base established at Palembang.   Seven aircraft were allocated in direct support – four Army Sioux helicopters for moving survey teams, one Army Pilatus Porter for transport and aerial photography, one RAAF Caribou short range transport for moving forward operating bases, survey teams and resupply, and one Beechcraft Queen Air (VH-FWG) equipped with *Aerodist* MRC2 Master equipment. From 15 April to 7 July 1971, the *Aerodist* MRC2 measured 153 lines to establish 47 new survey stations. This was the dry season when it was not uncommon for five to six inches of rain to fall overnight. Eight Remote teams were routinely deployed at one time with this increasing to ten occasionally. Major Laker praised the technical skills and determination ‘to get the job done’ of the surveyors and radar mechanics, most of whom had less than two years training and experience and all were in their early twenties[51]. Before the equipment was sent to Sumatra it was tested with VH-FWG at Toowoomba in Feb/March with RAEME technicians operating the Master and a static Remote

[50] ‘Gading’ meaning ‘elephant tusk’

[51] The National Bulletin of Aust Survey Corps Associations 1972 http://www.rasurvey.org/actindex.html

operated by personnel from 1 Fd Svy Sqn (Sergeant Jim Clarke, Corporal Kevin Kennedy, Corporal Allan Shepheard) who travelled from Brisbane each day[52].

Figure 30. 1971 Operation Gading 1 - Corporal Allan Brown (2 Fd Svy Sqn) and an Indonesian Army (JANTOP) surveyor with a local civilian operating an Aerodist Remote atop a 10 metre high tower which the locals built for this purpose (National Bulletin of Aust Survey Corps Assocs - 1972). The words on the brassard on Allan's left shirt sleeve were 'Operasi Pemetaan 'Gading'' meaning Mapping Operation 'Gading'. These were worn by all Australian and Indonesian troops and were worn on all survey/mapping operations in Indonesia with the relevant operation name.

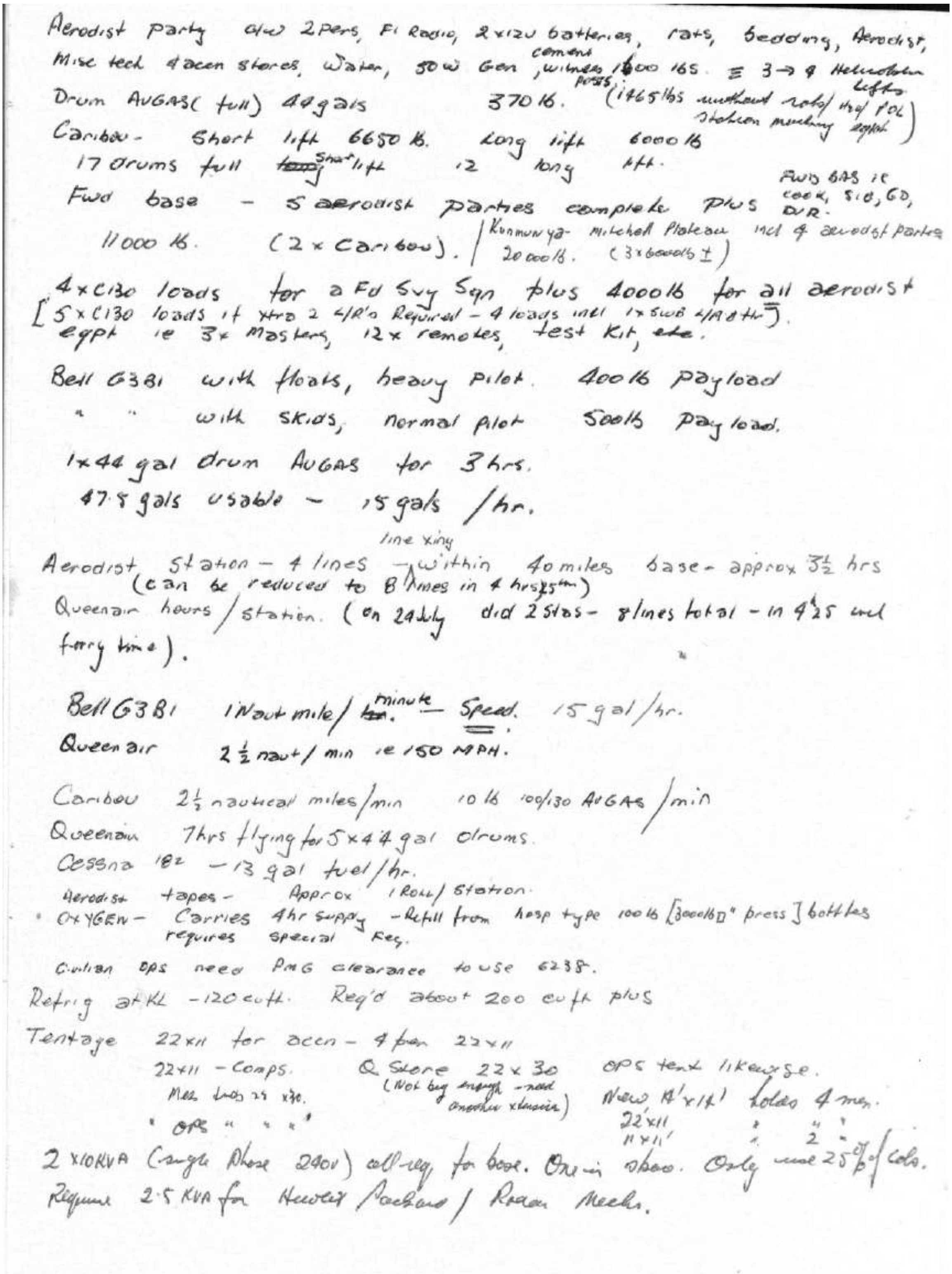
After Sumatra, the *Aerodist* system was transferred to 5 Fd Svy Sqn (Perth - Major Clem Sargent) then deployed firstly to survey Bathurst and Melville Islands NT then to the Buccaneer Archipelago in the Kimberley WA area to complete the mapping control which was commenced there in 1968. Main Bases were Darwin NT and Kalumburu WA. The NT phase measured 50 *Aerodist* lines to establish 13 new stations and the WA phase measured 216 lines to established 53 new stations. *Aerodist* average progress rates in NT were 4.5 lines per day, WA 5.2 lines per day and an overall operation rate, including movement of forward operating bases was 3.8 lines per day from 5 July to 12 September. This from Captain Noel Sproles then the Operations Officer:

> *From mid-June to mid-October 1971, I was attached to 5 Fd Svy Sqn for aerodist and heighting operations in the NT and the Kimberley region of WA.*
>
> *On 3 September, we established a forward base for four aerodist parties at the Mitchell Plateau airstrip. There was no one else there other than a mining exploration team that had established a camp just down the road. On 7 September, a 19-something-year-old was sent up by the exploration team with instructions to clear the long grass around the wind sock on the airfield. He decided that it would be easier to burn it off instead of cutting it as instructed.*
>
> *This, of course, was well into the dry season. The resulting bush fire raged unchecked through the Kimberley for a good two weeks before it reached the sea and died out.*
>
> *Unfortunately, our forward base camp was in the path of the fire's march to the sea. Much personal gear and accommodation stores were lost. The Bristow crew managed to scramble their helicopter(s) into the air and to safety but they too lost personal gear and their mechanic's tools.*

[52] Kevin Kennedy

> *Our technical equipment, including several sets of MRA2 Tellurometers, escaped unscathed, apparently because the tents they were in were fully closed down. I came down from the main base at Kalumburu with the RAAF Caribou later that day with replacement accommodation stores and food. Clem Sargent had, of course, also lumbered me with the job of investigating officer.*
>
> *On arrival, the Caribou captain doubted that he would be able to land as large sections of the runways were, literally, on fire. He eventually found a safe area to land but had to move the aircraft several times to avoid the fire while we were on the ground.*
>
> *Bill van Malenstein, then a sergeant, was in charge of the forward base. He did a sterling job mustering his troops and the civilians into safe areas as the bushfire moved back and forth around them. It was a close call and we were lucky not to have incurred any injuries, let alone fatalities.*

A major and essential element of all *Aerodist* operations was a very detailed, well planned and executed logistics plan. More often than not, it was the case that since the Second World War survey operations were the only military operations, or exercises, to have been conducted in areas where *Aerodist* was deployed, normally in remote and often difficult environments. Aside from the technical element of operations, survey officers and warrant officers often had more experience in planning and executing insertion, sustainment and extraction of forces than staff on supporting headquarters. In 1971, Captain Noel Sproles as a forward operating base commander and operations officer, compiled a very useful aide-memoire for staff duties in the field (Figure 31) which would have been of great utility for training, planning and operations of a field survey squadron (survey troop) inserted and extracted by RAAF C130 Hercules, forward operating base moved and resupplied by RAAF Caribou and survey teams *(Aerodist)* supported by helicopter.



Aerodist party o/w 2 pers, F1 Radio, 2x12v batteries, rats, bedding, Aerodist, Misc tech & accn stores, Water, 50w Gen, cement witness posts, 1600 lbs ≡ 3→4 Helicopter lifts.
Drum AVGAS (full) 44 gals 370 lb. (1465 lbs without rats/dry POL station marking eqpt)
Caribou - Short lift 6650 lb. Long lift 6000 lb
17 drums full short lift 12 long lift.
Fwd base - 5 aerodist parties complete plus FWD BAS ie cook, sig, GD, DVR.
11000 lb. (2 x Caribou). / Kunmunya - Mitchell Plateau incl 4 aerodist parties 20 000 lb. (3 x 6000 lb ±)

4 x C130 loads for a Fd Svy Sqn plus 4000 lb for all aerodist [5 x C130 loads if xtra 2 4/R's Required - 4 loads incl 1 x SWB 4/A & tlr].
eqpt ie 3 x masters, 12 x remotes, test kit, etc.

Bell G3B1 with floats, heavy pilot. 400 lb payload
" " with skids, normal pilot 500 lb payload.

1 x 44 gal drum AVGAS for 3 hrs.
47.8 gals usable - 15 gals /hr.

Aerodist station - 4 lines - line xing within 40 miles base - approx 3½ hrs (can be reduced to 8 lines in 4 hrs 25 min)
Queenair hours / station. (on 24 July did 2 stns - 8 lines total - in 4 25 incl ferry time).

Bell G3B1 1 Naut mile / minute - Speed. 15 gal/hr.
Queen air 2½ naut / min ie 150 MPH.

Caribou 2½ nautical miles/min 10 lb 100/130 AVGAS /min
Queenair 7 hrs flying for 5 x 44 gal drums.
Cessna 182 - 13 gal fuel/hr.
Aerodist tapes - Approx 1 Roll / Station.
OXYGEN - Carries 4 hr supply - Refill from hosp type 100 lb [3000 lb/□" press] bottles requires special key.
Civilian ops need PMG clearance to use 6238.
Refrig at KL - 120 cu ft. Req'd about 200 cu ft plus
Tentage 22 x 11 for accn - 4 per 22 x 11
22 x 11 - Comps. Q Store 22 x 30 (Not big enough - need another x-tension) OPS tent likewise.
Mess tents 22 x 30. New 11' x 11' holds 4 men.
" OPS " " " 22 x 11 " " "
11 x 11' " 2 "
2 x 10KVA (single phase 240v) all-reg for base. One in shop. Only use 25% of cap.
Require 2.5 KVA for Hewlett Packard / Recon Mechs.

Figure 31. Logistics aide-memoire for planning and conduct of Aerodist survey operations compiled by Captain Noel Sproles (courtesy Noel Sproles)

The over-the-horizon reach of *Aerodist* was used to extend the Australian Geodetic Datum 1966 to Ashmore Reef and Cartier Island with RAN patrol boats supporting the Remote teams. Ashmore Reef is 350 km north-west of the Kimberley mainland. The Operations Officer network plan is Figure 32.

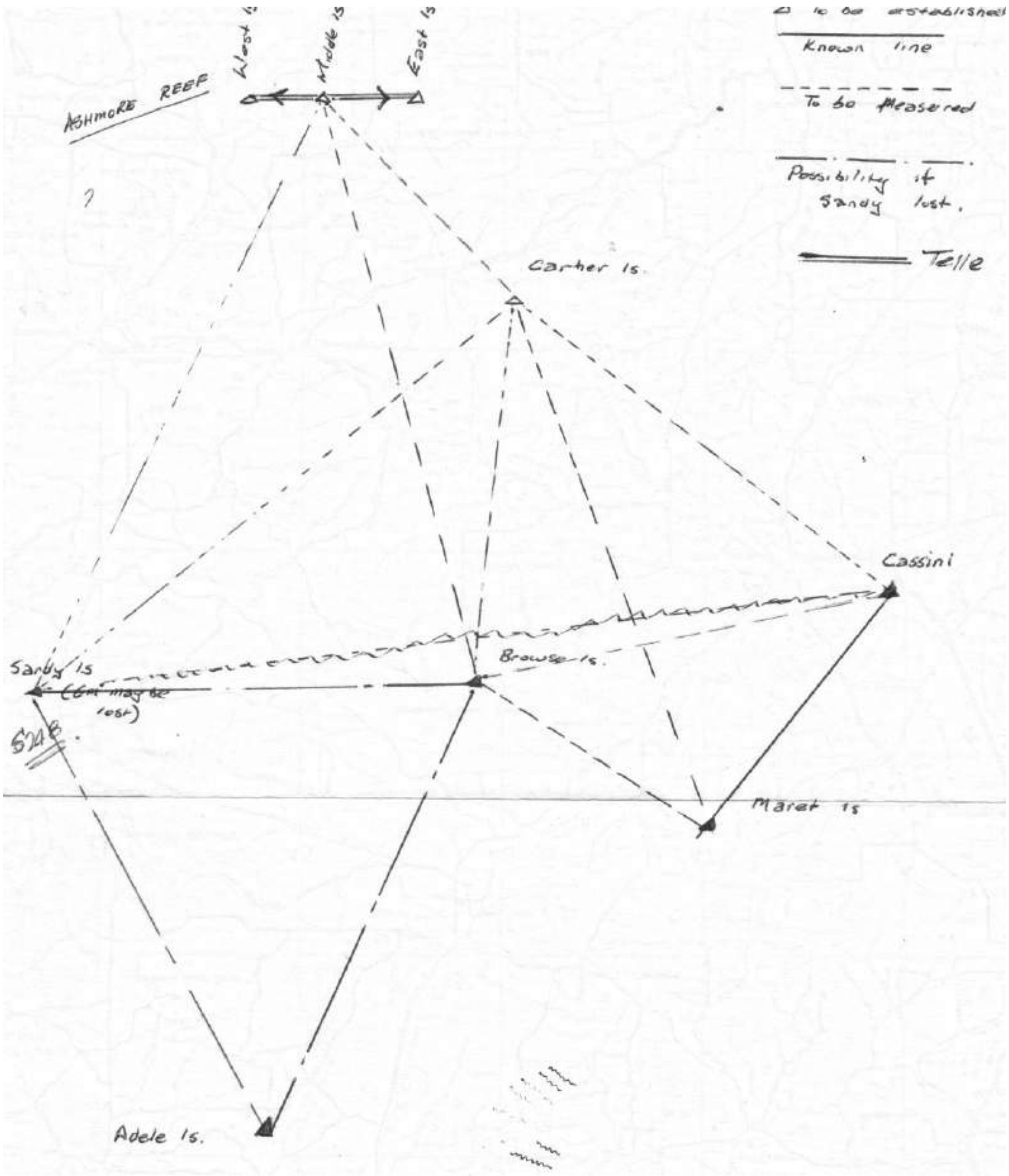


Figure 32. Plan (not to scale) for extending the Australian Geodetic Datum 1966 to Ashmore Reef by Aerodist. Ashmore is about 350 km north-west of the Kimberley mainland around existing survey station Cassini. Aerodist line Ashmore to Browse Is 209 km (courtesy Noel Sproles)

Figure 32a. The 1971 Aerodist Computing Sect 5 Fd Svy Sqn at Main Base Kalumburu, the Kimberley WA. From the left: Sappers Phil Bray, Rodney Moss, Peter Colwell, Tim Allanson, Ken McKinnon, front Sapper Lindsay Clark[53] *(Photo: Faces of the Corps – John Mobbs)*

Primary higher order survey stations were often occupied for many weeks at a time while many *Aerodist* lines to mapping control points were observed:[54]

> *I was a young Sapper on that Kimberley operation. I had many different roles during the operation but my main one was using and operating aerodist. In late August 1971 I was paired with a Corporal (at least I think that was his rank?) and positioned on Bigge Island to conduct aerodist operations from an existing Trig station.*
>
> *We spent the first week or so clearing vegetation to gain the appropriate elevations and clearances (not too many environmental concerns or restrictions then!!) and only occasionally had the energy or time to venture the long trek from the top of the Island to a beach where we could grab a quick swim to freshen up. Dodging the sharks close to the shore was an interesting experience but we did manage to survive. We were resupplied about once a week from the forward base at Mitchell Plateau which was always very welcomed.*
>
> *As a young Sapper I was only allowed to use the chainsaw on a few occasions and unfortunately the corporal (I have forgotten his name?) did have an accident with the chainsaw and had to be sent back to base camp for treatment.*
>
> *As there was an oversupply of competent Corporals, Corporal Biorac was sent to continue and supervise our operations on the Island.*
>
> *To occupy ourselves of an evening, Peter and I played many many games of euchre and fortunately we only bet small change and pocket money to keep things interesting. If I remember correctly, I had to take out a loan on return to Perth to pay my debt! - only joking, ...but Peter certainly did*

[53] Names provided by Sapper Phil Bray (later Staff-Sergeant)
[54] Sapper Mike Venn (later Sergeant) 5 Fd Svy Sqn

teach me a thing or two about the game and as a result I did become a very good "500" player which was the game of choice at 5 Field Survey Squadron for many years in the early 1970's.

