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NATIONAL MAPPING AERODIST PROGRAM

by

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NATIONAL MAPPING'S AERODIST PROGRAM

ABSTRACT

The Division of National Mapping's Aerodist surveys between 1963 and 1974 provided horizontal control for 1:100 000 scale mapping over slightly more than half Australia and extended the survey network to various reefs and islands.

This report describes the Aerodist program, both the surveys in the field and the computations in the office.

1. INTRODUCTION

Prior to the Aerodist survey, the Division of National Mapping used third order astronomical observations to supplement triangulation and traverse stations of the geodetic survey as control for mapping.

From 1957 the geodetic survey was rapidly extended with the Tellurometer electromagnetic distance measuring equipment (Ford 1979). Aerodist, the airborne version of the Tellurometer, became a rapid and economical method of providing additional control points for mapping, particularly in the flat areas of inland Australia, where lines of sight between stations were short (Lambert 1967). However, field parties with traditional survey skills had to develop the ability to operate electronic equipment; electronic technicians were required to maintain the equipment in the field; and field parties increased in size.

Processing the data benefited from electronic computers. In Canada the Department of Mines and Technical Surveys favoured computation in the field (McLellan and Yaskowich 1966), but in Australia National Mapping preferred merely to verify in the field that adequate data had been obtained, and to compute in the office.

The Royal Australian Survey Corps also used Aerodist in its areas of responsibility, particularly in northern Australia and Papua New Guinea.

2. DEVELOPMENT

The Aerodist system was essentially an airborne development of the Tellurometer system of microwave measurement of distance. It was developed by the South African firm of Tellurometer Pty Ltd under a contract awarded by the United States Army Engineers Research and Development Laboratories in 1958.

Prototype equipment was static tested in South Africa and tested in the air in the USA and the UK in 1959 and 1960. The maximum range achieved, ground station to ground station, exceeded 300 km. The maximum instrumental error was claimed to be 1 metre, with a consistency of repeated measurements over any one line of 2 metres ±10 parts per million. The range and accuracy of any particular measurement was dependent on ground reflection and atmospheric conditions (US Army ERDL 1961).

National Mapping's subsequent experience found these to be optimum results only achievable in ideal conditions, and only after the equipment had been modified.

3. PURCHASE

In October 1960 National Mapping received approval to purchase a set of Aerodist equipment.

The first set to arrive in 1961 did not pass its acceptance tests and was rejected. A two-channel system of two master and four remote units was delivered and accepted in 1963. A channel consists of an airborne master unit and a remote unit on the ground. Each remote is referred to by a colour code. Frequencies are separated to prevent interference between channels when they are operating simultaneously. Two channels are needed to measure a line.

In the following years more equipment was bought, much of it was modified, and it was installed in a succession of aircraft - see Annex A.

4. SURVEY METHODS

National Mapping used the Aerodist system to measure distances normally between non-intervisible ground survey stations, building up a regular trilateration pattern of 1º, sometimes 30', squares. The Aerodist master units in the aircraft were flown across the line between remote units at the ground stations - see Figure 1. The changing distances between the master and remote units were recorded on a chart recorder in the aircraft.

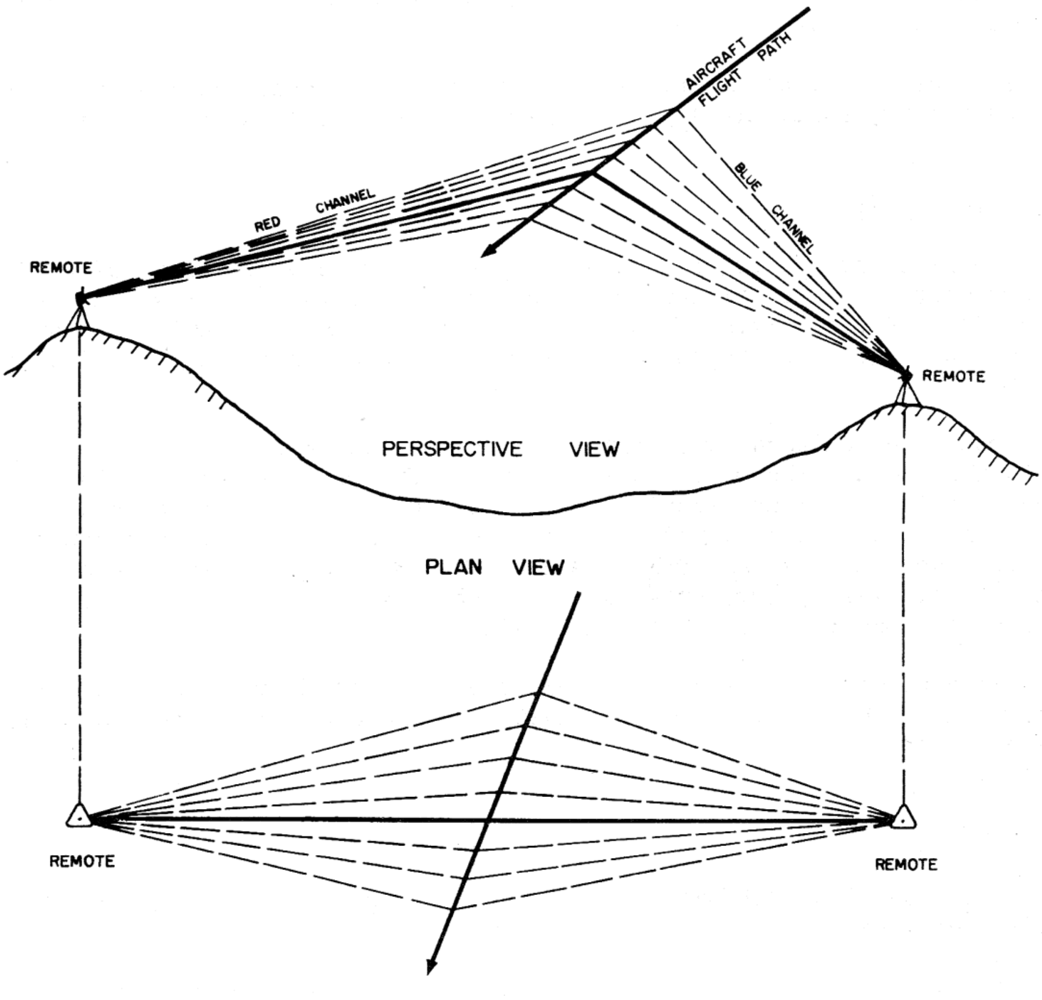
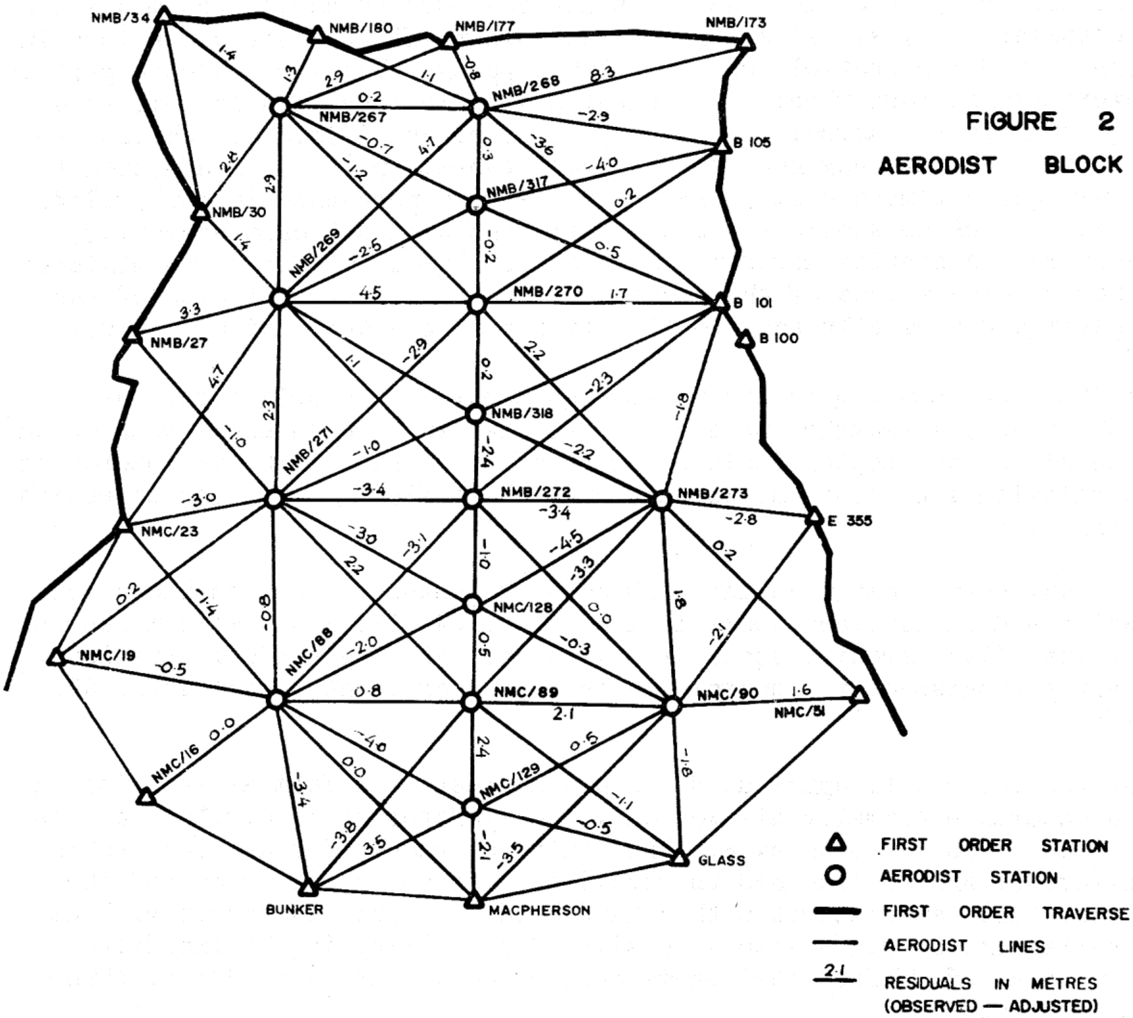