Our time on Bigge Island went well and after 42 days, operations concluded in the first week of October. I remember the helicopter trip from Bigge Island to Mitchell Plateau very well because of two memorable reasons. Early October was my 21st birthday and on landing at forward base Mitchell Plateau we found the camp had just been destroyed by a bushfire. The only welcome news was that a Caribou had landed and had about a dozen or so letters and 21st birthday cards waiting for me.

That night of my birthday, those at the base camp were invited to the nearby mining camp for an evening meal and a cold drink. The only thing I remember about the evening at the mining camp was a great meal that we didn't have to cook and didn't come out of a ration pack. Perhaps the mining camp management were friendly to us because one of their employees was responsible for the bushfire! The only drinks I remember having were of the soft variety but because they were icy cold I thoroughly enjoyed them - no complaints.

On 15 September 1971 a hangar fire at Union Air, Toowoomba, QLD, destroyed five aircraft including DH Leopard Moth VH-AJN, Beech Baron VH-RUU, and Beech Queen Air VH-EZM.[55] EZM had been fitted with an *Aerodist* Master set but luckily the equipment had been removed to be temporarily stored in a corner of the hangar. The *Aerodist* survived the fire. I am not sure whether this was a spare MRC2 Master set or the new yet to be trialled and accepted-into-service MRB3/201 set.[56]

1972

Another Union Air Queen Air VH-RUU[57] was the *Aerodist* MRC2 Master aircraft attached to 2 Fd Svy Sqn (Sydney - Major Ted Laker MBE) on Operation Gading 2 in southern Sumatra, Indonesia from early-May to 27 August 1972. Forty-six new survey stations were established from 191 Aerodist lines completed.

Figure 33. Beechcraft A65-8200 Queen Air VH-RUU with extended nose meteorological probe (red-white stripped) and Aerodist MRC2 under-wing antenna pods in May 1973. Possibly in-transit to Operation Gading 3 Sumatra, Indonesia. (Photo: Mike Madden)

[55] https://aviation-safety.net/wikibase/18300
[56] Kev Kennedy
[57] VH-RUU was the registration of the Beech Baron destroyed in the Union Air hangar fire 15 Sep 71.

Until 1972 helicopter support for survey operations was either Army Sioux light observation helicopters or civilian charter. After No. 9 Squadron (9SQN) RAAF (Iroquois helicopters) withdrew with the Australian force from Vietnam in December 1971, RAAF was then in a position to provide the larger UH-1H for tasks of transport and resupply of survey teams. The Army Sioux light observation helicopter had a load carrying capacity of up to about 500 pounds. One *Aerodist* team including two people weighed up to 1,500 pounds. The UH-1H was capable of carrying at least three times that of the smaller helicopter and could also winch personnel and stores into difficult locations. In TPNG, and Indonesia, survey operations were something which Army and RAAF pilots relished as the flying conditions of weather and terrain, often operating near the limits of aircraft performance especially around small and difficult high altitude landing sites, was a sought after training experience unlike normal Australian conditions.   The RAAF history website says: *'A major though little-known role for Iroquois detachments has been survey operations. Much work has been carried out over the past quarter century in mapping the remote areas of Papua New Guinea and Indonesia.'*   No. 5 Squadron (Iroquois UH-1H) was the first RAAF helicopter unit to support *Aerodist* surveys (2 Fd Svy Sqn - Operation Gading 2) in southern- Sumatra in 1972. Soon after, they deployed to TPNG in support of 4 Fd Svy Sqn (Adelaide) using *Aerodist* on Operation Wine Glass. 9SQN followed on supporting 4 Fd Svy Sqn on *Aerodist* surveys in PNG in 1973 and 1974.

In 1972, operating the Iroquois in TPNG where air temperature was often higher than standard temperature at high altitude, was new to most of the pilots. This was especially so for challenging tasks of hovering, landing and take-off from small high altitude survey station landing sites with varying weights and sometimes untested pads with close rain forest obstacles and rapidly changing local weather conditions. Degraded aircraft performance in these conditions was not in the flight manuals. For the previous six years 9SQN's role was to support the Australian Task Force, Vietnam, where flying operations were mainly over low elevation terrain.   From one of 9SQN pilots [58](written in 2021):

> *"I believe it was from here (Morehead) that A2-383 (Iroquois) later (1974) came to grief on Mt Bosavi (elevation 8,500 ft), with high density altitude again taking its toll. It was interesting to note a spot height on the WAC chart at the time (southwest of Mt Bosavi) was accurate to + or – 1,500'. The Iroquois was good for sea level operations but we lacked the data for high altitude ops. This deficiency was later rectified with the introduction of a "Prayer Wheel" calculator from Aircraft Research and Development Unit, but much too late for PNG work………PNG flying was very exciting and nothing like I had ever experienced before. Extremely rugged and hostile country, with a chequered history of aircraft crashes even to this day. It was only later, when I arrived back in Australia in October, that 9SQN in their wisdom scheduled me for a Jungle Survival Course. On one trip in the Strickland George we came across head-hunters*

[58] https://raafdocumentary.com/trevormoxham/ (2021) This document includes many photographs of Iroquois aircraft on *Aerodist* survey operations in PNG. Included in these photographs are the three Iroquois which crashed beyond repair on survey operations in PNG and Irian Jaya (now West Papua) Indonesia. A2-383 crashed and was later demolished in-situ on Mt Bosavi in 1974 (supporting 4 Fd Svy Sqn - Aerodist). A2-379 crashed killing the aircraft captain (FLTLT Ralph Taylor 9SQN) on impact and seriously injuring four near Wamena, Irian Jaya, Indonesia on survey Operation Cenderawasih 1977 (supporting 2 Fd Svy Sqn – Doppler satellite survey). A2-772 crashed and was destroyed by fire, seriously injuring two of the five on board at survey station Hiran Nandan, New Britain in 1973 (supporting 8 Fd Svy Sqn – 1st Order traverse survey).

who had never seen a white man before. A story has it that a local native managed to put a spear through the bottom of an aircraft, trying to bring the "Big Bird" down. The scenery in the highland was spectacular with giant unmarked limestone sink holes, and rivers gushing from the side of steep hills originating from underground streams."

Footnote 58 includes photographs of A2-383 wreckage.

As a result of a Board of Inquiry into the accident, Chief of the Air Staff ordered that the aircraft captain of A2-383 be Court Martialled for 'negligent conduct in operation of the aircraft'. The Flight Lieutenant pilot opted for the charge to be summarily heard by a RAAF officer of Air Rank (Air Commodore or Air Vice Marshall). He either pleaded guilty or was found guilty being awarded a 'severe reprimand'.[59]

Rob Langley[60] recalls this incident:

The Iroquois was positioning an Aerodist Remote Party on Mt Bosavi when that incident occurred.

After a difficult landing (apparently from the effects of high density altitude) the chopper slid off the helipad down the side of the mountain. Rob doesn't recall who the initial Surveyors were in that remote party and how they and the RAAF crew got off Bosavi after the crash.

Rob and Craftsman Tony Pardey (Royal Australian Electrical and Mechanical Engineers Electronics Technician - Aerodist) were taken to Bosavi Mission airstrip from main base at Goroka. From there they walked up to the station (Mt Bosavi is nearly 6,000 feet above the elevation of the mission). They were tasked to check the helipad for safety and repair it. Then retrieve the Aerodist remote from the crashed chopper and check its serviceability.

Once on top of Bosavi they climbed down the mountain side to the Iroquois wreck to retrieve the survey equipment and other items as instructed which included the pilot's survival weapon. He particularly remembers that item as the pilot was very concerned about its recovery. Rob recalls that the helipad required very little reparation.

Rob and Tony remained on Mt Bosavi and became the insitu Remote Aerodist party until the line measuring was completed.

While they were on site the RAAF sent in an air investigation team which remained there for a couple of days.

Rob remembers that a Bosavi Wooly Rat became a pet whilst on station. Why he remembers the rat is because in the 1990's a British Scientific Expedition went into the Bosavi volcano crater, set up a research base and discovered a whole new ecological system. I personally recall seeing this programme on Foxtel many years ago.

1973

The first two Operations Gading in southern-Sumatra, Indonesia were conducted by 2 Fd Svy Sqn (Sydney). In 1973, the area of operations changed to northern-Sumatra and 5 Fd Svy Sqn (Perth - Major Hugh Taylor) was assigned the task using *Aerodist* MRC2 mounted in VH-RUU from early-May to late-August 1973. Main base was at Medan. The equipment was ageing but to the credit of the system maintenance technicians and operators, 149 lines were completed

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[59] Albatross to Black Hawk Part 2 | RAAF Documentaries (raafdocumentary.com)

[60] Corporal Rob Langley, 4 Fd Svy Sqn, via an email from Stevo Hinic

establishing thirty survey stations. This work included lines across The Straits of Malacca to connect the survey networks of Indonesia and Malaysia.[61]

On completion of Operation Gading 3 and another twelve like it over the previous ten years, the *Aerodist* MRC2 was assessed to be beyond economic repair, then being retired and offered for disposal.

Figure 34. 1973 Operation Gading 3 – Sumatra, Indonesia. 5 Fd Svy Sqn topographic surveyors, back row from left: Corporal Peter Colwell, Corporal Phil Bray, Corporal Don Musgrave, Sapper Mick Venn, Sapper Brett van Leeuwen. front row from left: Corporal Phil Boyle, Corporal Cliff Webb, Sapper Rod (Bim) Bechaz (Photo: Phil Bray)

In 1974 and 1975, 5 Fd Svy Sqn (Perth - Major Alex Laing) used Transit Doppler satellite geodetic receivers AN/PRR-14 Geoceivers on Operations Gading 4 and 5 to establish a geodetic framework which went on to define the Indonesian Datum 1974 with a Doppler satellite based coordinate set at Padang. All of the Sumatra *Aerodist* lines were included in an extensive network adjustment (VARYCORD) prepared and computed by the Svy Sect DSVY AHQ (Canberra) of Indonesian, Dutch, Australian, Japanese, British and Malaysian geodetic surveys over many years and connected to the Indonesian Datum 1974.

Aerodist MRB3/201

The Tellurometer development in 1970, and the successor to the *Aerodist* MRC2 was the MRB201 being a variant of the MRB2 *Hydrodist*. MRB201 was adapted to produce the second generation *Aerodist* known as MRB3/201, or MRB 201/301 also known by the Survey Corps simply as the MRB3 or MRB301. It was computer assisted to reduce observations to spheroidal distances in near real-time. RA Svy was equipped with what was believed to be the only MRB3/201 in the world in 1972, after three months of trials at School of Military Survey,

[61] Telephone conversation Author – Captain Peter Bates-Brownsword (later Lieutenant-Colonel) who was Op Gading 3 Operations Officer

Bonegilla VIC. The Canadians commenced development of a computer assisted MRC2 in the late-1960s but I don't know if that progressed to an operational system. The trials were assisted full-time on site by Mr Andreas Hiddas a hardware and software engineer from the system developer and supplier Tellurometer Division of Plessey UK. This was a key aspect as the system was the only one of its kind and hardware and software modifications were made on site as the system developed.

Like the *Aerodist* MRC2, the purpose of the Corps' MRB3/201 was to measure distances between ground stations to form trilateration networks for horizontal survey control primarily for 1:100,000 topographic mapping.

Figure 35. Queen Air VH-FWG with extended meteorological probe but without Aerodist antenna pods (mounts under the wings) at Darwin 1971. Note the Royal Australian Survey Corps badge and name to the right of the main door behind the wing. Pilot may be Kelvin Grady (Union Air). (Photo: Phil Vabre) http://www.adf-gallery.com.au/gallery/Queenair-VH-FWG/Queen_Air_VH_FWG_at_Darwin_in_1971_Photo_Phil_Vabre

Figure 35a. 1972- Aerodist MRB3/201 Master system installed in Queen Air VH-FWG. Pilot – Kev Sullivan (Union Air), operator Corporal Peter Jensen (1 Fd Svy Sqn). The ASR33 teletype with punch paper tape reader is on top of the mini-computer (DEC PDP8/e), the three Tellurometer MRB3/201 measuring units and antenna control boxes are on top of the meteorological equipment, HF radio, quartz clock, thermal paper printer, nixie tubes displays of meteorological data, magnetic tape recorder and various power supplies and switch boxes. (Photo: Author)

Figure 36. ASR33 teletype on top of the DEC PDP8/e minicomputer – 8K 12bit words of core memory expanded to 16K words in 1975. A radiation shield around the computer protected it from electronic interference from any of the transmitting devices and vice-versa. The computer program was loaded via a punch paper tape reader on the left side of the teletype or from the half-inch magnetic tape reader/recorder using the front panel switches on the PDP8/e using binary coded octal register addresses. The Aerodist measures reduced to spheroidal distance were printed on the teletype in near real time after each line-crossing (Photo: Author)

Figure 37. Aerodist MRB3/201 Remote under the survey beacon quadrapod at Station 19 in the grounds of School of Military Survey, Bonegilla VIC on the corner of Bonegilla Road and Kookaburra Point Road (opposite the Kangaroo store) during the equipment acceptance trials March 1972. A clock-work aspiration psychrometer (dry and wet temperature) is hanging on the survey beacon quadrapod and a Baromec (digital dial) barometer is on the ground. The backpack is for the Remote instrument. (Photo: Author)

Equipment configuration is outlined below and acceptance trial results from late 1971 and 1972 are in Table 2[62].

Measuring sub-system

The MRB3/201 was identical to the MRB201 with the exception of a range of 'plug in' modules, for specific applications, in the front of each of three identical Master instruments. Unlike the MRC2 the MRB3/201 Master instruments (Figure 35a) were basically the same as the Remote instruments (Figure 37).

The microwave carrier wave frequency of the MRB3/201 was 3,000 MHz. The resolution of phase measurement was 0.1 metres and as phase could be read to 1 part in 1000 the fine pattern wavelength was 100 metres from a modulation frequency of 1.5 MHz. The number of these 100 metre wavelengths between Master and Remote was ambiguous so a further five related modulation frequencies were used to solve the coarse distances. The limit of accuracy was not

[62] AG Marshall, Development of the MRB 201/301, Tellurometer Division of Plessey UK, International Hydrographic Review

from the measuring instruments but from the inability to determine the true atmospheric refractive index along the entire line and hence the velocity of wave propagation.

The optimum antenna beamwidth for direct phase measurement was 25 degrees. This meant that both Master and Remote antennas needed to be pointed accurately and at times direction finding was required by both Master and Remote for the Master to receive a strong measuring signal.

The major 'plug in' module was an analogue to digital converter (ADC) whose primary function was to convert the analogue slant range pattern phase information to binary code decimal form for download to the on-board computer and a half-inch eight track reel-to-reel magnetic tape and in metres to output to a three-inch wide thermal paper printer. Other facilities built into the ADC included a cycle counter to indicate the time at which each range reading was taken and an event marker triggered by an external output, such as a camera shutter which can record the time of occurrence of an event such as an aerial photograph with an accuracy of nearly 1 millisecond.

Another key 'plug-in' module on each of the three identical Master instruments (known simply as 1, 2 and 3) was the Programmer Interface Unit (PIU) which plugged into the socket normally occupied by the manual dial readout. The PIU controlled rapid sequential switching of the patterns. The Fine, or A Pattern, was interspaced between each coarse measurement in order to obtain the maximum resolution and is therefore available every alternate 250 millisecond period. PIU timing was controlled by a crystal clock which was also used to provide sequential readings on each pattern which were integrated over a 200 millisecond period. There was a dead period between patterns of 50 milliseconds. The patterns were switched in the following sequence: *A, A— , A, D, A, C, A, B,* which gives a total measuring time of two seconds, after which the next sequence automatically begins. A facility known as the "A Pattern Override" was also incorporated which enables continuous "Pattern readings" to be obtained. A further function of the clock was to time the Pattern Selection programme via the Programmer Interface Unit. The system was designed to operate at high speeds and this, combined with the fact that all pattern information was not simultaneously available meant that the coarse pattern information had to be adjusted according to the rate of change of range, or slant range velocity, before being compared with the fine (A) information. Four external 6-digit data inputs were also included to enable external data such as meteorological information (atmospheric pressure, dry and wet temperature) to be included in the serial or parallel outputs of the ADC for output to the recording sub-systems.

Recording and computing sub-system

All information provided by the ADC was available either in parallel or 2-digit serial form. The parallel data fed the thermal printer unit providing on-the-spot measured distance information and the serial output fed the on-line computer (Digital Equipment Corporation PDP8/e – Figure 36) and magnetic tape recorder. In its simplest form the system could operate with only the thermal printer recording the measured slant ranges in metres and the Master meteorologic data. The data could then be processed by hand or by base computer in order to obtain full range information. One potential source of error with this system was introduced by the fact that A pattern information was only available every 250 or 500 milliseconds and not continuously, whereas the event marker could be timed to the nearest millisecond. In practice, however, it was found that interpolation between successive A readings was very accurate as can be seen from the following acceptance trials results.

The PDP8/e was programmed to obtain the slant range velocity from the rate of change of the A pattern. A predictive Kalman filter enabled ranges to be predicted before they actually occurred. In this way, readings which varied by more than, say, two standard deviations from the predicted range could be rejected thereby improving the noise performance of the system. With inputs of accurate aircraft meteorologic data via the ADC, and remote station heights and remote meteorologic data input by the operator via the teletype, the computer solved the spheroidal distance between the Remote stations in near real time after the 'line-crossing', by correcting the approximate slant range minimum sum for: least-squares estimation of at least 21 terms (balanced 10 either side) of slant range sums to compute the minimum slant range sum; refractive index; aircraft height; Remote station heights and chord-to-arc. To be able to compute this the Remote station heights were needed. In many cases this part of the survey was done by helicopter barometric heighting in an earlier phase of the operation. This aspect was of course essential to the *Aerodist* operation but is not included in any detail in this story.

The power supply for the computer, teletype and magnetic tape was 110VAC provided by an inverter (from 28VDC aircraft power) in the aircraft's nose luggage compartment.

If the computer was not working, the slant range and aircraft meteorologic data recorded on the thermal printer was reduced to survey station-to-station spheroidal distances in the field by a computations section using Lincross 2 and 3 computer programs on a HP9100B programmable calculator/computer. This manual computing time was about 45 minutes for each line and was normally done in the evening after the days flying by a Master operator on respite rest.

The next step was to compute preliminary coordinates (for VARYCORD adjustment) of each new station from distances in two triangles into the new station. This could be done later.

Meteorogical sub-system

The precision barometer, fed with air from a long probe more than 2 metres long in front of the aircraft nose to avoid aircraft induced affects, and dry and wet thermometer sensors fed into the Tellurometer ADC for output to the various recording and computing devices to compute the refractive index for atmospheric refraction correction and aircraft height for spheroidal distance. Nixie tube displays of aircraft height, atmospheric pressure, dry and wet temperatures were available for manual recording and real-time logic checks of lapse rates of atmospheric pressure (about -30 millibars per 1,000 feet of altitude gain) and air temperature (about -2degC per 1,000 feet of altitude gain).

Improved systems for determining refractive index and aircraft height were investigated later by School of Military Survey. See notes by then Major Hebblethwaite, page 82.

Master installation

Unlike the MRC2 which was mounted across the passenger cabin of the Queen Air, such that the operators sat on the regular, but not very comfortable fold down seats, looking forward, the MRB3 equipment was mounted in long frames on the left side seat rails along the length of the cabin. This meant that the two man crew (tellurometer and computer operator) had to sit sideways on the fold down seats. Not very comfortable for sorties of up to five hours. Operator comfort was definitely not on the design requirements list.

Maintenance

For the first few years of the MRC2, RAEME personnel for *Aerodist* maintenance were posted to AHQ Survey Regiment as that unit's Topographic Squadron was a major user unit. This changed for the MRB3/201 when a Survey Support Section, Sydney Workshop Company (RAEME) was established. In 1972, Lieutenant Wally Rotow was the officer in charge of that section attached to 4 Field Survey Squadron operating *Aerodist* in Goroka, TPNG. In 2009, Wally (then Lieutenant-Colonel) helped to compile the Survey Corps Nominal Roll by running computer records searches and converting microfiche records to computer records at Central Army Records Office.

1971-72 Acceptance Trials including training

In November 1971, Queenair VH-FWG was fitted with the *Aerodist* MRB3/201 Master equipment for the acceptance trials and operator training at School of Military Survey, Bonegilla VIC (based at Albury airport NSW) from December 1971 to March 1972.

The *Aerodist* distances (line-crossing method), compared with the known geodetic distances, from the early part of the trial and reported by the Tellurometer Division of Plessey UK in the International Hydrographic Review are summarised below[63].

Table 2. Line Measured – Boomanoomana (near Yarrawonga NSW) to Kookaburra Point (Bonegilla VIC), known spheroidal distance 104 486.2m

Date	No. Line Xings	Mean *Aerodist* spheroidal distanc (m)	Error (m) Known spheroidal dist – *Aerodist* spheroidal dist	Range (m) of line crossing spheroidal distances
1 Dec 71	7	104 486.1	+0.1 (1:1,000,000 or 1ppm)	4.9
2 Dec 71	3	104 487.0	-0.8 (1:130,000 or 7 ppm))	2.2
3 Dec 71	7	104 486.0	+0.2 (1:500,000 or 2 ppm)	1.9
4 Dec 71	7	104 486.8	-0.6 (1:170,000 or 6 ppm)	3.6
6 Dec 71	4	104 487.5	-1.3 (1:80,000 or 12 ppm)	1.4
Mean	Total 28 Xings	104 486.5	-0.3 (1:300,000 or 3 ppm)	

Three other lines were also measured, the results being tabulated in the same form:

[63] AG Marshall, Development of the MRB 201/301, Tellurometer Division of Plessey UK, International Hydrographic Review

Line	No. Line Xings	Known spheroidal distance (m)	Mean *Aerodist* spheroidal distance (m)	Error (m) Known spheroidal dist – *Aerodist* spheroidal dist	Range (m) of line crossing spheroidal distances
Loka NSW– Kookaburra Pt VIC	10	30 458.3	30 458.9	-0.6 (1:50,000 or 20 ppm)	4.6
Kookaburra Pt VIC – Mt Benambra VIC	8	63 675.5	63 677.5	-2.0 (1:30,000 or 30 ppm) (see note)	9
Mt Benambra VIC – Loka NSW	12	84 478. 1	84 478.6	-0.5 (1:160,000 or 7 ppm)	3.8

Note: *The line Mt Benambra to Kookaburra Point is over Lake Hume with consequent signal reflection off the water (ground swing).*

A distance of 203 km was also measured from Bendigo to Kookaburra Point with a mean error (difference from known geodetic distance) of 0.8 metres (4 ppm or 1:250,000) over 6 crossings.

The 'errors' being the differences between the *Aerodist* MRB3/201 reduced spheroidal distances and the known adjusted geodetic distances indicate the 'accuracy' of the whole system: Master tellurometer measurement, master meteorologic and computing sub-systems; Remotes and meteorologic systems; operating procedures. These line accuracies showed the system capability in ideal measuring conditions especially with stable and consistent air masses. The mean difference of about 10 ppm (1:100,000) was consistent with the Canadian MRC2 experience observed to a higher specification.

Estimated accuracies under operational conditions in Gulf of Carpentaria and Cape York in the dry season with reasonable weather, are summarised under the Operation Sandy Hill 1975 section.

Stories from the acceptance trials and training at School of Military Survey[64]:

> *On a Sunday morning towards the end of the acceptance trials and the Aerodist Operator Course 1/72, the aircraft was taxiing for take-off at Albury airport when the cabin filled with the 'dreaded electric/plastic burning smell'. The pilot immediately popped the Aerodist circuit breakers, stopped quickly, then shut all aircraft systems down. The smell was strongest in the cockpit and as nothing there seemed to be burning we suspected the Aerodist 28VDC to 110VAC inverter (for the PDP8/e computer/teletype etc) in the nose luggage compartment. A quick exit but we couldn't see any smoke. The nose compartment door wasn't hot to-touch so with fire extinguisher in hand we gingerly opened the door. There was no fire, just that terrible brown smell. We taxied back to the hangar where the aircraft engineer, the Aerodist hardware/software engineer and Major NRJ (John) Hillier[65] Staff Officer Grade 2 (Equipment) DSVY AHQ were surprised to see us return. The two engineers soon confirmed that the problem was the inverter. Being a Sunday and apparently no way of getting needed spares, Major Hillier decided to stand-down the Remote teams awaiting the days' work. Meanwhile the engineers 'found a way' into the hangar engineer*

[64] Author
[65] Major John Hillier (later Colonel DSVY AHQ)

section and 'borrowed' some parts for a temporary repair. A radio check raised only one Remote team. It was not Loka which was one of the Remotes needed for that days' trials. The Major told me to pre-flight and take-off for the line between Loka and the Remote which replied to the radio check. He then headed off in his Holden station wagon staff car not saying anything else. By the time we got to our 'line crossing' area the Loka Remote called on the radio. The Major had guessed correctly that the Loka team had taken the stand-down opportunity to enjoy a Sunday pub lunch at the nearby Gerogery Hotel. What a surprise when NRJ burst through the back bar doors. In those days the front bar doors were shut on Sundays as trading was for 'bona fide' travellers only.

Not everyone was suited to be a Master Operator (Warrant Officer or Non Commissioned Officer) or Operations Manager (Commissioned Officer). A car with two students heading to School of Military Survey for an Aerodist course had the misfortune of hitting a kangaroo resulting in a damaged radiator which had to be replaced. What was greater misfortune for the officer involved was that he decided that being a few days late for the course was okay and that the School needn't be informed. The Commanding Officer/Chief Instructor Lieutenant-Colonel Clem Sargent did not see it that way. And he was not amused on hearing the story that a student nearly caused a mid-air disaster when he was the tapping the ash from his cigarette into the printer thermal paper bin recording the raw measurement data. Luckily the paper smouldered and did not ignite.

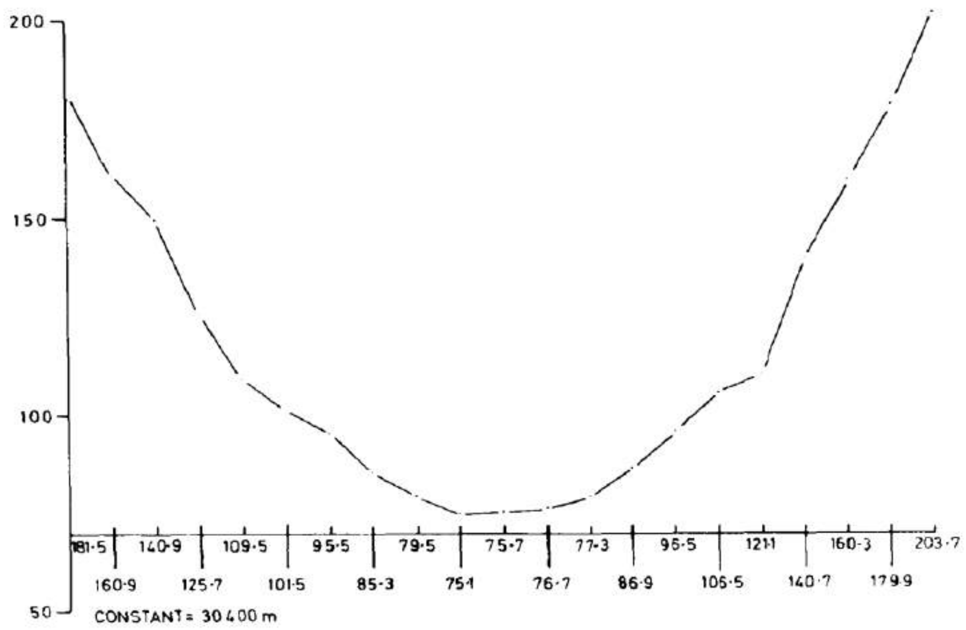


Fig. 3
Line 9   Stn 1, Kookaburra Stn 2, Loca   Date 18.1.72

Figure 3 above refers to a single crossing performed on the Kookaburra/Loca line. The vertical scale corresponds to slope distance added to the 30 400 m constant. The horizontal scale shows actual range readings taken at 2-second intervals during flight. The minimum slope distance from the graph is 30 475.1 m.

Figure 38. Plot from the 21 dynamic slant range sums (10 either side of the approximate minimum sum) used in the least squares estimation (parabola fit) of the minimum sum slant range[66]

[66] AG Marshall, Development of the MRB 201/301, Tellurometer Division of Plessey UK, International Hydrographic Review

Aerodist MRB3/201 operations

1972

The first deployment of the *Aerodist* MRB3/201 was Project A6 (Gulf of Carpentaria scale 1:100,000 topographic mapping) based at Normanton QLD and conducted by 1 Fd Svy Sqn (Brisbane - Captain Charlie Watson[67]) from 4 April to 18 August 1972 immediately after the acceptance trials.

The *Aerodist* task from 24 April to 21 July was to establish horizontal control for scale 1:100,000 topographic mapping across eleven 1:250,000 blocks between 16-20degS and 138-144degE (Westmoreland, Burketown, Lawn Hill, Donors Hill, Croydon, Georgetown, Camooweal, Dobbyn, Millungerra, Gilberton) see the control diagrams following with the 1:250,000 map names in the corners. The Master computer sub-system worked intermittently which slowed measuring progress such that only 9 of the 11 blocks were completed. Unfortunately that also meant that the lines measured each day had to be computed on the HP9100B programmable calculator/computer taking up to four to five hours depending on the number of lines measured. The system was committed to TPNG in late July so the two blocks not surveyed, Croydon and Millungerra, were postponed to be done later (completed in 1975). A total of 28 primary lines (6 line-crossings per line) to existing high order traverse stations or primary new stations in map sheets corners, with at 6 lines from high order stations or other primary stations, and 128 secondary lines (4 line-crossings per line) established 43 new stations, with 4 lines from primary stations, at locations chosen for photogrammetric triangulation of mapping air photography.

Army Sioux helicopters flew 88 barometric heighting traverses (photo Figure 4) to establish 258 height points including the new Remote stations. Knowing the height of the Remote stations was needed so that the spheroidal distances could be computed in the aircraft in near real-time. Reconnaissance (selection of stations for photogrammetric control), clearing and station marking teams operated in-front of the *Aerodist* Remote teams and placed line bearing pickets to adjacent stations from the trilateration control plan (Figure 40).[68]

This was a large mainly Army operation based at Normanton airport. Forward operating bases were established at Gregory Downs, Kamileroi, Burketown and Croydon. Main logistic elements comprised:[69]

- 10 officers and 60 other ranks (all Corps)
- Two convoys of 29 vehicles, including a Royal Australian Army Service Corps Transport platoon, from Brisbane to Normanton each taking seven days
- Fourteen ¾ ton Landrovers with trailers, five 5 ton trucks (six wheel drive), one 1¼ ton general duties truck, one 3 ton truck (four wheel drive) Telecommunications maintenance variant
- Three Army Sioux light observation helicopters for barometric heighting and Aerodist Remote party positioning and resupply – allocated 400 hours / actual 314 hours
- One Army Pilatus Porter fitted with air camera for identification photography – allocated 600 hours / actual 619 hours

[67] Captain Charlie Watson RFD (later Major) was the only Captain to command an Aerodist operation
[68] 1 Fd Svy Sqn Project A6 Report 1972 (courtesy of Charlie Watson)
[69] ibid

- One Queen Air (Aerodist MRB3/201) – allocated 250 hours / actual 349 hours
- Withdrawl to Brisbane was by road/rail via Townsville, road via Townsville, three RAAF C130 Hercules from Normanton to Brisbane
- One RAAF Caribou from Normanton to Goroka TPNG with the *Aerodist* Master and Remote equipments

Comments from Officer Commanding (Captain Charlie Watson):

After the 1972 field season I was asked to give a presentation to the Aust Army Aviation Corps staff course at Amberley explaining Survey Corps Operations. Eg What are control points? How many do we need? Where should they be positioned? It proved beneficial to both sides. I don't know if such cooperation continued, even after Aerodist was finished.