FIGURE I AERODIST LINE CROSSING

The Aerodist survey configuration was basically a series of braced quadrilaterals of measured lines, linked to and contained within the existing geodetic network, forming discrete blocks of trilateration - see Figure 2.

FIGURE 2
AERODIST BLOCK 15



Aerodist distances were measured between geodetic stations at regular intervals during each survey to calibrate the equipment. Corrections were computed and applied to all Aerodist distances.

Subsequent reductions using Aerodist charts, meteorological observations and height information enabled the spheroidal distance between the ground stations to be calculated.

Finally each Aerodist block was adjusted by least squares to the surrounding geodetic control, using program Varycord (Bomford 1967) to obtain coordinates on the Australian Geodetic Datum.

5. FIELD PROGRAM

The Aerodist survey began in eastern Australia and moved west into the more remote areas.

5.1 The Evaluation Phase 1963-64

After static testing in mid 1963 the two-channel system was mounted in a Bell 47J-2 helicopter on charter from Ansett-ANA, and airborne trials and personnel training started using trigonometric stations in western Victoria. The first new survey then followed in south-east Queensland, a ten-man field party measuring sixty-six lines in a 10 network to fix seventeen stations in six weeks to provide control for 1:250 000 mapping. The three remote parties used International four-wheel drive one-ton vehicles modified for off-road and long range work. Aerodist stations, at sites accessible by vehicle, were usually established in advance by a separate two-man party. An additional master unit and a remote unit - see plate 1 - were purchased in early 1964. They provided back-up should a channel fail, and when all were operating, made fewer remote station movements necessary. It was important to minimise the number of occupations of the ground stations as the travel time of the remote parties was usually the limiting factor on the speed of the survey.

In 1964 the mounting of the master equipment in the helicopter was improved. Co-axial switches were fitted so that the two antennae mounted on each side of the helicopter could be switched to either of the two operating masters allowing line crossing measurements while flying in either direction across the line.

The 1964 survey extended the 1963 network southward into northern New South Wales and in nineteen weeks in 1963 and 1964, 176 lines were measured to fix thirty-five Aerodist stations. With the existing geodetic stations sufficient photogrammetric control was obtained for twenty-seven 1:250 000 map areas.

The chartered helicopter used was not an ideal platform as its limited load and endurance normally allowed only one operator to be carried, and he had too much to do - see Annex B. The equipment required continuous tuning and monitoring, and he also had to record line crossing altitudes and the wet and dry bulb temperatures with a hand-held Lambrecht thermometer. The helicopter's limited range also necessitated refuelling in the immediate operation area, often from fuel drums carried on a four-wheel drive, three ton Bedford truck.

5.2 The Development Phase 1965-66

For the 1965 field program the master equipment was installed in an Aero Commander 680E high-wing aircraft chartered on a two-year contract from Executive Air Services, Melbourne. This firm remained the master aircraft contractor for the remainder of National Mapping's Aerodist program.

Installing the equipment in this aircraft was a tight fit, and required the master operator to face aft; but a second operator was carried to record and book the data.

A psychrometer was installed with a thermocouple sensing head mounted outside the aircraft to record master temperatures.

The 1965 survey extended the 1963-64 networks and, remeasured fifty lines to improve their precision. Late in 1965 measurements were made in a separate block in the Broken Hill area of New South Wales.

In 1966 Aerodist control was intensified in central Queensland and south-western New South Wales. A chain of quadrilaterals was measured westwards from Charters Towers to Mount Isa and the first offshore work was undertaken off central Queensland. A total of 310 Aerodist lines were measured and forty-nine new stations were coordinated.

The aim now was to provide control to the density and accuracy required for the 1:100 000 mapping program, which had been approved late in 1965.

Aerodist control in one degree squares with stations at thirty minute intervals around the perimeter of the photogrammetric blocks - see Annex C - was adopted to help control slotted template assemblies. Vertical control was provided by the airborne radar or laser terrain profile recorders (Wise 1979).

The servicing of the Aerodist equipment in the field had so far been done in primitive conditions by one or two technical officers. In 1966 a custom-built workshop caravan, equipped with electronic test equipment, and with space for office work and Aerodist chart and field book examination, was brought into use. Comprehensive overhauls of the equipment and field testing prior to each year's surveys also became standard practice.

From 1966 an Aero Commander 680FL (Grand Commander) was used as the master platform - see Figure 3 and Plates 2 and 3. The larger cabin allowed the equipment to be installed in shock-mounted racks and the two master operators to sit side by side facing forwards. A wild HC1 horizon camera was also installed, linked to a Vinten 70 mm camera, enabling simultaneous horizon and vertical photography during photo-trilateration measurements - see Plate 4. The Vinten camera was also used for spot photography of the Aerodist survey control points so that they could be precisely identified on the mapping photographs. This spot photography became standard procedure on all Aerodist surveys.

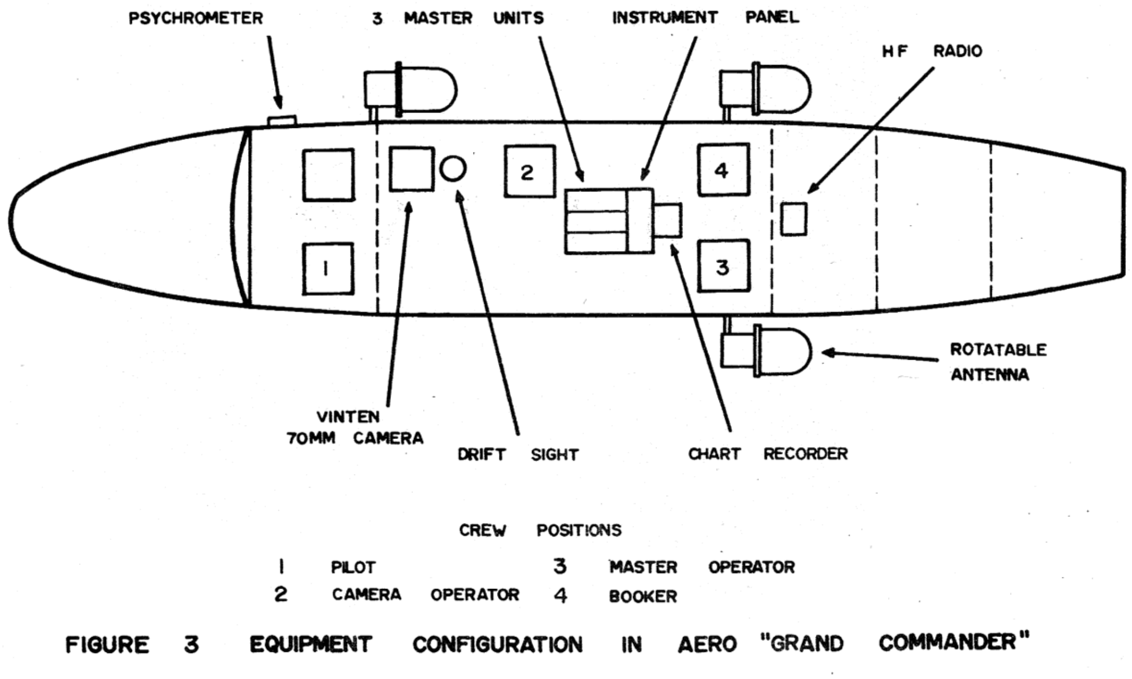


FIGURE 3 EQUIPMENT CONFIGURATION IN AERO "GRAND COMMANDER"