When we had drawn up the layout of the survey control points, we submitted the plan to the Survey Regiment for their comments from the perspective of photogrammetric aerotriangulation as they would be responsible for that activity. This was in response to their criticism of the layouts of previous operations as voiced at the annual Director of Survey Planning Conference.

Much effort was needed in the detailed planning, particularly on the preparation of load tables and Petrol Oils Lubricants (POL) usage estimates. Travelling by RAAF air, particularly, every item had to be dimensioned, weighed and numbered and entered in a manifest. There were many smaller lots.

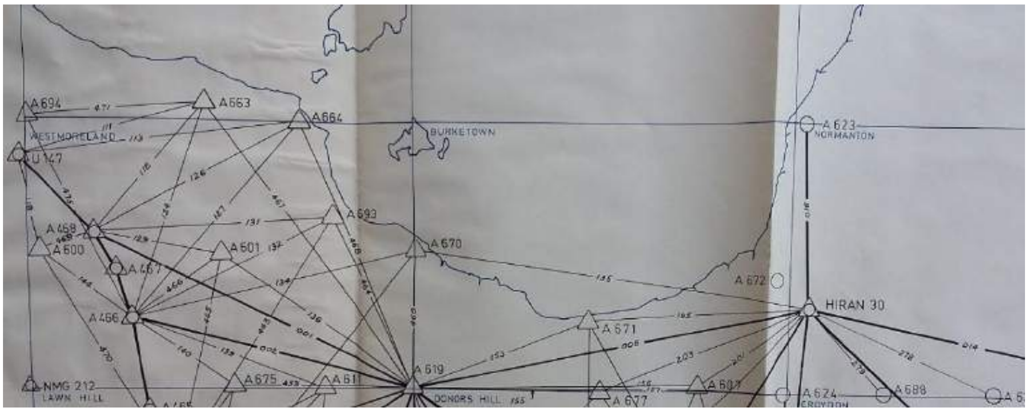
POL was required in quite large quantities and some had to be prepositioned, either by contractor, road vehicle or air. Forward base required 15-20 drums of fuel (mostly Avgas) daily. In 1972 this was transported by unit 5 Ton trucks. In 1973 a RAAF Caribou aircraft did most of this work – ten 44 gallon drums per sortie. In 1972 the estimated requirement including spoilage was for: Motor Transport (MT) Spirit – 332 drums, Aviation Gasoline (Avgas for Army Sioux helicopters and Aerodist Queen Air) – 562 drums, and Aviation Turbine (Avtur for Army Pilatus Porter) – 350 drums. Having delivered the fuel on site the drums had to be recovered where possible. Bob Skitch (1975 Op Sandy Hill) has explained the poor quality of the drums supplied by the agent. Glossy on the outside and rusty on the inside. I drew up a large table on A3 size paper showing the POL requirements. No spreadsheets in those days.

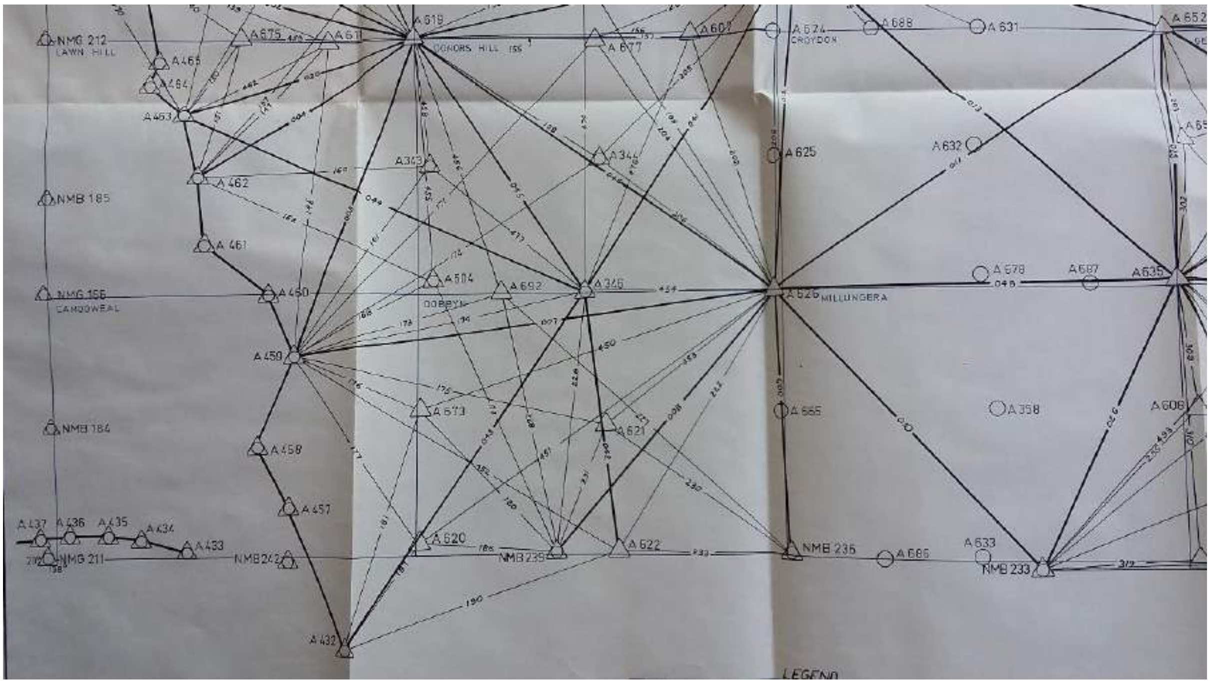
I must agree with Bob Skitch about appointing a senior non-Survey Corps officer as the detachment Commanding Officer. Such a non-survey officer would not be able to keep up with the amount of detailed planning, technical matters in particular.

Figure 39. 1972 Project A6 - Aerodist MRB3/201 Remote at HIRAN 30 Eccentric, Normanton QLD, June 1972. The beach umbrella is shading the clockwork aspiration psychrometer (dry and dew point thermometers) and the Baromec digital dial readout barometer (on the boxes). The radio on the ground with the rod antenna next to the 'chair- millionaire' is a HF radio AN/PRC-F1 for communication with the Aerodist aircraft and other stations on the survey radio network. The vehicle is a Land Rover Series 2A Topographical Survey variant, 109 inch long wheel base. (Photo: Author)

Figure 40. 1972 Project A6, Army Sioux helicopter returning to Forward Operating Base Westmoreland after flying a barometric heighting traverse near the Northern Territory border (Photo: Charlie Watson)

The *Aerodist* control diagram in three parts is Figure 41. The 1:250,000 photogrammetric blocks are the named rectangles. The Wellesley Islands group in the southern Gulf of Carpentaria were not included in the 1972 operation as necessary RAN and RAAF support was not available at the time[70]. That island survey area was completed on Op Sandy Hill 1975.





[70] Charlie Watson

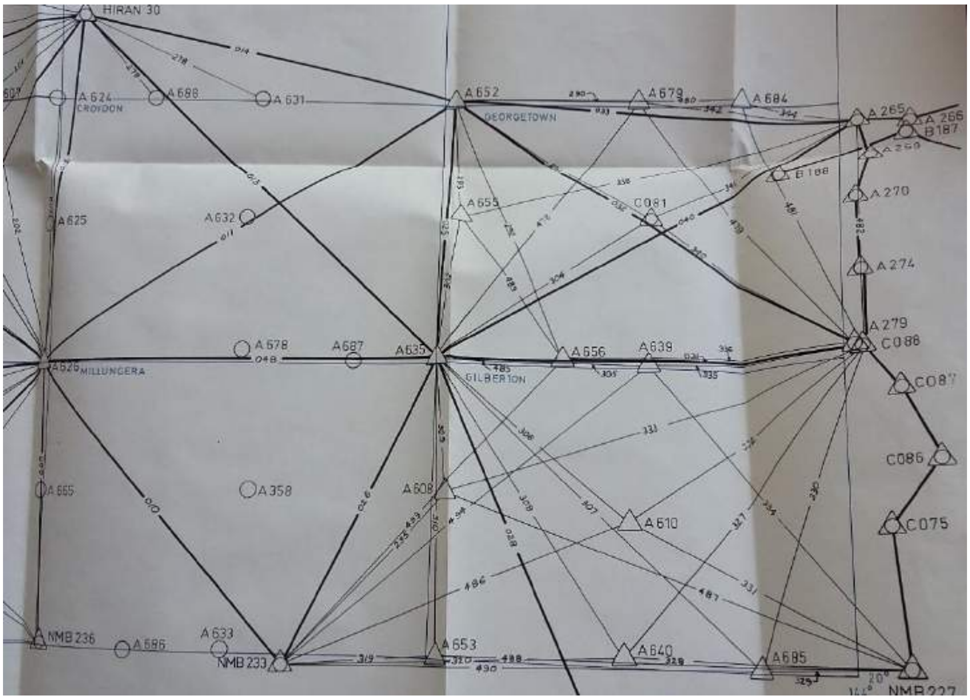


Figure 41. 1972 Project A6 network diagrams(3) of existing surveys (triangle with circle inside), completed new stations by Aerodist (triangle), measured Aerodist primary line (heavy line), measured Aerodist secondary line (light line)[71]

The 1972 Project A6 Aerodist network was adjusted (by VARYCORD) in two stages. Firstly, the primary net of stations and lines connected to existing geodetic surveys and then the secondary/tertiary network. The coordinate set from that adjustment was used by Army Survey Regiment for the photogrammetric aerotriangulation as the basis for minor control for the photogrammetric compilation of the scale 1:100,000 topographic maps. The 1972 network produced the best adjustment results to date[72]. The system acceptance trials had shown that very good results were possible in favourable meteorological conditions just as was the case in the Gulf of Carpentaria compared with MRC2 operations in less favourable areas of Papua New Guinea, Indonesia, Arnhem Land and the Kimberley.

After Operation Sandy Hill 1975, all *Aerodist* lines from 1972, 1973 and 1975 were combined into one composite adjustment the results of which are reported under that section.

The days work from a Master operator[73]

> *Pre-requisite training was a two day RAAF Aviation Medicine course at RAAF Amberley. Day one was theory about the physiological effects of lack of oxygen (hypoxia). Day two was a session in the hypoxic chamber to experience the simulated effects of flying to an altitude of 25,000 feet without oxygen then later using oxygen to 25,000 feet and experiencing an 'explosive decompression'. Everyone reacts differently to lack of oxygen and the important training objective was to recognise the effects of lack of oxygen in your own body and at what height and how long it would take for you to lose consciousness. It was comforting knowing that the Aerodist Queen Air would not be flying at 25,000 feet.*
>
> *After finishing the trials at Bonegilla, myself and another Master operator (Corporal Alan Kavanagh) returned to Brisbane to find that the two of us and two signallers from 139 Sig Sqn were soon to depart for Normanton. We had to drive two Landrovers with trailers to Normanton in three days (the first convoy had six days) and set out the main base camp at Normanton airport before the convoy arrived. We arrived there, liaised with the local council to borrow a grader for*

[71] 1 Fd Svy Sqn Project A6 (1972) – Project Report (courtesy Charlie Watson)
[72] Advice from DSVY AHQ (Lieutenant Dan McCluskey – later Lieutenant Colonel) to Charlie Watson
[73] Author

constructing camp drainage and used a theodolite and tape to lay out the site of each tent with dumpy pegs. The convoy of trucks arrived a few days later and duly drove over every dumpy peg. Materials for the showers and toilets (corrugated iron roof and walls and hardwood 4 inch x 2 inch frame) were amongst the stores but RAE sappers from Townsville sent a Warrant Officer supervisor rather than sappers to build the camp. That ended up our job. But we never did pass the Warrant Officer's test of driving a 6 inch nail with only one whack of the hammer[74]. But we did construct a solar hot water system for the showers which was way ahead of its time. This was a very long snake of white PVC pipe painted black laid out on the ground. It held enough solar heated warm-hot water for all, or at least most, to enjoy a hot 'pulley' canvas bucket shower at the end of the day. But I do remember cool showers, having arrived late from the days' work. By then VH-FWG had arrived from Toowoomba after a service following the Aerodist acceptance trials, so it was time to return to our main duty, operating the Aerodist Master system.

On good weather days, and most days were, the daily routine was a morning sortie 0700hrs to about 1130hrs, lunch and refuel at a forward base, then an afternoon sortie 1230hrs to not later than 1700hrs. On average of six days flying and then a pilot's rest day we regularly flew 100 hours in just over three weeks. This was the equivalent of four return trips Sydney to Los Angeles every three weeks. The next day's mission planning started as soon as the aircraft returned to base late afternoon, after reviewing the days progress, equipment serviceability, fuel (Avgas) dumps and the flying weather forecast. The pilots played a huge part in this process with essential input on aircraft capability and endurance, fuel needs and review of Aerodist line lengths looking at expected flight levels. If the computer sub-system was working well there was little manual computing to be done, but if the computer was not working that days hard copy 'line-crossing' digital printouts had to be checked to ensure valid completed lines and spheroidal distance were computed on the HP9100B calculator if time permitted. Next day work plan was then sent by radio to the Remote stations.

Preflight preparation started well before take-off time. The Master operators were often up, showered, shaved and dressed before the cooks, so had the unenviable duty of lighting the 'chuffers' for boiling water for the kitchen (cooks had the reputation of blowing themselves up with these apparatus). The PDP 8/e computer program for transfer of data and computation of near real time spheroidal distances could not be stored in the very limited core memory and so had to be loaded by paper punch tape through the Teletype or magnetic tape drive either before each sortie from ground power (220-240VAC transformed to 110VAC direct into the computer) or through the aircraft 24VDC to 110VAC inverter. This all took about 30 minutes so if the first line was less than about 60 miles from base (aircraft speed 120 knots on climb) or to be sure that the computer was working before take-off, it was best to use 220-240VAC ground power to load the program. The computer was very sensitive to small voltage fluctuations from the inverter and if the computer 'hung-up' a fly around for 30 minutes was necessary to reload it. Although being shock mounted, the computer was sensitive to vibrations on rough airfields, and sometimes rough weather, when the electronic boards would shake loose (we did at times in flight remove the computer from the frame to expose the internals and reseat the boards).

Before take-off the Master operator would conduct a HF radio check with all of the Remote stations and confirm the plan for the day. In most areas there was no aircraft electronic navigation aids and so the pilots navigated by compass, map and the ground. The Aerodist operators often had the cabin blinds down to stop sun glare thus requiring a very good sense of time and 3D-space to navigate and operate efficiently and effectively. Sometimes we got the Remote station to flash us

[74] Charlie Watson - the Engineer Warrant Officer was Ian Watkins. The nails were 6 inches long. The usual nail used in Far North Queensland for carpentry of this type was 4 inches. So the 6 in was a lot harder to drive.

with a mirror for a visual aid. With a climb rate of 500 feet a minute to a desired altitude above the mean terrain of not more than 1,000 feet per 10 miles of line length, navigating to a 'line-crossing' could be done by flying to an offset a few miles from the middle of the line then turning on to the crossing at right angles, or flying over one of the Remote stations and track along the line with the antennas pointed aft and forward until both Remotes were 'locked-on' and then turn to proceed with the 'line-crossings' with antennas turned to the sides. If Remote signals were weak or not found we normally tried direction finding then turned towards that station to find a strong signal and/or climb another 1,000 feet. This all took time and fuel. There was no lobe antenna diagrams showing the best place for optimum signal strength as there was for the MRC2. During the climb to line altitude the operator checked the logic of the meteorologic data gradients of about -30 millibars atmospheric pressure and -2 degC per 1,000 feet altitude.

Tuning each of the two Master instruments was similar to the Tellurometer MRA301 to maximise return (from the Remote) signal strength and minimise noise on the voice channel. Good 'measuring' signal strength was indicated by a small yellow light on the top of the analogue to digital (ADC) converter on strongly. Once both yellow lights were 'on' the pilot was told to maintain altitude and heading and 'line-crossing' commenced and the thermal printer (with the paper streaming out and folding into a bin between the operator's legs) was turned on to record the two slant ranges and aircraft meteorological data. The operator checked the printed slant ranges to make sure that the minimum sum was achieved and that there were at least ten points either side of the 'line-crossing'. An asterix indicated a loss of signal or poor signal which the operator should have been aware of from a flashing yellow light.

Meanwhile the computer operator entered the header data of line number, Remote stations name/number, Remote stations heights and Remote meteorologic data from the HF radio or Tellurometer voice. Once the 'line-crossing' started with data from the Master ADCs, measured slant ranges were printed on the Teletype (the chattering sound of the Teletype was always comforting as it indicated that all was working) and after corrections applied the computed spheroidal distance was printed. After each 'line-crossing' a summary of spheroidal distances with standard deviation of the mean and range were printed. The pilot would then make a two-minute turn onto the reciprocal heading and the Master operator would switch the antennas for each of the Master instruments and retune each Master eagerly awaiting the solid yellow light on the ADC. If the computer system was not working correctly, the digital data on the thermal paper printer was scanned by eye to ensure that a valid 'line-crossing' was achieved.

Operator comforts were few. The only toilet on board was a motor mower fuel can with screw cap. To use it required kneeling on the floor next to the door behind the computer, hiding from the pilot who if he saw what was going on enjoyed the effect of a quick 'jab' on the control stick. A steadying hand on the folded stairs on the door was good insurance. Sick bags were at hand but not needed very often. The standing pilots/mechanics order was 'you make a mess you clean it up.'

After a four and a half to five hour morning sortie, lunch at forward operating base was often a quick sandwich, cold drink and then a half hour hand pumping up to three 44 gallon drums of Avgas for the afternoon sortie. This often involved making sure that the drums for following days refuelling were stood up properly, with a log or rock under each, such that any water or foreign particles in the fuel would settle at the bottom of the drum opposite where the pump spike reached. After this workout in the hot sun it was always a pleasure to get back to the cooler air.

On early morning flights in the Burketown area we happened by accident to observe the meteorological phenomenon now known as the 'morning glory' and now highly sought by glider pilots and other light aircraft tourists. We did not know about it then and did not know to look for the rolling tube of cloud, but we did note that there was an inversion layer of air about 3,000 feet thick or more where the temperature lapse rate on climb was positive and not negative. The first time we thought the temperature sensor had failed but then corrected itself. Weird, so we tried to *avoid that area for 'line-crossing' although we did not know how extensive that layer was. On return to Brisbane I was sent to the State Library to find something about the effect on the computed refractive index, but found no reference. Second World War pilots did report the rolling tube clouds.*

At Croydon we had to 'buzz' the airstrip before each landing approach to scare off a herd of feral goats that frequented the airstrip. Sometimes it was wheels-up, flaps up, power-up and a go around when they appeared on short finals.

Figure 42. 1972 Project A6 – at 1st Order theodolite and tellurometer survey station A432 north of Mt Isa – established by RA Svy 1960. Sapper Mick McCosker (1 Fd Svy Sqn) is operating the Aerodist MRB3/201 Remote primary station. Online Aerodist eccentric setups were often used on existing stations with pole, discs/vanes and cairn. (Photo: Mick McCosker)

From one Remote team member:[75]

I remember that location (A432) all too well – the bloody Aerodist aircraft broke down/ due for service (returned to Toowoomba) – and Rick Downie and I sat on that steep hill for 2 weeks without any contact from anyone (except for radio). The location was too steep and dangerous for us to 'head into town' in the Land Rover on a regular basis – for refreshments! (Photo: Mick McCosker)

Figure 43. 1972 Project A6 Forward Operating Base Kamilero (north of Mt Isa) – a spare astronomical observing tent being put to good use sheltering latrine users from the harsh mid-day sun. Not as windy there as a mountain top trig station but obviously not taking any chances with the well pegged out shelter. The Aerodist aircraft is in the background.(Photo: Author)

[75] Sapper Mick McCosker (later Corporal) 1 Fd Svy Sqn

Figure 44. 1972 Project A6 - lunch at Gregory Downs with an interested local. The truck's radiator was gravity fed by water from the 4 gal drum which was topped up with a bucket from water in the 44 gal drum. The wire/bolt cutters on the tray-back were for any eight-gauge fencing wire needed for truck repairs.(Photo: Author)

VH-FWG was then attached to 4 Fd Svy Sqn (Adelaide – Major George Ricketts) on Operation Wine Glass based at Goroka TPNG from July to December 1972, working on control for the scale 1:100,000 topographic mapping. On completion of the work of 1 Fd Svy Sqn in the Gulf of Carpentaria, a RAAF Caribou transported all of the *Aerodist* Remotes, spare parts and Master operator (Corporal Peter Jensen) to hand-over the system and to conduct manager and operator continuation training in TPNG) from Normanton to Goroka. Over the next four months 28 new stations were established from 171 Aerodist lines measured in TPNG.

Figure 45. 1972 Kangarilla near Adelaide SA – No 5 Squadron (Fairbairn ACT) RAAF Iroquois UH-1H conducting 'hoist' training for 4 Fd Svy Sqn Aerodist Remote operators prior to deployment on Op Wine Glass to TPNG. (Photo: 4 Fd Svy Sqn)

Figure 46. 1972 Operation Wineglass, Goroka TPNG (4 Fd Svy Sqn) – VH-FWG Beechcraft Queen Air (right) Aerodist MRB3/201 aircraft with underwing antenna pod, and VH-RUU Beechcraft Queen Air (left) with Wild RC10 air camera for survey station identification photography and gap mapping photography. Pilots were civilians (Union Air) and Aust Army Aviation Corps. (Photo: 4 Fd Svy Sqn)

Figure 47. 1972 Operation Wineglass TPNG – RAEME Electronic Technicians Corporal Col Harley (right) and Craftsman Flink (both Survey Section Sydney Workshop Company) checking an Aerodist underwing steerable rectangular parabolic antenna on VH-FWG (Photo: 4 Fd Svy Sqn)

Figure 48. 1972 Operation Wineglass TPNG (4 Fd Svy Sqn) – RAAF Iroquois UH-1H helicopter at an Aerodist Remote station in the highlands (Photo: 4 Fd Svy Sqn)

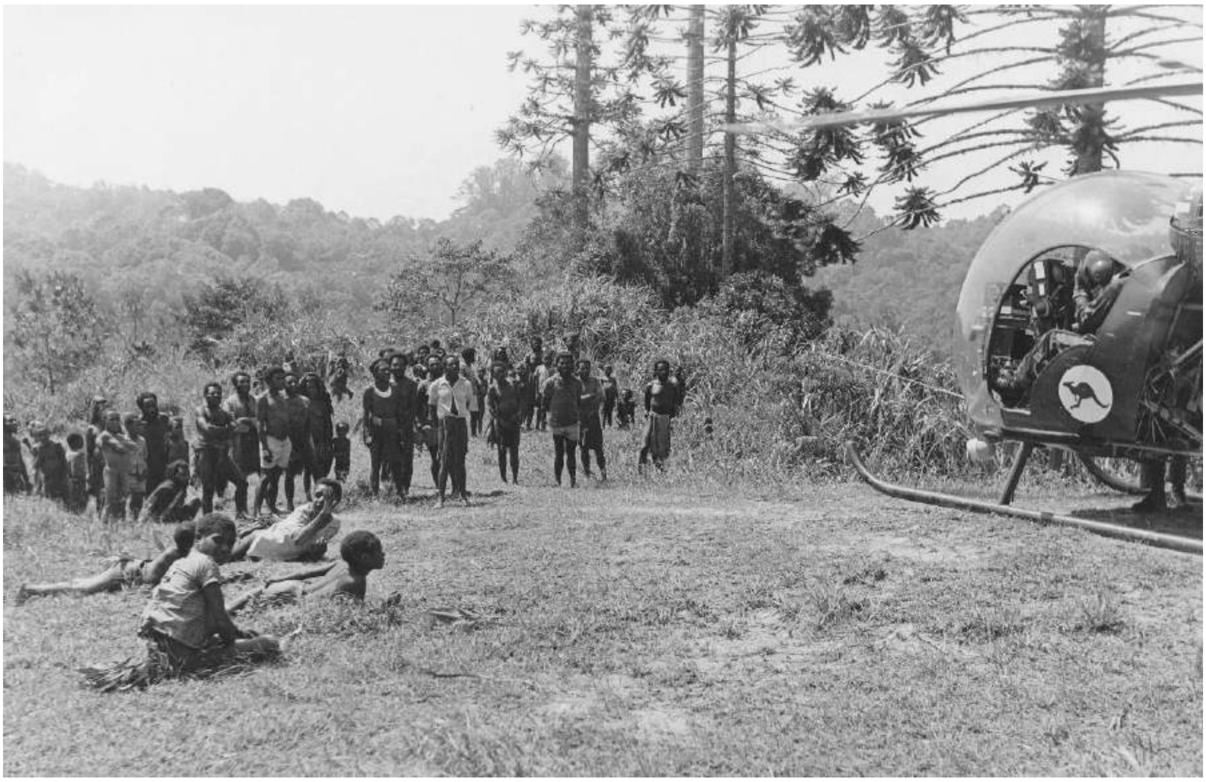


Figure 49. 1972 Operation Wineglass TPNG (4 Fd Svy Sqn) – An Army Sioux helicopter landing near a village always attracted a good crowd (Photo: 4 Fd Svy Sqn)

Figure 50. 1972 Operation Wineglass TPNG (4 Fd Svy Sqn) – Army Sioux helicopters at Forward Operating Base Pangia (Southern Highlands) (Photo: 4 Fd Svy Sqn)

Figure 51. 1972 Operation Wineglass TPNG (4 Fd Svy Sqn) – the pilots of a RAAF Iroquois UH-1H helicopter, weighing about 4 tonne, trusting a wooden landing platform of logs lashed together with vines, at Photo Control Point (PCP) 158 above the Purari River at the head of the Gulf of Papua. Sappers Stevo Hinic and Bob Garrittу established the Aerodist survey point occupying it for 23 days (Photo 4 Fd Svy Sqn and Stevo Hinic)

1973

In early-1973 VH-FWG was again attached to School of Military Survey for *Aerodist* MRB3/201 Master operator and manager training. Like the previous year the system was then attached to 1 Fd Svy Sqn (Major Keith Todd) in north Queensland this time on Project A2 (Cape York) based at Cooktown QLD. Main base Cooktown was constructed by 18 Field Squadron, 3 Field Engineer Regiment RAE. On completion of the operation the camp was mothballed to be used again in 1975.

That operation which planned to provide horizontal and vertical control for ten 1:250,000 map area blocks for 1:100,000 topographic mapping, was conducted in four phases: reconnaissance and station marking 18 April to 17 June; Army Sioux helicopter barometric heighting 16 April to 18 July (28 traverses establishing 259 height point for photogrammetric triangulation); station identification aerial photography 29 May to 17 July; *Aerodist* MRB3/201 21 May to 18 July.

With all field survey squadrons committed to field operations throughout the year, and map compilation commitments of Army Survey Regiment, there was little opportunity for topographic surveyor reinforcements from other survey units. This shortage of survey personnel was addressed by making up each Remote team as one topographic surveyor leader and one infantry or artillery soldier. The four infantry soldiers and two artillery gunners from 3rd Task Force, Townsville were quite up to the task and thoroughly enjoyed their attachment.[76]

The *Aerodist* established 30 new stations from 161 lines measured and completed eight of the ten planned 1:250,000 map area blocks – Normanton, Galbraith, Mossman, Hann River, Red River, Walsh, Rutland Plains, Cooktown. The two blocks, Croydon and Millungerra which were left-overs from 1972, were again not completed. Up to eight Remote teams were deployed at one time. Once again primary stations required six primary lines of at least six valid 'line-crossings' and secondary stations required four secondary lines of at least four valid 'line-crossings'. Control diagrams and a summary of the measured *Aerodist* line spheroidal distances (before geodetic adjustment) with standard deviation of the 'line-crossings' are Figure 52 and Figure 53 respectively. Once again if the Master computer system was unserviceable, there was the burden of up to five hours post-flight computations on the HP9100B programmable calculator/computer for six to eight lines daily.

The longest line measured was B070 (1st Order traverse station near Princess Charlotte Bay to A230 to the south-west) 225,849.8 metres with a standard deviation of seven line-crossings of 1.1 metres (reduced measured spheroidal distance).

Forward operating bases were established at Dunbar and Croydon.

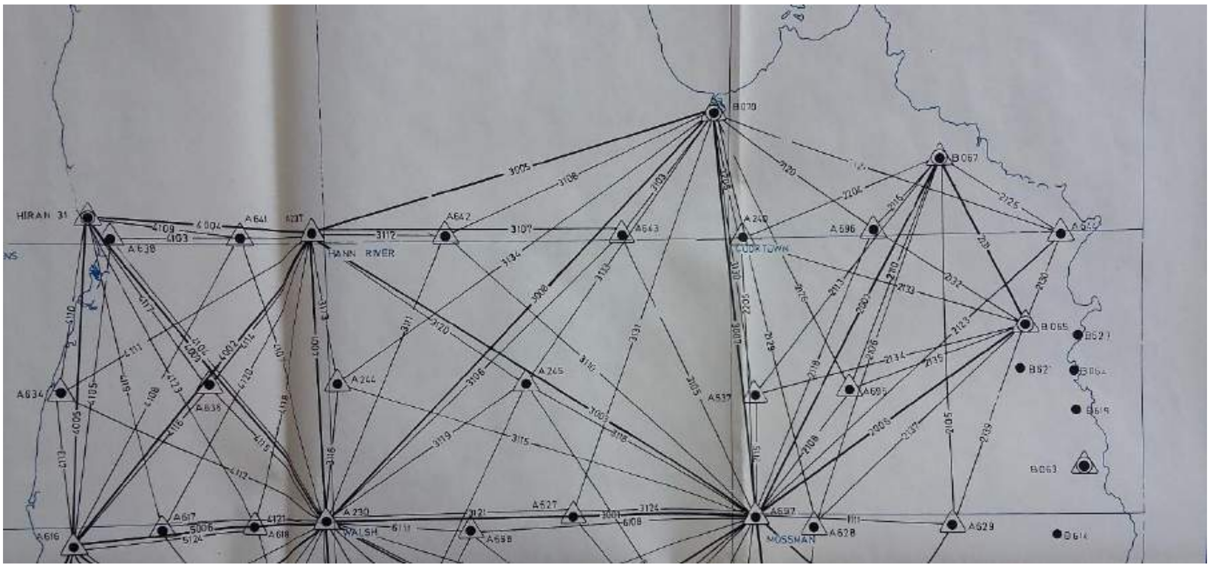
[76] Charlie Watson

Figure 52. 1973 Project A2 (1 Fd Svy Sqn) Aerodist Queenair VH-FWG at Dunbar, Cape York being prepared to return to Toowoomba for a two day 100 hour service. The wing Aerodist antenna pods have been removed and the cargo door forward of the main steps door is open to remove the computer/teletype. FWG was the only one of the three Queen Air with this facility which was of great benefit to install and remove equipment and mounting frames. The circular shaped item on the ground is the normal aircraft nose cone. The small blue painted Caribou head on the fuselage in front of the propeller cone was the symbol of No 38 Squadron RAAF (Caribou) being painted there by 38 Sqn maintenance crew. (Photo: Author)

Figure 53. 1973 Project A2 (1 Fd Svy Sqn) Sapper Ted Van Ginnekin at primary Aerodist remote survey station A697 (Palmerville) at the intersection of four 1:250,000 map areas (Hann River, Cooktown, Walsh, Mossman). Nine primary lines and fourteen secondary lines were measured from/to A697. The white panelling is for station identification air photography. (Photo: Charlie Watson)

Figure 54. 1973 Project A2 (1 Fd Svy Sqn) Forward Operating Base Dunbar, Cape York, sited on a lagoon south of the Mitchell River. The local pattern drink cooler – half 44 gal drums - in the lagoon complemented the limited refrigeration at the base. (Photo: Charlie Watson)

Figure 55. 1973 Project A2 (1 Fd Svy Sqn) Forward Operating Base vehicles crossing Staaten River enroute Dunbar to Croydon. The 5 ton (six wheel drive) MK5 GS truck has the Landrover on an A-frame tow. The 3 ton (four wheel drive) MK4 Tels-truck (electronic workshop variant) is the RAEME Aerodist maintenance vehicle. (Photo: Charlie Watson)