Plate 1 Remote equipment in use

Plate 2 Aero Commander 680 FL Grand Commander

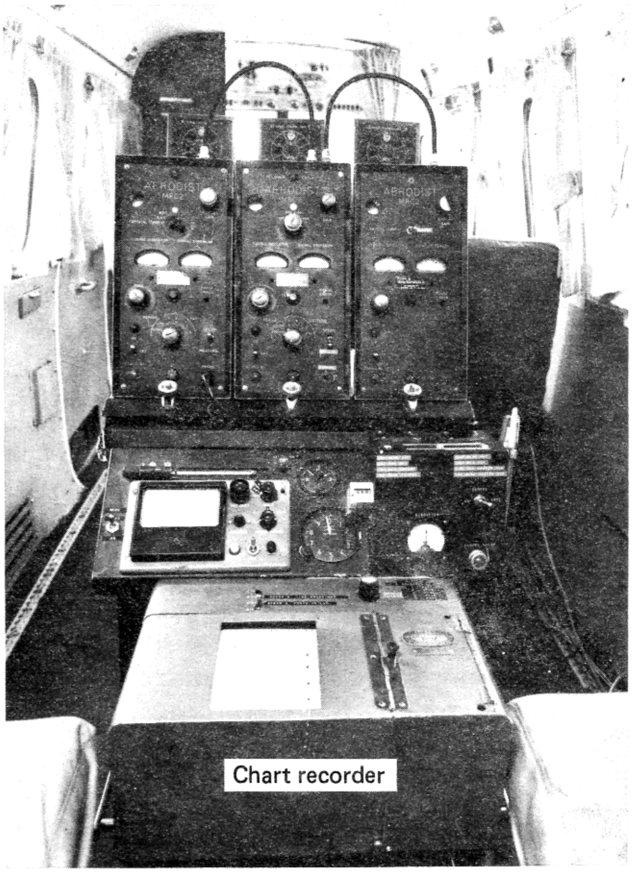


Plate 3   Master equipment

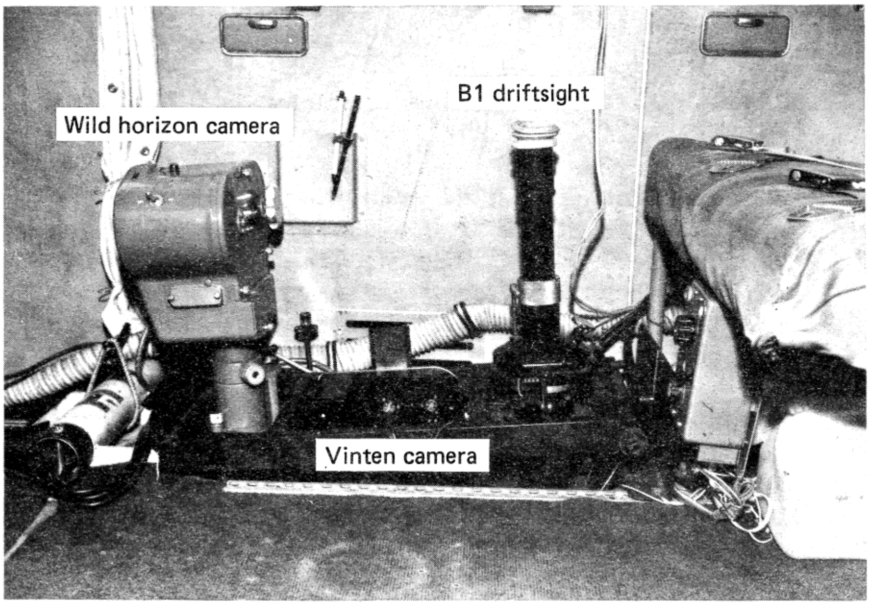


Plate 4   Photographic equipment

5.3 The Production Phase: 1967-74

By 1967 National Mapping had established satisfactory Aerodist working procedures which continued for the rest of the program.

The centre party with aircraft and workshop caravan was based at the nearest suitable landing ground. Each week an operational plan was drawn up showing remote parties, their vehicles, radio call signs, lines to be measured and the movement of parties. Subsequent changes to the program, made either by the Aerodist master operator or by the party leader, were relayed to all the field parties by radio.

From 1967 chartered helicopters were used for remote party transport in areas where ground access to control stations was difficult. Helicopter camps, with fuel supplies, were sited central to the work area.

Forward-control Landrovers were used by the field parties in 1967 but proved to be unreliable and were replaced by long-wheel-base Landrovers. International trucks continued to be used for the heavier work of towing the caravan or carrying fuel, but the lighter Landrover was the normal remote party vehicle.

An Aerodist field party typically consisted of:

Centre party:	1 surveyor, party leader 2 technical officers (Survey) 2 technical officers (Engineering) Pilot of the Aerodist aircraft
Helicopter camp:	1 surveyor 1 field assistant, fuel truck drivers Helicopter pilots and engineer
Remote parties:	4 technical assistants 4 field assistants

Aerodist field operations continued each year until 1972 when 517 lines were measured in thirty-four weeks ranging over 950 000 square kilometres in the Great Sandy, Gibson, Great Victoria Deserts and the Nullarbor Plain. This completed the main Aerodist surveys, but work continued in 1973 and 1974 to strengthen the existing network and establish control on groups of islands off Western Australia.

The table at Annex D summarises the total Aerodist field program, with more than 3000 lines measured to fix 480 stations.

Over 100 surveyors, technical officers and assistants in the Topographic Branch - later the Control Survey Branch - from National Mapping's Melbourne office worked on the field program from 1963 to 1974.

Some thought was given to the acquisition of a new system, of airborne position fixing equipment, but with the completion of the 1:100 000 mapping control and the arrival of Doppler satellite positioning equipment, the need for airborne work diminished.

Like the preceding Tellurometer traverses, the Aerodist program was a once-only task.

5.4 Phototrilateration Surveys

During the 1966 survey, an attempt was made to use the, phototrilateration method to intensify the control in the previous Aerodist areas of Queensland. This method did not require ground occupation of the new control thus enabling the survey to proceed at a faster rate.

Distances to three remotes set up at coordinated stations we simultaneously to provide a continuous fix of the aircraft's position- see Figure 4. Vertical and horizon photographs were taken throughout measurement and an event-mark was automatically recorded on the Aerodist chart at the instant of each exposure, allowing the three slant distances to each remote to be calculated. In practice, it was difficult to position the aircraft over the area of the proposed control station while record measuring traces to the three remotes, particularly as the forward antenna was mounted on one side of the aircraft fuselage.

The air coordinates at each exposure were subsequently computed by program TRILAT (Annex E) with good results, but because the horizon could not be satisfactorily located on the HC1 photography and the metric quality of the Vinten photography was poor, ground coordinates could not be accurately derived.

The technique was used again without the HC1 camera in 1973, to establish lower order control on offshore features off the north-west c of Western Australia.

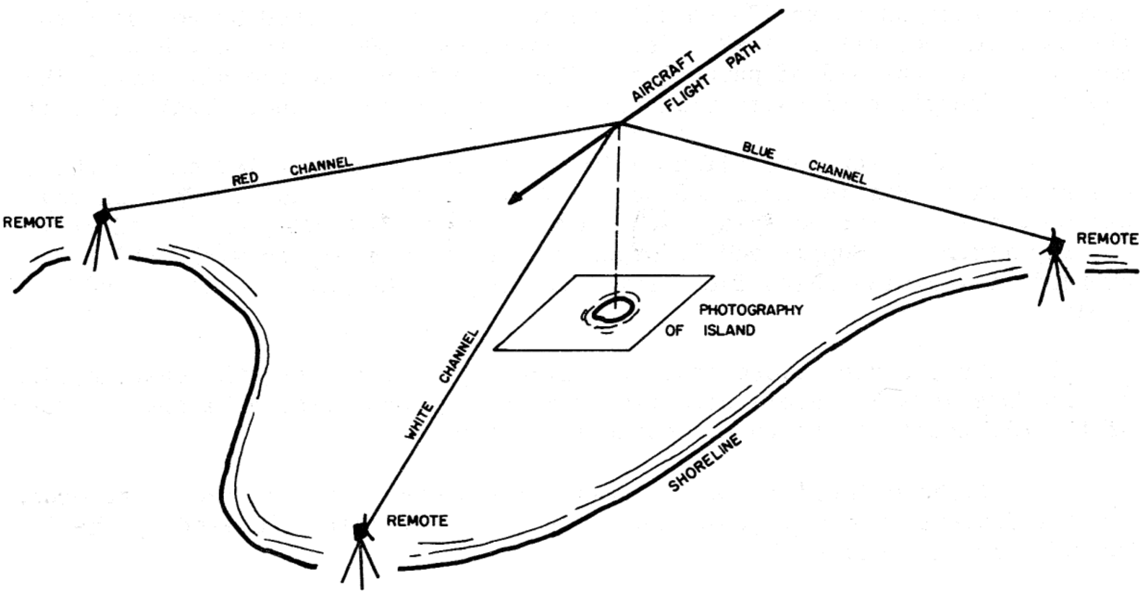


FIGURE 4 AERODIST PHOTO TRILATERATION

5.5 Offshore Surveys

A number of Aerodist surveys were undertaken between 1966 and 1971 over the Great Barrier Reef from Fraser Island to Papua New Guinea. Other surveys were made to islands off On slow and Port Headland in the Recherché Archipelago in Western Australia in 1973. These surveys presented special problems of transport, station establishment and network design.