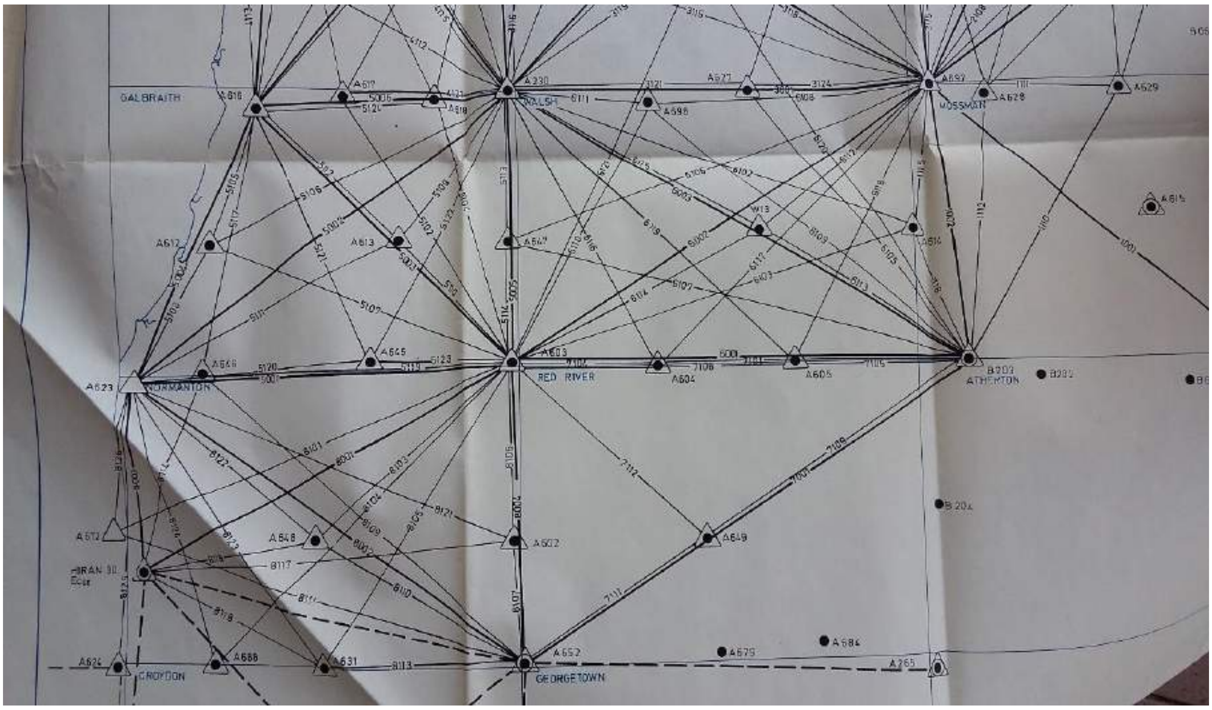


Figure 56. 1973 Project A2 (1 Fd Svy Sqn) network diagrams of existing surveys (triangle with open circle and dot inside), completed new stations by Aerodist (triangle with dot), measured Aerodist primary lines (heavy line), measured Aerodist secondary lines (light line), numbers on the lines are the line numbers[77]

[77] 1 Fd Svy Sqn Project A2/1973 – Project Report (courtesy Charlie Watson)

ANNEX M TO
REPORT PROJECT A2/73
DATED SEP 73

AERODIST LINE DATA

Serial	Line	From	To	No of Crossings	Length(M)	S.D. (M)
(a)	(b)	(c)	(d)	(e)	(f)	(g)
1	2121	B070	A644	5	145,123.9	0.6
2	2125	B067	A644	5	52,594.9	0.8
3	2123	A644	A697	4	165,785.2	0.1
4	2130	B065	A644	4	40,578.2	1.0
5	2132	B065	A696	4	69,570.4	1.0
6	2116	B067	A696	4	37,307.5	1.0
7	2120	B070	A696	4	82,425.1	0.5
8	2118	A697	A696	4	123,882.5	0.1
9	2133	B065	A240	4	117,256.1	0.4
10	3130	B070	A637	4	116,660.3	0.5
11	2115	A697	A637	4	47,069.6	0.4
12	2134	B065	A637	4	110,979.7	0.8
13	2135	B065	A695	5	72,951.8	1.3
14	2108	A697	A695	4	63,454.7	0.4
15	2126	B070	A695	3	126,350.6	0.4
16	1001	B600	A697	6	184,800.2	0.5
17	2110	B067	A695	4	98,037.0	0.2
18	2204	B067	A240	4	86,116.3	0.2
19	3206	B070	A240	4	55,627.4	0.7
20	2205	A697	A240	4	108,214.3	0.1
21	2113	B067	A637	3	119,697.9	0.3
22	3007	B070	A697	7	163,276.9	0.8
23	2002	B067	A697	6	159,612.7	0.5
24	2006	B065	A697	4	131,717.8	1.9
25	2131	B067	B065	3	73,299.5	0.3
26	2106	B067	A628	4	155,481.4	0.8
27	2105	B067	A629	3	145,606.2	3.3
28	2139	A629	B065	4	85,971.4	0.8
29	1112	B203	A628	4	106,322.9	0.5
30	2129	B070	A628	4	172,621.0	0.8
31	2137	B065	A628	4	117,486.5	0.4
32	1002	B203	A697	6	112,253.7	1.6
33	1110	B203	A629	4	124,335.3	2.1
34	1111	A697	A629	6	77,048.7	2.1
35	3103	B070	A643	4	62,912.1	0.2
36	3108	B070	A642	4	114,674.3	0.7
37	3005	B070	A237	5	167,385.6	0.3
38	3107	A237	A643	4	121,713.6	0.2
39	3112	A237	A642	4	57,513.6	2.4
40	3111	A642	A230	3	123,623.9	2.1
41	3110	A697	A642	5	161,400.7	0.4
42	3116	A230	A244	4	57,375.7	0.3
43	3106	A230	A643	4	163,519.9	0.3
44	3105	A697	A643	3	124,416.1	0.5
45	3115	A697	A244	4	173,141.5	0.5
46	3134	B070	A244	4	182,625.2	0.1
47	3113	A237	A244	4	57,355.9	1.0
48	4001	A237	A230	5	113,154.4	0.3
49	3121	A230	A627	4	99,123.4	0.4
50	3124	A697	A627	4	72,296.2	0.9
51	3008	A230	B070	7	225,849.8	1.1
52	3131	A627	B070	4	173,636.0	1.5
53	3120	A237	A245	2	104,369.2	0.9
54	3003	A237	A697	6	208,025.4	0.9
55	3119	A230	A245	6	100,997.6	1.3

- 2 -

(a)	(b)	(c)	(d)	(e)	(f)	(g)
56	6105	A627	B203	5	138,834.8	1.9
57	5114	A603	A647	7	51,318.9	4.4
58	5113	A230	A647	3	59,884.1	0.7
59	5005	A230	A603	7	110,757.8	0.7
60	3118	A245	A697	5	103,667.5	0.9
61	6120	A245	B203	3	194,656.7	0.5
62	3001	A230	A697	6	171,405.1	0.5
63	6108	A698	A697	6	113,538.8	2.2
64	6121	A603	A245	3	185,055.3	1.5
65	6111	A230	A698	4	58,209.7	0.8
66	6110	A603	A698	4	118,751.1	0.4
67	6003	A230	B203	6	214,554.8	2.0
68	6002	A603	A697	7	201,058.1	3.5
69	6109	A698	B203	5	164,401.4	1.6
70	6107	A647	B203	4	193,244.9	1.0
71	6106	A647	A697	4	184,320.2	3.0
72	6001	A603	B203	6	179,651.1	1.9
73	6116	A230	A604	4	124,420.0	0.7
74	6117	A697	A604	3	159,209.2	0.8
75	6103	A603	A614	4	167,590.1	0.8
76	7101	B203	A604	5	126,304.5	2.1
77	1115	A697	A614	5	59,596.9	0.8
78	1118	B203	A614	4	56,377.2	0.9
79	6102	A230	A614	5	173,350.7	2.6
80	6112	A697	W13	4	91,410.1	0.7
81	6115	A230	W13	4	116,072.6	0.4
82	7104	A603	A604	4	53,349.0	1.1
83	6114	A603	W13	5	110,517.3	1.4
84	6118	A605	A697	3	126,704.8	3.7
85	4123	Hiran 31	A618	4	135,605.7	0.2
86	4003	Hiran 31	A230	6	153,012.9	0.8
87	6113	W13	B203	4	98,557.1	0.7
88	4118	A237	A618	4	117,763.3	0.8
89	7105	A605	B203	4	70,458.4	2.4
90	7108	A603	A605	4	109,207.3	0.8
91	6119	A230	A605	4	159,170.9	0.5
92	4004	Hiran 31	A237	6	89,021.6	0.6
93	5104	A618	A603	4	116,637.1	0.5
94	5102	A617	A603	4	132,335.8	0.6
95	4119	Hiran 31	A617	5	124,879.7	1.5
96	5006	A616	A230	7	101,791.7	1.4
97	5124	A616	A618	5	67,528.2	0.9
98	4121	A617	A230	4	69,613.6	1.0
99	4120	A617	A237	5	131,543.0	1.7
100	4002	A616	A237	7	157,231.0	1.1
101	4115	A636	A230	4	87,192.3	0.4
102	4116	A616	A636	4	72,346.2	1.1
103	4005	A616	Hiran 31	5	132,565.0	3.1
104	4117	A636	Hiran 31	4	80,713.6	0.8
105	4114	A636	A237	4	70,124.2	1.6
106	4103	A638	A237	4	75,655.8	1.8
107	4104	A638	A230	4	137,218.4	0.6
108	4105	A638	A616	4	124,105.8	0.9
109	4111	A634	A237	4	113,909.0	0.9
110	4112	A634	A230	5	116,816.7	1.9
111	4113	A634	A616	4	66,429.3	2.4
112	4110	A634	Hiran 31	4	66,614.6	1.6
113	4109	A641	Hiran 31	4	54,096.4	1.4
114	4107	A641	A230	4	117,985.3	3.9
115	4108	A641	A616	4	136,370.4	1.0
116	5112	A613	A616	4	74,525.7	1.3
117	5110	A613	A603	4	71,352.0	0.6
118	5123	A645	A603	4	59,173.0	6.3

/119.

- 3 -

(a)	(b)	(c)	(d)	(e)	(f)	(g)
119	5109	A613	A230	4	73,108.6	4.0
120	5120	A645	A623	4	94,736.8	2.0
121	5111	A613	A623	4	118,351.9	4.3
122	5002	A623	A230	6	186,985.0	3.6
123	5121	A616	A645	4	106,758.9	1.6
124	5122	A230	A645	4	119,758.8	0.7
125	5107	A612	A603	4	133,311.8	0.9
126	5106	A612	A230	4	131,076.6	1.4
127	5105	A612	A616	4	49,771.3	0.8
128	5108	A612	A623	4	63,589.5	1.8
129	5001	A603	A623	5	153,566.8	1.6
130	5004	A616	A623	6	112,920.8	1.4
131	5003	A616	A603	6	145,577.1	0.8
132	5117	A616	A646	4	101,734.8	1.7
133	5119	A603	A646	4	126,620.5	1.8
134	7001	B203	A652	6	207,352.3	2.0
135	7109	B203	A649	4	126,845.3	1.5
136	7111	A652	A649	4	80,512.8	2.0
137	7112	A603	A649	3	97,418.6	2.2
138	8106	A603	A602	4	64,918.1	1.4
139	8003	Hiran 30	A623	5	73,373.2	0.7
140	8114	Hiran 30	A646	4	79,481.8	0.7
141	8107	A652	A602	4	44,055.7	1.2
142	8121	A623	A602	3	163,986.4	2.0
143	8109	A652	A646	4	169,678.6	1.7
144	8117	Hiran 30	A602	4	148,243.0	3.0
145	8004	A603	A652	6	108,659.4	1.5
146	8002	A623	A652	5	189,546.9	3.1
147	8103	A603	A648	4	104,099.6	1.3
148	8122	A623	A648	4	93,557.5	1.5
149	8110	A652	A648	4	97,205.8	1.2
150	8001	A603	Hiran 30	5	167,817.2	1.6
151	8116	Hiran 30	A648	4	68,314.3	1.7
152	8104	A603	A688	4	162,503.2	2.1
153	8113	A652	A631	4	78,591.5	2.3
154	8101	A603	A672	4	178,340.5	1.5
155	8111	A652	A672	4	175,065.1	0.7
156	8118	Hiran 30	A631	3	82,660.5	0.2
157	8105	A603	A631	4	134,173.4	1.5
158	8123	A623	A631	3	134,117.1	1.2
159	8112	A652	A688	4	121,369.4	2.1
160	8126	A623	A672	4	63,808.8	1.1
161	8124	A623	A688	4	115,122.7	1.7

Figure 57. 1973 Project A2 (1 Fd Svy Sqn) – a summary of the 161 Aerodist lines measured. Column (f) Length is unadjusted Aerodist measure reduced to spheroidal distance, Column (g) is the standard deviation of the number of 'line-crossings' (Column (e)) in metres. This is a measure of the closeness of the 'line-crossing' observed distances to the mean measured/observed distance. [78]

[78] 1 Fd Svy Sqn Project A2 (1973) – Project Report (courtesy Charlie Watson)

The 1973 Project A2 *Aerodist* network was adjusted (by VARYCORD) in two stages. Firstly, the primary net of stations and lines connected to existing geodetic surveys and then the secondary network. Like the 1972 project, the coordinate set from the adjustment was used by Army Svy Regt for the photogrammetric aerotriangulation as the basis for minor control for the photogrammetric compilation of the scale 1:100,000 topographic maps.

After the 1975 survey operation (Op Sandy Hill) all *Aerodist* lines from 1972, 1973 and 1975 were combined into one composite adjustment the results of which are reported under that section.

After a successful Cape York project, VH-FWG with *Aerodist* MRB3/201 was again attached to 4 Fd Svy Sqn (Adelaide – Major George Ricketts) on Operation Plastic Flagon based at Goroka TPNG from August to November 1973. There the equipment frustrated all involved with frequent malfunctions resulting in a very disappointing total of 35 lines measured. Ironically the MRC2 was coaxed along in Sumatra (Operation Gading 3) that year to produce 149 lines, and was then retired from service being assessed 'beyond economic repair'. Remote survey teams included non-Survey Corps personnel most of whom enjoyed the experience so much that they volunteered for next years' *Aerodist* Operation Sea King also in Papua New Guinea[79].