The initial offshore survey using the normal line crossing technique was conducted in a two-week period in September-October 1966. Forty lines varying in length from 35 to 180 km were measured, connecting PAN triangulation stations on islands off the Queensland coast between Bundaberg and Proserpine to the mainland first-order traverse. The RAN survey vessel HMAS Paluma, supplemented by locally hired boats, was used to transport the remote parties between the islands.

Ground reflections due to the steep topography at many of the stations caused problems, and on many lines usable measurements were only obtained by flying at very low line-crossing altitudes.

In 1968, HMAS Teal, a coastal mine-sweeper, transported a National Mapping reconnaissance and station-marking party around the central Barrier Reef. This party also established local survey control by running Tellurometer traverses from the Aerodist stations and fixing stations on various features including shipwrecks and shifting sand cays.

To help recover marks on shifting sand cays, permanent marks were established in nearby live coral.

Following the computation and adjustment of the coordinates of the 1966 survey, the Aerodist network was extended seawards in 1969 and 1971. Ten offshore stations up to 500 km off the coast were connected by Aerodist to the existing network in 1969. Several lines over 300 km in length were measured with the aid of parabolic reflector antennae on the aircraft. The RAN again supplied offshore transport using the mine-sweepers, Teal and Gull.

The final Queensland offshore Aerodist survey was carried out in the northern Great Barrier Reef and across Torres Strait in 1971. This survey was supported by two vessels, the Cape Pillar and Cape Don, chartered from the Department of Supply and Transport. They were equipped with LARC amphibious vehicles which facilitated landing at the various islets and reefs.

The shore-based remote station parties operating along the eastern side of the Cape York Peninsula were transported by a chartered helicopter because of the difficult access to the geodetic stations.

The offshore Aerodist network was cantilevered out from the first order coastal traverse, the design of the network being largely dictated by the location of suitable reefs.

During the Great Barrier Reef surveys, 38 Aerodist stations were coordinated on offshore features and 160 lines were measured, the two longest exceeding 373 km.

A number of the offshore stations were reoccupied from 1978 by National Mapping survey parties using JMR Doppler positioning equipment. The resulting computations showed that one of the Aerodist station coordinates was in error by fifty metres but the remaining differences were less than ten metres, with an average of about 6 m. The gross error was due to misinterpretation of poor Aerodist charts.

5.6 Station Marking

Aerodist stations were normally established as a separate operation in advance of the measuring surveys, and involved the reconnaissance, selection and marking of the stations. Where feasible, Tellurometer connections were measured between the Aerodist stations and stations on the geodetic network to strengthen the Aerodist configuration.

Marking surveys were generally undertaken by National Mapping parties, with the exception of thirty-eight stations established in western Queensland in 1967 and twenty-one in the eastern Northern Territory in 1968-69 by survey firms on contract.

The working party usually consisted of a surveyor and up to ten technical staff, often with the aid of a helicopter in remote areas.

The main site selection criteria were:

> The station was to be located within five kilometres of the normal point for 30' quadrilaterals, and within eight kilometres for 1º quadrilaterals; and preferably within the lateral overlap of the mapping photographs.
>
> The site was to be selected with a view to permanency and ease of future location and access.
>
> Rays to adjacent stations were not to be obscured by natural or man-made features located within 5º either side of a ray or within an elevation of 1º.

Stations were heighted by spirit levelling if a bench mark on a known datum was within eight kilometres; otherwise a barometer height traverse was run to provide provisional heights for Aerodist line reductions. Station heights on the Australian Height Datum were subsequently provided by a separate program of third-order levelling.

Topographic Instruction 1/7/1 (Natmap 1965) sets out the Aerodist station marking procedures.

6. COMPUTATIONS

6.1 General Procedure

The Aerodist charts were examined in the field to confirm that at least seven usable crossings had been obtained for each line, by checking that the line had been crossed and that the summed distances either side of the crossing were at least 80 m greater than the minimum sum.

Coarse distances were computed on at least two runs, checking that B, C, D patterns were present on all runs. The field book information was checked particularly any eccentric mark details - see Annex F.

Charts and field books were sent by air to the office where three or four officers were continuously engaged on reductions, supplemented by field party members between field trips.

Height differences between the remotes and the air station were determined from differential air pressures recorded at the instant of each line crossing. The digital "Mechanism" remote barometers were calibrated regularly and correction graphs drawn. Aircraft altimeter height were checked regularly by flying the aircraft directly over an Aerodist remote station at various altitudes and comparing the measured distance to the distance calculated from the pressure differences. Aircraft altimeter corrections were derived, and if significant, applied prior to the distance reductions.

Corrections to Aerodist distances were applied by comparing calculated distances between geodetic stations with the measured Aerodist distances during discrete operational periods.

The transmitted A frequency used for measuring was subject to minor phase defects resulting in inaccurate measurements. To overcome this a so-called negative A trace was recorded and the arithmetic mean value of positive and negative A gave a correct A reading.

It became a standard procedure to record a short section of A+ and A- traces from the remote instruments at the start and finish of each line measurement.

Each run was broken out and the chart values at twenty-one spaced regularly points along the chart were read off and transcribed to data sheets with the relevant field book and station information.

The data was punched on to cards by a service bureau and batch jobs were run through the CSIRO computing network, initially on a Control Data 3200 computer, later on Control Data 3600 and 7600 computers.

Ambiguities due to poor Aerodist chart traces and incorrect station data could be resolved by computing each quadrilateral. Preliminary coordinates of the new stations were computed by intersection (program Intsect - see Annex G) using a minimum, of three Aerodist distances radiating from previously coordinated stations.

Preliminary coordinates and the proven distances resulting from the Intsect run were used as initial data in program Varycord, weighting distances and azimuths inversely to the 1ength of the lines. Several iterations of Varycord were necessary.

6.2 Aerodist Line Reductions

Line crossing data, in the form of a continuous strip-chart recording the changing ranges from the aircraft to the two remote stations, had to be reduced to the spheroidal distance between the stations.

A minimum of seven good line crossings were measured and the mean of the separate reductions adopted.

A range to a remote station was transformed by the recorder from a phase difference between the emitted and received signals of the primary ‘A’ frequency.

A zero or 360º phase difference deflected the pen to the top of the chart, while a 180º phase difference deflected the pen to the bottom of the chart. The maximum pen deflection was set equal to the width of chart, enabling the distance to be read at any instant.

As the changing deflection of the pen was similar when the distance was increasing or decreasing, an ambiguity resulted that was resolved by a second pen trace, which had two positions. A downward deflection of this pen indicated a phase difference in the range 0º to 180º (0-50 metres) while an upward deflection indicated 180º to 360º (50-100 metres).
To determine the whole number of wave lengths ("the coarse figure") of which the A frequency gave the final fraction, three additional frequencies (B, C, D) were automatically transmitted and recorded for short periods at regular intervals. These frequencies were such that the values read from the chart, when subtracted from the A frequency, gave the tens of thousands of metres, thousands and hundreds respectively.

The sum of the two distances between the aircraft and each end station reached a minimum as the line was crossed. Summed distances at ten points equally spaced in time either side of the minimum were used in each reduction. These sums were plotted against time, producing a parabola, whose minimum value was the sum of the two distances at the instant of line crossing - see Figure 5. The minimum sum was determined by fitting a parabola to the 21 points by least squares. Each minimum sum was reduced to a spheroidal distance.

Using the atmospheric pressures and wet and dry bulb temperatures recorded at the ground and air stations the refractive index of the air between the stations was calculated for each run.

The refractive index was calculated from:

$$n = 1 + 77.601 * 10^{-6} (P + E) / (273 + t)$$

where $E = 4744e / (273 + t)$
and P is the mean barometric pressure in millibars
t is the mean dry bulb temperature in degrees centigrade
e is the vapour pressure.

As the A frequency gave a direct chart readout in metres using a mean refractive index of 1.000330, the corrected path length L was given by:

$$L = 1.00033 * d/n$$

where n is the calculated refractive index of the air between the stations, and d is the minimum distance extracted from the chart.

For an aircraft height (master station) h_2, and ground height (remote station) h_l, the chord length C at sea level is given by:

$$C = [\ R / (R + h_1)\ ] * [L^2 - (h_2 - h_l)^2]^{\frac{1}{2}} * [\ (1 - h_2 - h_l) / 2R]$$

where R is the radius of the earth, for which a mean value of 6 365 000 m was adopted.

The spheroidal distances were calculated by adding the chord-to-arc correction:

$$S = C + C^3 / 43R^2$$

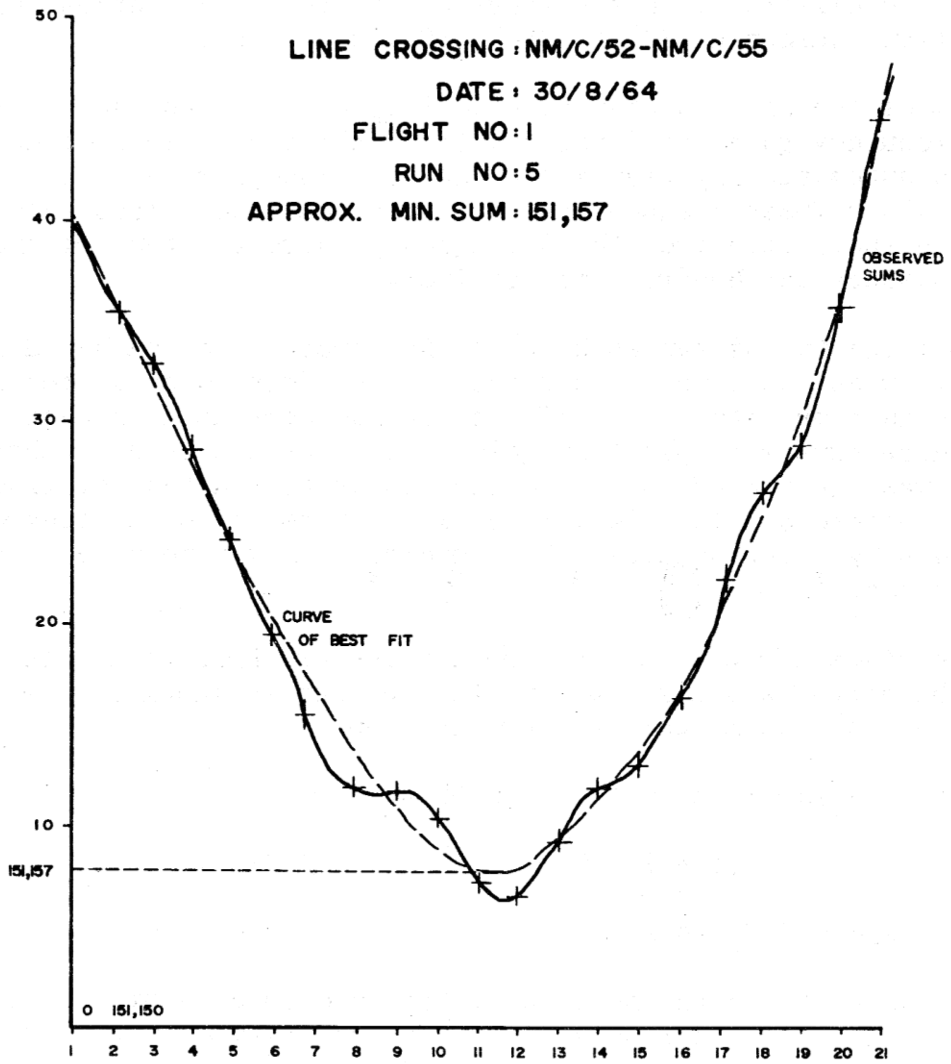


FIGURE 5 LINE CROSSING GRAPH

Eccentric corrections to the ground mark were added where necessary, and a correction was added for the separation of aircraft antenna.

The final accepted distance was the arithmetic mean value of at least seven runs. The range between the maximum and minimum values on any line was usually about five metres.

Computer programs (AERO, AERONU, -see Annex H) were written to compute the corrected spheroidal distance from the manually derived chart data and the field book information.

6.3 Chart Reader

A strip chart conversion unit developed by the CSIRO Division of Land Research and Regional Survey was purchased in 1966 to automate the time consuming manual extraction and reduction of Aerodist data.

The Aerodist chart trace was converted to a digital record on punched paper tape allowing direct input to the computer. The field book and station data was punched on cards and software written for the complete reduction from the breakout of the chart through to the final spheroidal distance.

The system was run with moderate success in parallel with the manual reduction for several years but because of increasing mechanical and electronic problems with the reader it was eventually discarded in favour of manual reduction.

6.4 Accuracy

Aerodist measurements of known geodetic distances were made as the surveys progressed. The difference seldom exceeded five metres. When they did, the reasons were usually apparent:

> Poor quality A traces, due to marginal equipment performance, long lines, or steep outlooks at remote stations causing large ground swings.
>
> Blunders in eccentric station connections.
>
> Inaccurate meteorological observations.
>
> Misreading the aircraft altitude at the line crossing, subsequently overcome by reading two altimeters, one imperial and the other metric.

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 fixes at a number of Aerodist stations verify that the Aerodist coordinates are accurate to better than 5 metres, with the exception of the one offshore station mentioned above.

ACKNOWLEDGEMENT

The author wishes to thank his colleagues in the Division of National Mapping who assisted with the preparation and editing of this report.

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Annex A

AERODIST EQUIPMENT - MAJOR PURCHASES AND MODIFICATIONS

1963	Purchase of Aerodist model MRC2: 2 master, 4 remote units, chart recorder, rotatable master antennas, ancillary equipment.
1964	Modification of aircraft antenna switching by manually changing cables.
1964	Purchase of 1 master, 1 remote unit.
1965	Purchase of 1 remote unit.
1966	Modifications of 1 remote unit to two frequencies.
1966	Purchase of 3 master units.
1967	Modification of 2 remote units to two frequencies.
1968	Purchase of spare chart recorder.
1969	Purchase of 2 remote dipole assemblies and bases for new fixed master antenna.
1971	Modifications to remote units to enable front panel control of A+ A- switching and Klystron coarse tuning. Crystal calibration was also made more accessible to the operator.

Annex B

GUIDANCE NOTES FOR AERODIST MASTER OPERATORS

Preliminary

1. Check psychrometer bottle for water and check evaporation sock for wetness before take-off.

2. Switch on Aerodist master, chart recorder, intercom, radio and psychrometer as soon as aircraft is airborne. Master equipment requires 20 minutes to warm up.

3. Check for crystal current after a few minutes - tweak triode if necessary for maximum reading. Klystron tune should be at the centre of its run, about 7 turns from either end.

4. Check master modulation (mod) after warm up time - A75, B75, C75, D65.

5. Switch the remotes to H.T. 15 minutes before they are required. Tune in and check for performance whilst ferrying into the measuring position, if possible.

6. Cheek the A, B, C and D crystal visual displays on both units.

7. Adjust the topping and bottoming of the chart recorder channels.

8. Check chart for quality trace and correctness of aircraft headings.

Tones and Mod Checks to Remotes

a) Tones (instruments in measure mode)

Master switches to D.

Remote switches to D tone position and adjusts switching level until D goes negative.

Master stays on D.

Remote switches to A and remote adjusts switching level so that A reads 15 - 25 on meter.

The same procedure can be used to clean up B and C if one is in doubt.

b) Mods

Remote goes to MOD.

Master switches to A.

Remote adjusts A mod to read 75 then asks master for B.

Master switches to B.

Remote adjusts B to read 75 then asks master for C.

Master switches to C.

Remote adjusts to read 75 then asks master for D.
Master switches to D.

Remote adjusts D to read 65 and informs master.

To Adjust Switching Levels and Mods in Master

If it is suspected that the master is not switching a pattern in, i.e. not switching on either channel, then adjust the tone levels.

Go to measure and turn function switch to mod.

Select A on pattern switch and adjust the mod with a screwdriver to read 75.

Select B on pattern switch and adjust B mod to minimum.

Adjust B tone gain control to 15-20.

Readjust B mod to 75.

The signal now comprises 15-20 tone and mod 75.

Repeat this for C - 15-20 tone and mod 75.

Repeat for D - 15-20 tone and mod <u>65.</u>

Aircraft Headings

As soon as the aircraft is lined up to come into the crossing position and sufficient signal strength is obtained, briefly check the chart to determine aircraft position in the sky. If equipment adjustment is necessary, determine where the crossing is and ask the pilot to fly backwards and forwards on long runs until the units are set up. This is quite important as the aircraft may fly out of the effective heading range of remotes whilst equipment is being set up.