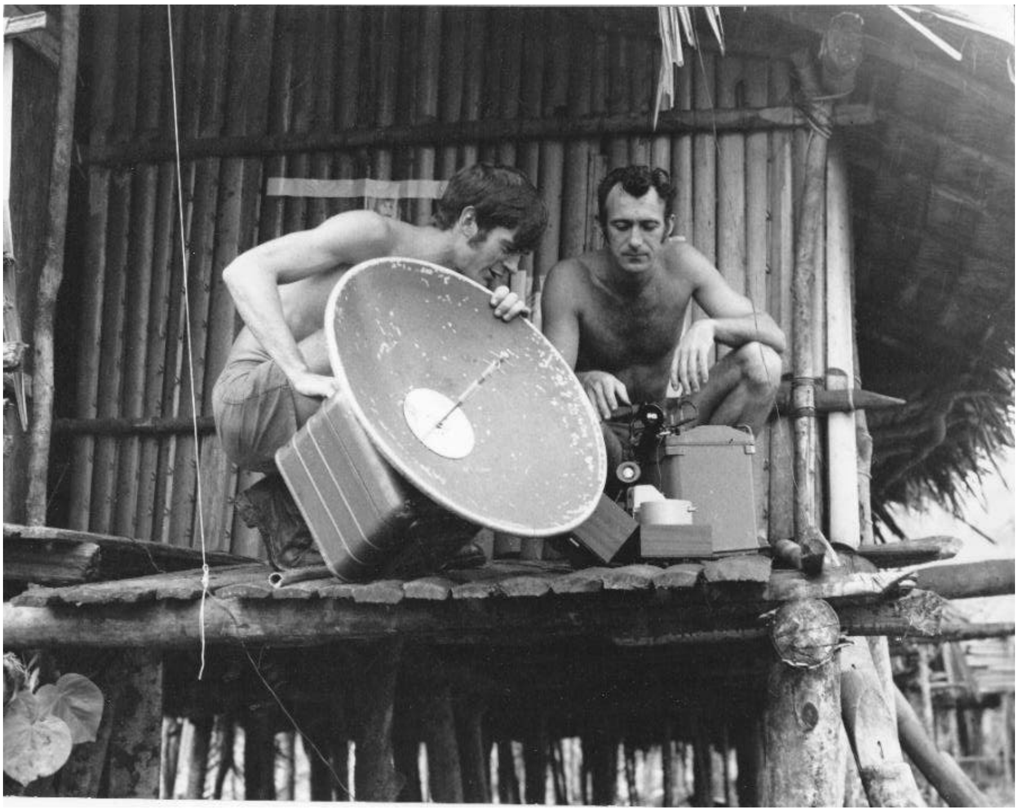


Figure 58. 1973 Operation Plastic Flagon TPNG – Corporal Greg Fitzgerald (4 Fd Svy Sqn)(left) and Lance-Corporal Doug Poole operating a MRB3/201 Remote on the banks of Paibuna River (at the head of the Gulf of Papua). A Baromec digital dial readout of atmospheric pressure and a AN/PRC F1 HF radio are next to the Remote. The platform was to get above crocodiles that frequented the site at high tide and at night. (Photo: 4 Fd Svy Sqn)

[79] Corporal Stevo Hinic (later Warrant Officer Class One) 4 Fd Svy Sqn

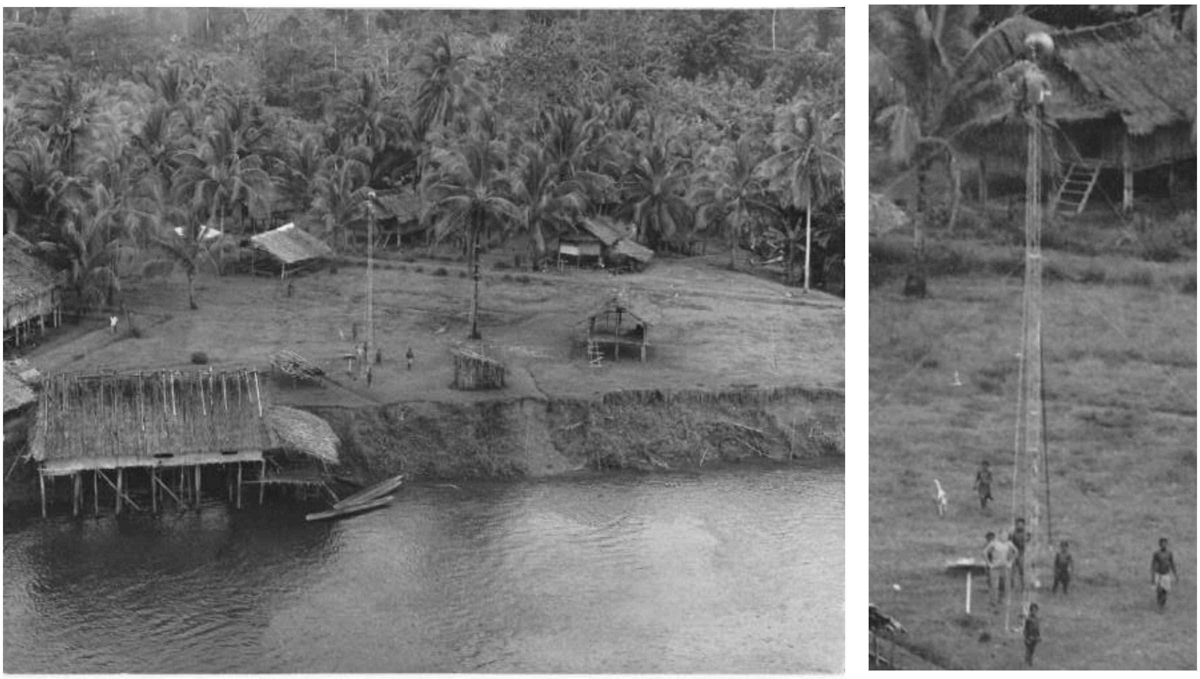


Figure 59. 1973 Operation Plastic Flagon TPNG (4 Fd Svy Sqn) – Aerodist MRB3/201 antenna is atop the two piece 10 metre portable tower above the survey mark in the riverside village. At the top of the tower is one of the operators who braved the climb on request from the Master operator in VH-FWG to direction find to improve the signal strength. Corporal Mick Sarson (4 Fd Svy Sqn) is believed to be the soldier at the base of the tower[80] (Photo: 4 Fd Svy Sqn)

Figure 60. 1973 Operation Plastic Flagon TPNG (4 Fd Svy Sqn) - Aerodist Remote team (radio callsign Romeo 3) set up on the steeply sided Mt Karimui N/M/J 20 (1st Order traverse station established by Aust Division of National Mapping in 1963) elevation 8,500 feet. The station rock cairn is on the right of the tent. An Army Sioux helicopter is on the landing pad with a resupply of rations, water, mail etc - Sapper Bob Dikkenberg is at the helicopter with his back to the camera. (Photo: Bob Dikkenberg)

[80] Stevo Hinic and Corporal Mick Sarson (later Warrant Officer Class One) both 4 Fd Svy Sqn

Figure 61. 1973 Operation Plastic Flagon TPNG (4 Fd Svy Sqn) – DSVY AHQ Colonel John Nolan (middle) being briefed on the Aerodist program by Lieutenant Paddy Strunks (right) and Officer Commanding Major George Ricketts (left). (Photo: 4 Fd Svy Sqn)

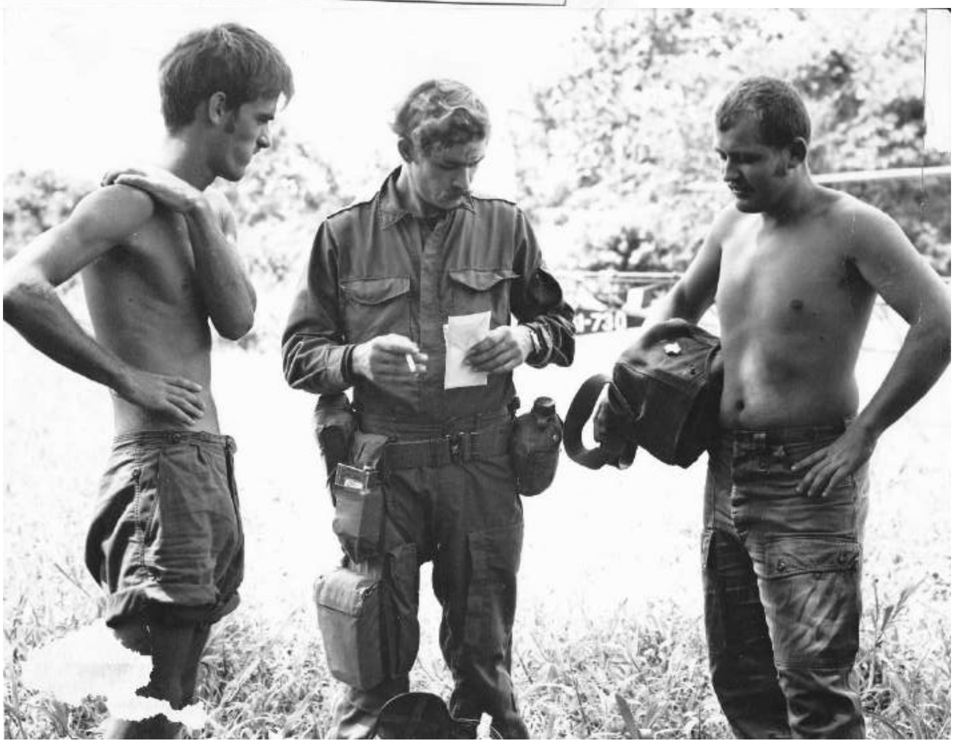


Figure 62. 1973 Operation Plastic Flagon TPNG (4 Fd Svy Sqn) – Army Sioux helicopter pilot Lieutenant Henk Pronk [81](centre) Aust Army Aviation Corps, delivering much anticipated mail to an Aerodist Remote team – Corporal Mick Sarson (right)(4 Fd Svy Sqn), Bombardier Roger Whittaker, Royal Australian Artillery[82] (left) (Photo: 4 Fd Svy Sqn)

[81] Bob Dikkenberg
[82] Stevo Hinic

Figure 63. 1973 Operation Plastic Flagon TPNG (4 Fd Svy Sqn) – Corporal Peter Rodriguez (4 Fd Svy Sqn) operating a MRA301 Tellurometer assisted by RAN Marine Technician Robert Crowley (Landing Craft Heavy HMAS Brunei which was in support – sailors were attached to survey parties for respite from ship duties) on Gabba Island 1st Order station B088, Torres Strait[83] *(Photo: 4 Fd Svy Sqn)*

Figure 64, 1973 Operation Plastic Flagon TPNG (4 Fd Svy Sqn) – Army Pilatus Porter (short take-off and landing turbo propeller) equipped with Wild RC10 aerial mapping camera for identification photography. A film magazine is on the box at the open door. (Photo: 4 Fd Svy Sqn)

[83] Stevo Hinic and Sergeant Dave Anderson (later Warrant Officer Class One)

Figure 65. 1973 Operation Plastic Flagon TPNG (4 Fd Svy Sqn) – Army Pilatus Porter equipped with Wild RC10 aerial mapping camera for identification photography of the Aerodist stations. The front of the aircraft is to the right. Components from the left – operator seat, wooden box has lens filters, navigation sight, control unit, universal mount with lens cone inserted and film magazines (Photo: 4 Fd Svy Sqn)

On the 29 November 1973, Second Lieutenant Kevin Shoppee, 1 Aviation Regiment, was killed in a helicopter (Army Sioux) accident on Mount Wilhelm (14,793 feet), the highest mountain in Papua New Guinea. Passenger Corporal Col Darch, 4 Fd Svy Sqn, survived the crash and was rescued the next day. Lieutenant Shoppee was the only fatality on survey operations in PNG and is commemorated on the Australian War Memorial Roll of Honour https://www.awm.gov.au/collection/R1729458 .

1974

Survey control for the 1:100,000 mapping of TPNG was still required, and VH-FWG was again fitted with the *Aerodist* MRB3/201 Master and attached to 4 Fd Svy Sqn on Operation Sea King based at Goroka TPNG from July to November 1974. The equipment worked better than in 1973 to complete 112 lines to establish ten new stations.

This was to be the last *Aerodist* operation in TPNG. In 1975, RA Svy was to be equipped with Transit Doppler satellite AN/PRR 14 geodetic receivers (Geoceivers) which would be used by 8 Fd Svy Sqn (permanently based in Popondetta, Wewak and Port Moresby PNG) in PNG later that year. Meanwhile, US Defense Mapping Agency loaned to RA Svy Geoceivers from May to November 1974 to establish 41 new geodetic and mapping control stations in Sumatra, Indonesia and geodetic stations in TPNG. The global, day/night, all weather, all terrain, independent point positioning satellite system would relieve survey operations of all that went with high levels of sub-system inter-dependency that the *Aerodist* system was. The two 4 Fd Svy Sqn Geoceiver teams in PNG in 1974 were led by Staff Sergeant Ed Schulze and Sergeant Jeff Turner.

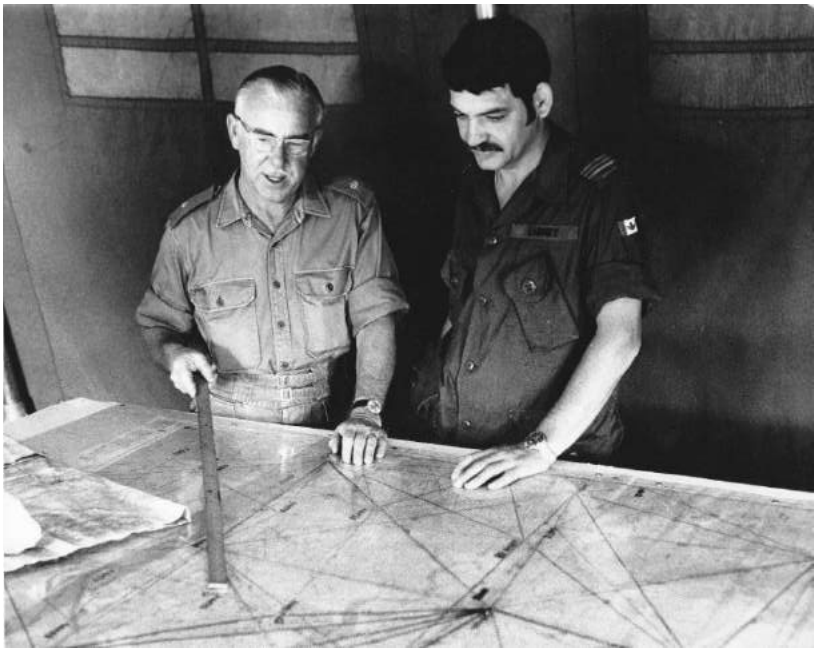


Figure 66. 1974 Operation Sea King TPNG (4 Fd Svy Sqn) – Officer Commanding Major George Ricketts briefing Royal Canadian Engineer (Survey) exchange officer Major Dave Carney, at Main Base Goroka (Photo: 4 Fd Svy Sqn)

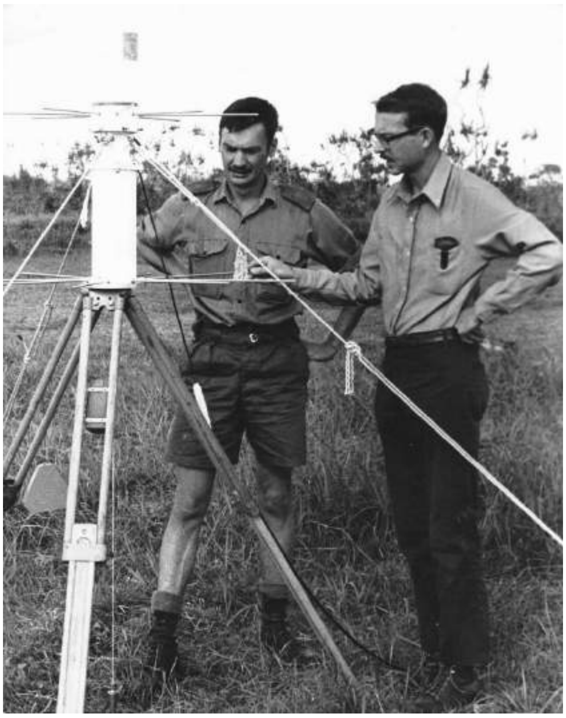


Figure 67. 1974 Operation Sea King TPNG (4 Fd Svy Sqn) – Lieutenant Peter Bion[84] *and Mr Allan Joll (US Defense Mapping Agency) with a Transit Doppler satellite AN/PRR 14 geodetic receiver (Geoceiver) antenna – the antenna is on top of the preamplifier which sits on the tripod, the horizontal ground-plane rods are to stop signal ground reflections into the antenna and preamplifier. (Photo: 4 Fd Svy Sqn)*

1975

Before the *Aerodist* MRB3/201 was retired in 1975, it performed sterling service for 1 Fd Svy Sqn Group on Operation Sandy Hill based at Cooktown, QLD, from April to September. Mounted in VH-FWG it successfully measured 166 lines to establish 41 new survey stations (for

[84] Lieutenant Peter Bion (later Lieutenant-Colonel)

1:100,000 mapping) in twelve 1:250,000 photogrammetric blocks from the Wellesley Islands in southern Gulf of Carpentaria, south to Julia Creek and north to Cape York (see the *Aerodist* control diagram Figure 64). After some initial problems with Master klystron maintenance all sub-systems worked well. At times Remote reliability was a problem for vehicle based teams.[85] The computer sub-system was used to validate 'line-crossing' quality in near real time with the observed data being used later to compute spheroidal distances on the HP9100B programmable calculator/computer.

Forward operating bases were established at Horn Island (27 April to 9 June), Croydon (15 April to 19 June), Weipa (27 May to 9 July), Mornington Island and Burketown (17 July to 10 August). These forward bases and sub-bases at Coen and Edward River Mission were occupied progressively by the several functional survey groups; the theodolite and EDM Traversing Group operating in the Torres Strait out from Horn Island, the Reconnaissance and Station marking and Recovery Group; the *Aerodist* Group. Operating out of our main base at Cooktown were smaller groups on laser terrain profiling, air photography and field completion (of maps resulting from earlier *Aerodist* operations – 1972 and 1973). The average personnel strength at any one time (all Services) was 120 all ranks. Attached personnel were rotated normally for a period of 1 – 2 months. That alone gives an indication of the complexity of Operation Sandy Hill which was very dependant in all of its phases on air support in various forms[86].