Heading Changes

To facilitate heading changes it is helpful to have previously determined the bearing of the perpendicular to the line to be measured. Apart from consideration of aircraft drift due to wind, the heading of the aircraft should be within plus or minus 7 degrees of the perpendicular bearing.

To flatten a steep increasing trace the aircraft must be turned towards the station providing that trace. Similarly, to steepen a flat increasing trace, the aircraft heading must be turned away from that station.

If both traces are too flat the heading is too square and must be altered constantly in either direction until one trace is flat and one trace is steep.

If both traces are too steep head more square to the line.

If both traces are decreasing evenly the heading must be changed to force one trace to "turn-over" and start increasing.

An alternate foolproof procedure to correct headings without prior consideration is to always ask for MINUS 5º first and watch for the immediate effect on the trace. If adverse, immediately follow with a PLUS 10º correction and add further 2 or 5 degree increments where appropriate.

If the initial minus 5º heading change has a beneficial effect, continue to take off degrees until the correct heading is obtained.

<u>Low Signal Strength</u>

The usual procedure is to go closer to the station yielding low signal strength and gain altitude. However the problem is sometimes best overcome by decreasing altitude.

<u>Aircraft Altitude</u>

As a general rule about 1000 feet of altitude for every 10 miles of line length produces good charts e.g. 60 mile line - 6000 feet altitude. However 1000 feet less is sometimes better, depending on terrain. To lessen the effect of height errors, the aircraft altitude should, as a general principle, be kept as low as possible.

<u>Interference</u>

If the trace repeatedly breaks or is poor with a sudden loss of signal strength at a particular point on the run this indicates that there may be interference on line, such as a tree, cairn or high ground. Generally the aircraft will need to gain a higher angle on the ray path from that station by going closer or higher. The remote setup may also be shifted in the case of local interference.

<u>Trouble Shooting</u>

<u>Master:</u>

1. If no signal is picked up from a remote, confirm that the remote is switched on and pointed at the right line.

2. Cheek that correct antenna connections to required Masters are being used, and check that the antenna switch is in the appropriate position for the present aircraft heading.

3. If contact is made with a remote, but signal strength is low, the remote should DF (Direction Find) slowly.

4. If contact continues to be poor, but speech communication exists, check triode tune on remote and transmission on remote. Have remote operator check reflector tune and maximum deviation position on his unit.

5. If signal strength is good, but there is no speech to one remote either way, and no FM is received, it is most likely that the lead to the remote IF is disconnected, or faulty.

6. If the signal strength is adequate, but the A trace very noisy or wide, whereas B, C and D are clean, check that A pattern is not over-modulating by first checking the master, and then having the remote operator reduce his switching level to zero. If this gives a clean trace, the problem is then reduced to setting up mods and tones. If only one pattern is clean, it suggests that this pattern is not switching out and is overlaying each of the other patterns. Generally, if there is no technician in the plane, take adequate notes and keep the chart for reference so that

the fault can be diagnosed on the ground. Try to determine whether the malfunction is the Master or Remote by trying other remotes of the same colour if available.

<u>Length of Line</u>

A difference of 200 metres should be aimed for, between the MINSUM from the crossing sum and the sums at the ends of each run.

Less than 100 metres difference is unacceptable.

A cross should be made on the chart at the crossing point and 200 metres counted from there, allowing more for head wind where necessary to avoid a short run-in in the other direction.

<u>Booking</u>

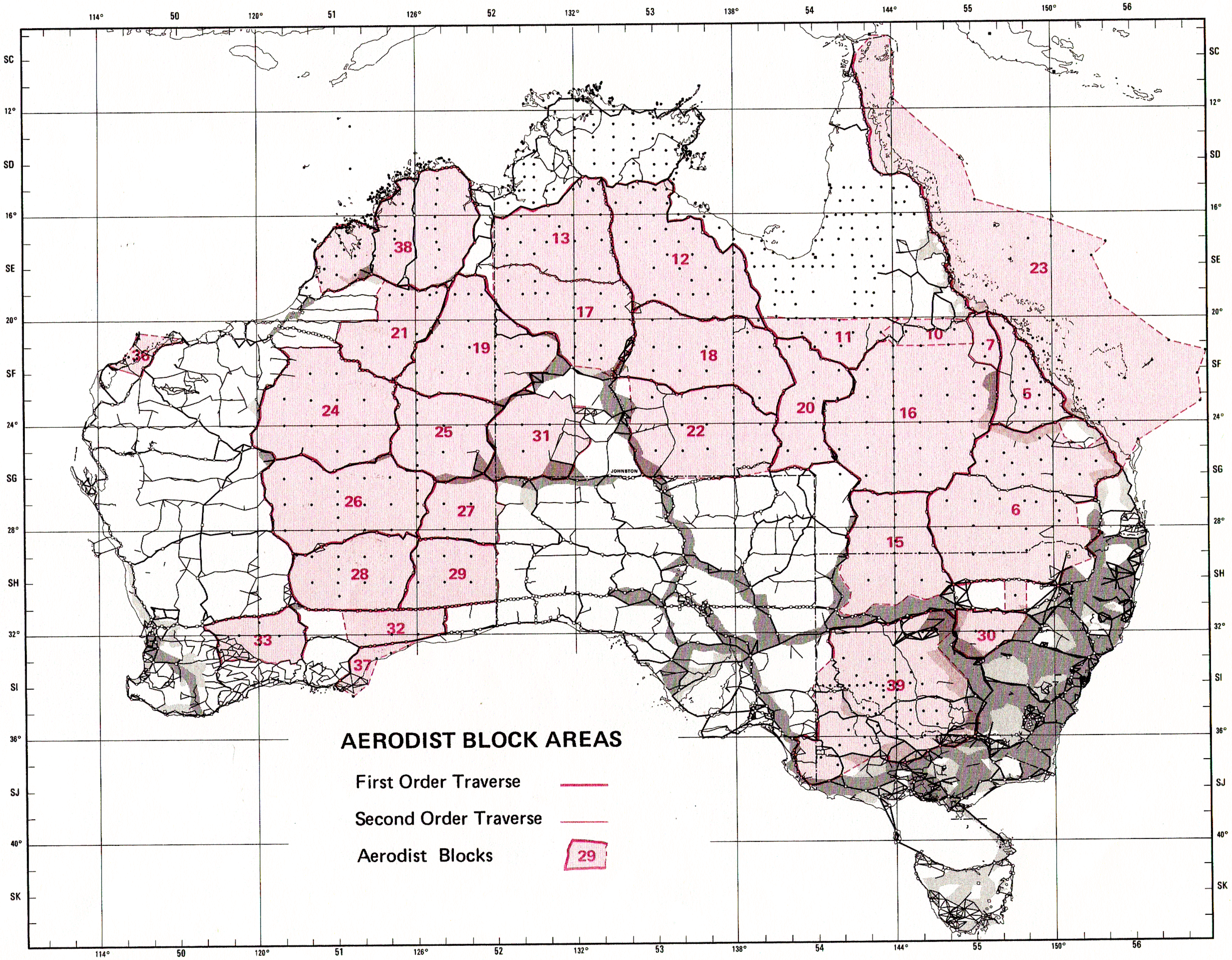
All marginal lines should be booked unless obviously hopeless, and a short annotation made if the line is considered unusable. Seven acceptable lines is the minimum requirement, and an extra one should always be taken where the aircraft has to head back through the line at the finish.

The foot and metric altimeters should ideally be read simultaneously at the crossing point, and at least one set of readings should be compared by the feet to metres conversion graph as a gross error check.

The readout on the psychrometer thermocouple is in volts, where 0.4 volts equals 10 degrees. Care must be taken to ensure that values are read on the correct scale. If in doubt about the wet bulb reading, the sock should be checked in flight.

<u>Navigation</u>

A visual check on the pilot's navigation during ferry flight and approaches to crossing lines is well worthwhile, and sometimes explains perplexing problems of poor signal strength and strange charts.



NMP/80/054

Annex C

Annex D

WORK COMPLETED

YEAR	AERODIST BLOCK ADJUSTMENT NUMBER AND GEOGRAPHIC AREA	CONTROL STATIONS FIXED	LINES MEASURED
1963	ADS BA 6 – Queensland	17	66
1964	ADS BA 6 - extended into northern New South Wales	18	110
	ADS BA 5 – Queensland		
1965	ADS BA 5/BA 6 - existing net intensified	11	150 (50 re-measured)
	ADS BA14 (part BA39) - New South Wales		
1966	ADS BA 5/AB 6 - intensification & phototrilateration	49	310
	ADS BA 7, BA10 – Queensland		
	ADS BA 8 (part BA23) - offshore central Queensland		
	ADS BA39 (includes BA14, BA34, BA35) - New South Wales and Victoria		
1967	ADS BA11 - Queensland	60	315
	ADS BA12 - Northern Territory		
	ADS BA13 (part) Northern Territory		
	ADS BA39 - extended & intensified		
1968	ADS BA13 - completed	40	223
	ADS BA15 - Queensland, New South Wales		
	ADS BA17 - Northern Territory		
	ADS BA23 - Southern Great Barrier Reef		
1969	ADS BA12 - new stations on Qld-NT Border	50	259
	ADS BA15 - completed		
	ADS BA16 - Queensland		
	ADS BA20 - Queensland		
	ADS BA23 - Great Barrier Reef		
1970	ADS BA17 - completed	50	390
	ADS BA18 - Northern Territory		
	ADS BA22 - Northern Territory		
	ADS BA31 - Northern Territory		

1971	ADS BA18 - completed	40	254
	ADS BA19 - Northern Territory & Western Australia		
	ADS BA21 - Western Australia		
	ADS BA23 - northern Great Barrier Reef		
	ADS BA30 - New South Wales		
1972	ADS BA21 - completed	80	517
	ADS BA24 - Western Australia		
	ADS BA25 - “		
	ADS BA26 -- “		
	ADS BA27 -- “		
	ADS BA28 -- “		
	ADS BA29 -- “		
	ADS BA33 -- “		
1973	ADS BA32 - Western Australia	50	327
	ADS BA39 - control intensification		
	ADS BA36 - Onslow - Monte Bello offshore, WA		
	ADS BA37 - Recherché Archipelago, WA		
1974	ADS BA38 - Western Australia	15	100

Topographic Survey Branch.

Division of National Mapping

Program TRILAT

AERODIST TRILATERATION

Fortran Computation Data

1	8	42	47	56	63	65	69
SURVEY	BA 36 TRYAL ROCKS EAST TRITESTS	DATE	09/09/73	FLIGHT	1	RUN	03

	Stations (1)	Latitude Deg. (15)	Latitude Min. (18)	Latitude Sec. (21)	Longitude Deg. (28)	Longitude Min (32)	Longitude Sec (35)	Temp. °F Dry (42)	Temp. °F Wet (47)	Press. (mb) (53)	Height (ft) (61)	Ecce. Corr. (m) (67)	Ant. Corr. (m) (73)	Index Corr. (m) (77)
A	TSC	20	24	59·499	115	34	25·299	74·8	65·10	1011·84	89	0·0	·	−1·5
B	TSH	20	51	07·340	115	20	23·338	77·9	65·10	1010·71	121	0·0	·	+1·3
C	NMF653	20	39	23·409	115	34	33·954	75·6	64·40	1012·26	72	0·0	·	+3·0
	AIRCRAFT	20	16	30·000	115	23	00·000	17·0	0·00	0·08	2235	No. of Fixes =	2·0	

	Stations A (5)	Stations B (12)	Stations C (19)		Stations A (32)	Stations B (39)	Stations C (46)		Stations A (59)	Stations B (66)	Stations C (73)
1	5	12	19	28	32	39	46	55	59	66	73
011	25100	64914	47103	012	24991	64832	46994				
Unit	RED 1	WHITE 3	BLUE 3	Field Book	NM12537	NM12530	NM 12544	A/C Field Bk.	NM 12617	Photo Field Bk.	NM —

Notes: (1) Temperatures for ground stations are to be entered in degrees farenheit.

(2) For aircraft readings: enter Reference temperature in degrees centigrade under column "Dry".
enter Diff. Dry in meter's units under column "Wet."
enter Depress. in meter's units under column "Press. (mb)".
enter Ind. Alt. corrected for index error of altimeter under column "Height (feet)".

(3) Enter camera exposure distances in sequence across the page, as enumerated, before commencing a new line.

Compiled: R W Gold	Checked: E Zang
Date: 10/4/74	Date: 10/4/74

PROGRAM TRILAT – DATA SHEET

ANNEX E

PROGRAM TRILAT - OUTPUT

SURVEY BA 36 TRYAL ROCKS WEST TRITESTS DATE 09/09/73 FLIGHT 1 RUN 03

STATION	LATITUDE	LONGITUDE	DRY	WET	PRESS	ELEV	ECCE	ANT	IND	A/C ELEV
TSC	20. 24. 59.499	115. 34. 25.299	74.7	65.30	1011.98	89.	0.0	-0.0	-1.5	764.6
TSH	20. 51. 7.340	115. 20. 23.338	77.7	64.40	1010.70	121.	0.0	-0.0	1.3	765.2
NMF653	20. 39. 23.409	115. 34. 33.954	77.0	65.30	1012.10	72.	0.0	-0.0	3.0	762.0
AIRCRAFT	20. 16. 30.000	115. 23. 0.000	18.0	0.00	.19	2370.	-0.0	2.0	-0.0	763.9 MEAN

EXP	OBSERVED DISTANCES			REDUCED DISTANCES			ADJUSTED DISTANCES			LATITUDE	LONGITUDE	EXP
20	25082.0	64012.0	46618.0	25069.9	64004.9	46609.8	25067.7	64003.0	46613.4	20 16 32.017	115 23 8.959	20
21	25018.0	63958.0	46547.0	25005.9	63950.9	46538.8	25002.3	63947.7	46544.9	20 16 33.911	115 23 10.244	21

Date: 23/4/66	Flt.: 1	Line: NM/C/39 TO ULALU (TRIG)
A/C: EXZ	Pilot: I. BELL	NOTES: R.A. VASSIL Operator: C. McMASTER
Take off: E.S.T. 0850	Land: 1145	Base: HAY, N.S.W.

Remote Positions		
Red 1	ULALU (TRIG)	(G.J.)
White 2	NM/C/39	(P.W.)
Blue –	–	

Run	Time E.S.T.	Head	Signal Strength 1 Red	White 2	~~Blue~~	Atmospherics 1 Dry	2 Dep.	Alt. FEET	
						REF. TEMP. 19.7°C			
1	1032	135	17	22	–	0.47	0.135	5850	
2	1038	310	25	25	–	0.52	20.6 0.135	5820	✓
3	1041	135	33	19	–	0.525	20.8 0.13	5830	✓
4	1044	315	27	22	–	0.52	20.7 0.125	5830	✓
5	1046	130	30	19	–	0.51	20.4 0.125	5820	✓
6	1050	315	27	22	–	0.48	20.3 0.125	5810	✓
7	1053	135	33	20	–	0.49	20.3 0.127	5810	✓
8	1056	315	27	22	–	0.49	20.4 0.118	5810	✓
9	1059	140	32	21	–	0.48	20.2 0.12	5830	✓
10	1103	315	25	22	–	0.47	20.4 0.12	5850	✓
11	1106	135	31	18	–	0.49	20.7 0.117	5830	

Height Checks END. RAV

Time	Altitude	Position

Met Conditions 1/16 CIRRO ~~AND~~ ALTO STRATUS
WINDS SSE. 10 TO 15 KNOTS
A LITTLE CUMULUS ALTO STRATUS
FAIRLY CLEAR HORIZON

Topo. Conditions
SANDY, LEVEL PLAINS.
SCATTERED CLUMPS OF TREES

Equipment Performance
REF. TEMP. HAD SOME SUN ON RUN 2 ~ Cabin Temp is fluctuating
✓ Denotes Good Run.
On Easterly side of Line Crossings – Terrain Difficulty
1054 hrs: MODS: A 70, B 70, C 70, D 65

Remarks
NOISE ON RED 1, TREES 50 YARDS AWAY ON LINE, AT ULALU – FOR RUN 1.
Co-AX. POSITION 2 FOR RUN 2
RUN 1 IS VERY POOR.

AERODIST REMOTE FIELDBOOK

Barometer No.: 33

Psychrometer No: 29574

Met. Conditions: 5/8 CLOUD COVERAGE 10-15 KNOT S-E WIND.

Topo. Conditions: FROM HIGH CLEARED HILL ACROSS HIGH HEAVLY TIMBERED UNDULATING COUNTRY

Equipment Performance:

Remarks.

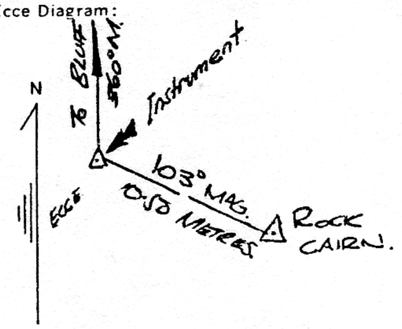
Eccentric Station Data.

Ecce Mark: IS A 3/8" COPPER TUBE SET IN CONCRETE

Ecce to Station Mag. Brg.: 103° MAG.

Distance: 10.50 METRES.