> *The only major activity undertaken which did not use air support was the Aerodist operation in the Croydon-Millungera area which was fully road vehicle mounted. It was probably not coincidental that most trouble experienced with remote Aerodist equipment was during that period and considerable time was lost in replacing unserviceable remote equipment by road. During the remainder of the operation on Cape York Peninsula and the Wellesley Island group the Aerodist was fully supported by Army Kiowa Light Observation Helicopters (LOH)[87].*
>
> *The Army Aviation component from 1st Aviation Regiment commenced deployment to Cooktown from their base at Oakey by C130 (Hercules) aircraft to Cairns then to Cooktown by the Kiowa LOH from 14 April. Stores including a huge canvas covered hanger known as a Salzman Hanger were moved to Cooktown by LCH (Landing Craft Heavy). In all, ninety Aviation Regiment personnel served at Cooktown from 14 April to 24 June. These personnel were then rotated with the same number of personnel from the 162 Reconnaissance Squadron from mid-June until the end of the operation. These numbers include individual replacements during the period of the deployment. This turnover of personnel imposed a huge burden on our very limited administrative staff.*
>
> *The following survey task hours were flown by support aircraft during the operation.*
>
> - *LOH (6 aircraft for 4 on-line 171 Operations Support Squadron, Oakey and 162 Reconnaissance Squadron, Townsville): 1150.2 hrs*
> - *Porter (1 aircraft for survey station identification air photography - RC10): 321.2 hrs*
> - *Caribou (1 aircraft No 38 Squadron RAAF): 513 hrs*
> - *Queen Air VH-FWG (Aerodist): 288 hrs*
> - *Queen Air VH-RUU (laser APR): 81 hrs*
>
> *The LOH proved to be an effective aircraft for survey operations. It is not a good load carrier. Maximum payload for maximum endurance is in the order of 560 pounds and this is reduced to 400*

[85] Operation Report Op Sandy Hill 1975 – 1 Fd Svy Sqn Gp (courtesy Captain Paul Pearson – later Lieutenant Colonel)
[86] Major Bob Skitch (later Lieutenant-Colonel) from the Operation Report
[87] The Army Kiowa LOH replaced the Army Sioux LOH used on many previous survey operations

pounds when fitted with floats. Bulk is frequently more critical than weight since all loading is internal other than when a cargo sling is used. Nevertheless, provided load restrictions are planned into the operation and hours allocated accordingly, payload is not critical. 500 pounds is quite a useful load and allows an Aerodist remote station to be inserted in three lifts. The LOH can be fitted with cargo hooks or hoist and/or floats and/or long range fuel tanks. The choice is often a point of fine decision and sometimes the aircraft with the right equipment is at the wrong location. Hoist was used frequently on the operation for initial insertion of a station marking and clearing team and on existing survey stations where targeting only was required both insertion and extraction was carried out by hoist. All members received hoist training at Enoggera before the operation commenced. A hoist operator must be carried if the hoist is to be used; hence a further weight penalty.(Somehow the Brisbane Courier Mail came to hear of our activity and sent a photographer to take a look. A photo of one of our fellows[88] being hoisted up or down appeared in the CM the following morning – front page I think)

It was deemed by Headquarters 1st Division that survey personnel designated for Sandy Hill needed to be trained in rappelling, that is, descending from a hovering helicopter by rope for the purpose of clearing a helipad. This was really the role of Engineers and we had an Engineer detachment on our Sandy Hill manning. However, a few of our fellows undertook the training and seemed to enjoy it. I do not recall our surveyors having to rappel into a site to clear a helipad although Engineers may have done so.

A major problem with aviation fuel was caused by imperfect drum linings. Forty four gallon fuel drums are lined with a grey plastic material fused with the inner surface of the drum. Helicopters are fitted with a device called a 'metal detector' which detects any solid matter floating in the fuel. Red lights flash in front of the pilot and he must immediately put the helicopter down on the ground wherever that may be. We were having a high number of metal detector incidents occurring requiring a servicing mechanic with his tool kit to fly to the downed helicopter to check out the problem. Of course if the problem proved to be a metal fragment it would be serious indicating a major engine failure. But a tiny piece of plastic, a slither, may not be a concern but the pilot could not take a chance on that. The outcome was that large quantities of aviation fuel (Avtur) had to be condemned and replaced. The contract supplier sent a fuel expert to investigate. He found that more than half the drums he tested were contaminated. All stocks were replaced, yet another irritating and time consuming problem. We had fuel dumps at a number of remote airstrips throughout the Cape. In fact most contaminated drums were simply marked and left insitu for the supplier to worry about.

For his work in the planning and management of key parts of the operation Warrant Office Class One William (Bill) Harvey was awarded the Member of the British Empire (MBE) (military division) in 1976.

Geodetic adjustment Gulf of Carpentaria and Cape York 1972, 1973 and 1975

The Croydon and Millungera map sheets part of the 1975 *Aerodist* network was adjusted (by VARYCORD) with connections to the existing geodetic surveys. A composite network of all of the *Aerodist* lines from 1972, 1973 and 1975 (being all of the MRB3/201 lines measured in Australia for 1:100,000 topographic mapping) was then assembled and adjusted as one network constrained to the existing Australian Geodetic Survey (Australian Geodetic Datum 1966) where connected. This was a total of 479 lines (including some Tellurometer lines in the Torres Strait area), 28 fixed stations and 122 variable stations. The mean line residual (measured distance – adjusted distance) was 2.82m with a standard deviation of 3.8m. This was consistent with School of Military Survey investigations in 1976. Like all coastal regions where survey station

[88] Believed to be Paul Pearson

locations were chosen for photogrammetric aerotriangulation, survey network design could rarely be optomised on the basis of 'strength of figures'.

Of concern was the maximum line residual (18.36m) which involved a First Order station B077 (HIRAN 26) to A718. Other high residuals were about this station and also HIRAN 31 Edward River Mission. This was investigated by observing six high order stations with Transit Doppler satellite AN/PRR-14 Geoceivers in 1976 and rerunning the composite adjustment but I am not aware the outcome.

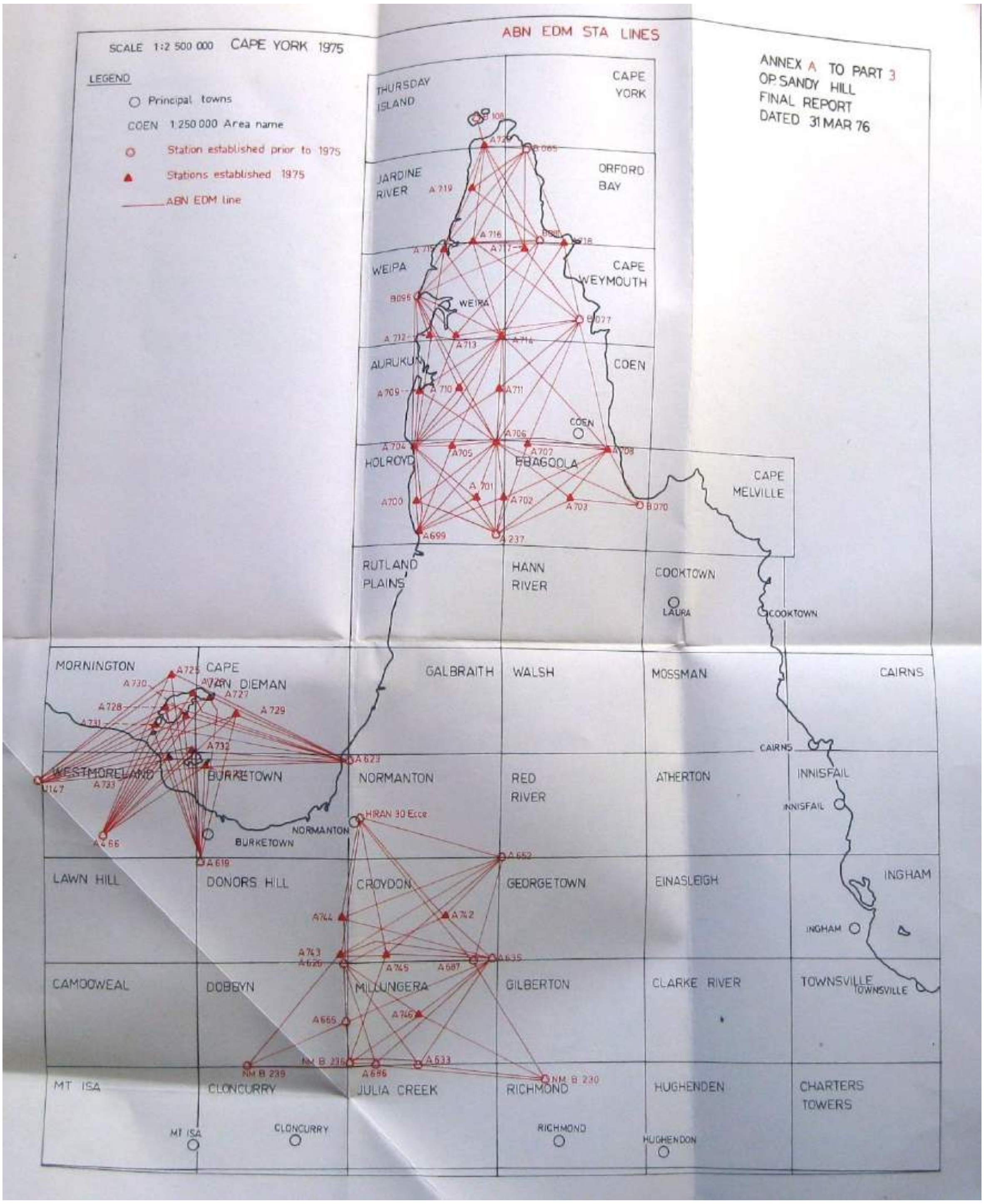


Figure 68. 1975 – Operation Sandy Hill (1 Fd Svy Sqn Gp) Aerodist control diagram

Aerodist Investigations – 1974-76 – School of Military Survey, Bonegilla VIC

Major Dave Hebblethwaite, who had been involved with Aerodist MRC2 from 1967, was posted as Senior Instructor School of Military Survey, Bonegilla VIC in early 1974. There he conducted a number of technical investigations to improve the accuracy of *Aerodist*. It was known in mid-1974 that the Corps was to be equipped with Transit Doppler satellite Geoceivers in 1975 but at that time their productivity in harsh environmental conditions over long periods was not known. To ensure that there was no gap in field survey capability it was prudent to continue to improve the *Aerodist* system and to understand its limitations:

> *On my (Major Hebblethwaite) arrival I was initially tasked with conducting the acceptance trials of the WREMAPS2 Airborne Terrain Profile Recorder developed by the Weapons Research Establishment in South Australia. After that I was involved in a number of investigations into the accuracy of various aspects of the Aerodist line measurement system and produced the following reports.*
>
> ***May 74 – Atmospheric Water Vapour Pressure***
>
> *Atmospheric water vapour pressure is one of the parameters involved in determining the speed of electromagnetic radiation through the atmosphere and hence the distance measured by the Aerodist system between the Master and Remote stations. Investigations had discovered that RA Svy was using an incorrect formula which could result in errors of 2.5m over a 150km line. This paper presented a more precise formula for use by RA Svy*
>
> ***May 74 – A Proposal For Better Determination Of Aerodist Aircraft Altitude.***
>
> *Data from three Aerodist operations (West Arnhem Land - 1968, Gading 1 - 1971 and Gading 2 - 1972) was used to examine the effect of Aerodist aircraft altitude errors on measured line length. The use of the Aerodist itself to determine aircraft altitude is described for each of the projects and graphs of altitude error compared to the barometric height were presented. Due to the characteristics of the MRB3 Aerodist system (compared to the MRC2 system) the techniques for determining aircraft altitude using the Aerodist system were not possible due to the aircraft antenna placement and the much narrower beam width. The paper proposed the installation of a vertically mounted laser rangefinder in the aircraft to measure true aircraft altitude.*
>
> ***Jul 75 – Airborne Measurement of Static Air Temperature***
>
> *This paper presented under one cover the theory and its application pertaining to the Rosemount Model 102 Non De-iced Total Temperature Sensor, including the derivation of the static air temperature, as used in the MRB3 Aerodist system operated by RA Svy. The static air temperature is required to estimate the refractive index of the air column between the aircraft Master and the ground Remote. The static air temperature cannot be measured directly from a moving aircraft as it is the temperature of a parcel of air at rest. The total air temperature can be measured (it is slightly higher than the static temperature) and can be used to compute the static air temperature. Another was the measurement of accurate temperature and humidity values from a moving aircraft. This investigation resulted in the eventual fitting of the Rosemount Model 102 Non Deiced Total Temperature Sensor to the Aerodist aircraft*[89] *.*
>
> ***Oct 75 – Determination of Aircraft Altitude Using the WRE Model 3 Laser Rangefinder***
>
> *This paper describes the testing of the WRE Model 3 Laser Rangefinder (LRF) mounted in the MRB3 Aerodist aircraft. The LRF was used to determine the true aircraft altitude. It had a sighting device and was connected to the MRB3 system so that the time of the ranging is*

[89] Hebblethwaite, DH Major, A full analysis of the operation of the Rosemount Model 102 is in a paper Airborne Measurement of Static Air Temperature, School of Mil Svy, Jul 1975.

recorded. The operator had to record the range and a Polaroid picture was also taken at the time of ranging. The paper recommended adoption of the system with a number of modifications.

Jul 76 – An Estimate of the Accuracy of RA Svy Aerodist Measurements

VARYCORD adjustment and individual line crossing data was analysed in respect of RA Svy Aerodist measuring procedure and a value of 3.7m was determined as the standard error of an Aerodist measure regardless of line length or number of crossings in the line measure.

Jul 76 – CCTV Aircraft Guidance System – A Report on Trials Held at WRE 12-16 Jul76

The need for a system to assist the pilot of an Aerodist or APR aircraft to fly within 100m of a ground control point was discussed. The results of a feasibility trial of a CCTV guidance system were given together with operating concepts and desired system parameters.

Figure 69. 1975 – Aerodist MRB3/201 Queen Air VH-FWG at Albury NSW on 3 September 1975 (Photo: Peter Kelly) This was after Op Sandy Hill and presumably at School of Mil Svy for the trials using the WRE Model 3 Laser Rangefinder in Oct 75 (see Major Hebblethwaite report) http://www.adf-gallery.com.au/gallery/Queenair-VH-FWG/Queen_Air_VH_FWG_Albury_3rd_September_1975_Photo_Peter_Kelly

Conclusion

For twelve years 1964 to 1975 the Royal Australian Survey Corps used airborne electromagnetic distance measurement systems (*Aerodist*) to great effect to provide survey control for scale 1:100,000 topographic mapping from air photography, of some of the most difficult terrain and environmental conditions in the world. Without those *Aerodist* surveys in Papua New Guinea, Indonesia and northern Australia, it would have been nearly impossible to establish survey control by conventional methods and those maps would not have been made by the early-1980s. The numbers speak for themselves. More than 3,050 lines measured to coordinate about 720 survey stations to support production of about 710 new 1:100,000 topographic maps. All of that would not have happened without the professionalism and determination of thousands of personnel from all three Services and civilians; tens of thousands of Army, Air Force and civil charter aircraft hours and Navy ships, either directly involved in the surveys or providing logistic support. Neither would it have happened without the collaboration and cooperation of the Indonesian, Malaysian and British armies, the Papua New Guinea Defence Force and Australia's Division of National Mapping. Such was the importance of surveys and mapping to the defence of the nation and for good international relations with our northern 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 first draft of the paper.

To acknowledge all of those who have helped in this endeavour I include a composite list and apologise to anyone who I have accidently missed: Dave Anderson, Peter Bates-Brownsword, Bill Black, Phil Bray, Alex Cairney, Bob Dikkenberg, Leon Griffiths, John Harrison, Bill Harvey, Dave Hebblethwaite, Stevo Hinic, Kev Kennedy, Sydney Kirkby, Peter Langhorne, Ken Lyons, Mick McCosker, Rob McHenry, Laurie McLean, Brian Murphy, Paul Pearson, Gary Petts, Dennis Puniard, Bob Skitch, Noel Sproles, Mike Venn, Charlie Watson, Bob Williams, Paul Wise