Ecce Diagram:



Instrument stand point to be clearly indicated on Ecce. Diagram.
Distences to be in METRES

Date: 28TH JUNE 65	Inst.: BLUE 1	Location: FAIRHILL
Operator: B. YARLEY	Inst. Brg.: 360° M.	To Station: THE BLUFF

Run	Time	Temp.		Pressure				Meter Readings.					
		Dry	Wet	1	2	3	Mean	Dev.	Trans.	+300 v	+ 6 v.	Batt.	S.S.
1	1600	59.5	51.2	2150	2140	2160	2150	5	.59	67	58	76	40
2	1603	59.6	51.3	2150	2140	2160	2150	5	.59	67	58	76	34
3	1606	59.0	51.1	2155	2145	2160	2153	5	.59	67	58	76	36
4	1616	59.0	51.2	2155	2145	2160	2153	5	.55	67	58	76	35
5	1618	58.9	51.1	2155	2145	2160	2153	5	.55	67	58	76	34
6	1620	58.7	50.9	2155	2145	2160	2153	5	.55	67	58	76	36
7	1622	58.9	51.0	2155	2145	2160	2153	5	.55	67	58	76	34
8	1626	58.0	50.5	2155	2145	2160	2153	5	.55	67	58	76	33
9	1628	58.0	50.6	2155	2145	2160	2153	5	.55	67	58	76	33
10	1630	58.1	50.7	2155	2145	2160	2153	5	.55	67	58	76	32
11	1633	57.8	50.0	2155	2145	2160	2153	5	.55	67	58	76	30

PROGRAM INTSECT

VARIABLE HEADING FOR OUTPUT

NO. OF STATIONS	7	AERODIST BLOCK ADJUSTMENT 29 1972

STATION NAME	LATITUDE Degs.	LATITUDE Mins.	LATITUDE Secs.	LONGITUDE Degs.	LONGITUDE Mins.	LONGITUDE Secs.	DISTANCE Metres
NM F 224 R.M.	30	51	31·896	128	01	58·145	138119·84
NM F 84 R.M.	30	57	07·287	127	02	45·278	105742·07
NM F 74 R.M.	31	00	50·780	125	55	43·136	151906·34
NM F 646	30	30	17·982	126	00	32·678	109966·43
NM F 643	30	00	24·436	125	59	55·866	95830·53
R 199	29	24	51·317	125	54	15·644	123630·89
NM F 639	28	59	27·312	125	59	45·960	147724·93
NM F 644 INTERSECTED POINT	30	00	0·0	127	00	0·0	

Compiled - B.W. 13.8.74
Checked - P.L. 14.8.74

PROGRAM INTSECT - DATA SHEET

ANNEX G

PROGRAM INTSECT - OUTPUT

TITLE
NO OF STATIONS 7 AERODIST BLOCK ADJUSTMENT 29 1972

NEW COORDINATES		LATITUDE	LONGITUDE
NM F 644	INTERSECTED POINT	29 59 57,606	126 59 31,412

STATION	LATITUDE	LONGITUDE	OBS DIST	ADJ DIST	DIFF
NM F 224 R,M,	30,51, 31,896	128, 1, 58,145	138119,84	138116,59	3,25
NM F 84 R,M,	30,57, 7,287	127, 2, 45,278	105742,07	105742,49	-,42
NM F 74 R,M,	31, 0, 50,780	125,55, 43,136	151906,34	151907,07	-,73
NM F 646	30,30, 17,982	126, 0, 32,678	109966,43	109963,89	2,54
NM F 643	30, 0, 24,436	125,59, 55,866	95830,53	95831,54	-1,01
R 199	29,24, 51,317	125,54, 15,644	123630,89	123632,48	-1,59
NM F 639	28,59, 27,312	125,59, 45,960	147724,93	147720,40	4,53

AERODIST LINE REDUCTION

COMPILED: P. LANGHORNE
CHECKED: C. McMASTER

PROGRAM AERONU

AERODIST PROJECT	DATE	STATION	HEIGHT (MS)	CORRN.	STATION	HEIGHT (MS)	CORRN.	ANT SEP.
SURVEY BA 19	21/ 6/71	NMF 597 E	420·3	4·0	NMG 252 E	492·9	0·0	1·5

RUN	SUB.CONSTANT	PROP. PARTS		DRY °C	WET °C	PRESS. (MBS)	TERMS 1 TO 11										
1	102200	499	523	19·3	8·6	971·2	178	147	118	97	75	54	42	33	20	14	12
REF. TEMP	DIFF.DRY	DEP	A/C ALT.(MS)	DRY °C	WET °C	PRESS. (MBS)	TERMS 12 TO 21										
20·9	0·44	·48	2067	19·2	10·4	963·8	155	127	100	79	62	48	32	21	14	10	
2	102200	468	554	19·3	8·7	971·0	96	74	61	50	38	31	21	18	14	13	11
21·0	0·46	·48	2073	19·8	9·2	963·8	109	91	77	65	42	36	32	22	18	14	
3	102200	478	544	19·5	8·7	971·0	159	131	104	84	63	48	32	22	17	12	11
21·0	0·46	·48	2067	19·4	10·2	963·7	173	142	105	90	70	51	38	28	21	10	
4	102200	482	540	19·6	8·8	971·0	100	80	63	49	43	35	22	16	14	13	12
21·0	0·46	·48	2070	19·2	9·2	963·7	105	86	73	59	49	37	24	19	14	12	
5	102200	499	523	19·6	8·8	971·0	102	100	86	72	53	42	30	21	20	15	12
21·0	0·46	·46	2067	19·3	9·4	963·5	76	62	55	45	33	24	14	12	8	9	
6	102200	466	556	19·7	8·8	970·8	110	93	76	58	47	37	31	24	15	13	13
21·1	0·47	·49	2070	19·1	8·6	963·5	101	80	67	62	39	29	22	19	17	14	
7	102200	478	544	19·7	8·8	970·8	163	130	108	86	64	50	37	26	18	15	14
21·1	0·47	·48	2070	19·6	9·0	963·4	176	147	109	96	72	50	36	27	20	16	
8	102200	501	521	19·9	8·9	970·6	166	139	106	88	66	50	27	26	18	12	16
21·0	0·46	·46	2067	19·9	11·0	963·2	168	137	111	89	69	51	33	29	17	12	END

PROGRAM AERONU - OUTPUT

SURVEY	DATE	STATION	HT.MS.	CORR.	STATION	HT.MS.	CORR.	A/C ECCE
BA 19	21 6 71	NMF 597 E	420.3	4.0	NMG 252 E	492.9	0.0	1.5

RUN	REFT	DDRY	DEPR	ALT	DRY	WET	PRES	DRY	WET	PRES	REF INDS A/C ALTS	SLOPE DISTANCES		CORR HNR		MINSUM	DIST
1	20.9	.44	.48	2067.	19.3	8.6	971.2	19.2	10.4	963.8	276.286.212.2180.2189.	49922.0	52323.1	53.5	51.3	102211.4	102145.87
2	21.0	.46	.48	2073.	19.3	8.7	971.0	19.8	9.2	963.8	276.276.211.2183.2195.	46821.0	55424.8	54.4	51.0	102212.1	102145.94
3	21.0	.46	.48	2067.	19.5	8.7	971.0	19.4	10.2	963.7	276.284.211.2177.2187.	47821.1	54424.0	53.8	51.0	102211.4	102145.83
4	21.0	.46	.48	2070.	19.6	8.8	971.0	19.2	9.2	963.7	276.278.211.2181.2189.	48221.0	54023.5	53.8	51.0	102210.8	102145.22
5	21.0	.46	.46	2067.	19.6	8.8	971.0	19.3	9.4	963.5	276.279.213.2178.2185.	49920.2	52321.1	53.4	51.0	102207.6	102142.36
6	21.1	.47	.49	2070.	19.7	8.8	970.8	19.1	8.6	963.5	276.275.210.2179.2186.	46621.0	55625.1	54.1	50.7	102212.4	102146.79
7	21.1	.47	.48	2070.	19.7	8.8	970.8	19.6	9.0	963.4	276.275.211.2179.2187.	47822.0	54425.1	53.8	50.8	102213.4	102147.98
8	21.0	.46	.46	2067.	19.9	8.9	970.6	19.9	11.0	963.2	275.287.213.2175.2184.	50122.2	52123.1	53.3	51.2	102211.6	102146.30

RUN	DISTANCE	DEVIATION	SUM RESIDUALS SQD
1	102145.87	.08	50.83
2	102145.94	.16	96.17
3	102145.83	.05	107.08
4	102145.22	-.56	79.22
5	102142.36	-3.43	174.43
6	102146.79	1.00	137.66
7	102147.98	2.20	110.55
8	102146.30	.51	142.72

MEAN 102145.79 RANGE 5.63