

**Nat Map Aerodist**

**in**

**Western Australia**

**1971-1974**

**Laurie McLean & John Manning**

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# **National Mapping's Aerodist Surveys in Western Australia 1971-74: Horizontal Control for the National Topographic Map Series**

**Laurie McLean and John Manning**

## **Introduction**

This paper describes the then Division of National Mapping's Aerodist field surveys in Western Australia between 1971 and 1974. These surveys completed the secondary survey control station network in remote areas of Australia needed to intensify horizontal control for the 1:100,000 scale national topographic mapping program. A brief outline of the history and progress of Australia's national topographic mapping coverage is given to provide the context in which National Mapping's Aerodist program was undertaken.

## **On Australian colonial mapping**

European settlement in Australia commenced in 1788 but topographic mapping coverage did not become a national government priority until about one and a half centuries later. It took a further half century to get the basic topographic mapping task completed. So why did it take over 200 years to achieve a uniform topographic map coverage of our nation?

For the early arrivals from Europe, both explorers and settlers, Australia was a vast and difficult country with a harsh and inhospitable interior. For over a hundred years the centre of the continent remained a *ghastly blank* that lacked extensive navigable river systems that could be used for transportation; there was no inland sea. Exploration was difficult and initially few resources were available for mapping away from the often struggling coastal settlements of the early colonies. Each colony was under separate control from London. Apart from exploration activities, the limited surveying and mapping resources were primarily employed in the surveying of land selections. Thus the early work had a quite separate and limited focus compared with the need to build an overall national survey framework for uniform topographic mapping.

The establishment of a geodetic survey framework as a basis for mapping away from coastal settlements was the responsibility of each separate colony. However, little progress was made in the mainland colonies. The terrain of the colonial hinterlands was generally flat. Thus the application of traditional line-of-site survey techniques to build triangulation frameworks was virtually impossible in much of the Australian continent. An exception was the work in Tasmania during the 1830s and 1840s by surveyor James Sprent (1808-1863). Here the terrain was suitable for triangulation surveys. But for Australia overall, progress was miniscule and little work of a suitable geodetic standard had been achieved away from settled areas by the close of the 19<sup>th</sup> century.

### **Some post federation frustrations**

At federation in 1901, constitutional responsibility for land administration was retained by the various States. A decade later, in 1912, the Commonwealth Director of Lands and Surveys, the Surveyor-General and the Government Astronomer from New Zealand and the Surveyors-General of all States (except Western Australia) conferred in Melbourne. Here the overall survey and mapping situation was assessed. Principal conference outcomes were a call for a national geodetic survey as a basis for mapping and land administration and for the Commonwealth to take the leading role in the topographic mapping of Australia. The mapping discussed at the 1912 conference included Australia's contribution to the fledgling 1:1,000,000 scale International Map of the World series (Conference of Surveyors-General, 1912). The IMW series had been proposed at an International Geographical Congress held at Berne in Switzerland in August 1891. This map series was later adopted by the International Civil Aviation Organisation as the base for World Aeronautical Charts.

For nearly four decades after the 1912 Melbourne conference there was no committed follow-up on the national mapping requirement by successive federal governments. For various reasons there was little resource commitment and national mapping was given low priority. Nevertheless, a small topographic unit was established in the Australian Army but this initiative was diverted by World War I requirements. For too many years, commitment to mapping Australia did not sufficiently recover from that wartime involvement.

However, the private sector of the surveying community continued to press successive federal governments for a national approach to mapping the country rather than simply leaving that massive task to the State authorities. Army map makers made little progress during the 1920s due to resource constraints. Nevertheless, the then Australian Survey Corps was revived as a unit in 1932 essentially to map the country by default.

The magnitude of this mapping task was overwhelming. But a start was made in trying to unify the separate geodetic surveys that had been undertaken by the individual States on different origins. This start included carrying the Sydney Observatory origin through Victoria to South Australia and extending triangulation by the Australian Survey Corps from Sydney to Adelaide. However, the limited resources available to military and State mapping agencies resulted in little progress being achieved on the nation's mapping task prior to World War II. At the end on the 1930s only about 2 per cent of Australia's land area had been adequately mapped.

Even progress with the small scale International Map of the World series was slow. It was not until 1926 that Sydney (SI-56) was produced; the first of the eventual 49 Australian related sheets in this series. By 1941 only a further eight IMW sheets had been prepared; namely, Bodalla, Melbourne, Canberra, Hamilton, Adelaide, Armidale, Broken Hill and Bourke (Lines, 1992).

### **The war time mapping imperative**

With the outbreak of war in 1939 and the subsequent prospect of invasion from the north, the Commonwealth government at last accepted the importance of adequate topographic mapping to meet the by then urgent defence need.

Accordingly, an emergency mapping program was undertaken by the Australian Survey Corps in collaboration with the State mapping agencies. By the end of the war preliminary emergency mapping coverage extended over less than 80 per cent of Australia's mainland. Also during 1942 and 1943, the United States Army Map Service in Washington DC produced the remaining 32 mainland sheets in Australia's small scale International Map of the World coverage (Lines, 1992).

### **Post war reconstruction organisational arrangements**

In early 1945, even before victory had been achieved in the Pacific theatre of World War II, governments throughout Australia accepted that national action was needed to effectively address the topographic mapping coverage required for post-war reconstruction, national development and other uses. By that time the then Department of Post War Reconstruction was pressing for a national geodetic survey and adequate topographic mapping. Accordingly, in March 1945, Prime Minister John Curtin (1885-1945) and the State Premiers agreed to establish a National Mapping Council to coordinate the national mapping efforts of State and Commonwealth mapping agencies.

As part of that agreement, the Commonwealth appointed its then Surveyor-General Frederick Marshall Johnston (1885-1963) as the Director of National Mapping to chair the National Mapping Council and lead the Commonwealth's civilian mapping activities. In early 1946, Johnston appointed the visionary former Australian Survey Corps Major Bruce Philip Lambert (1912-1990) as Deputy-Director of National Mapping. It was Lambert who had the hands-on role in getting the national mapping program implemented in cooperation with other National Mapping Council member organisations including the military mapping organisations. The Commonwealth also created a National Mapping section within the then Department of Interior to undertake the Commonwealth's own civilian national mapping activities. Significantly, the Commonwealth government at last commenced the allocation of considerable resources to the national mapping effort.

### **The national mapping program begins**

After first reviewing topographic mapping trends and emerging technologies in England, Canada and the United States, determining his initial priorities and getting his rudimentary mapping organisation in place (in Canberra and Melbourne), Lambert quickly started the field work (Lambert, 1989 and 1990). In May 1948, astronomical observation field work commenced on the Barkly Tableland in the Northern Territory. These observations were to obtain control for the initial R 502 topographic map series then being compiled at a scale of 4 miles to the inch (Hocking, 1985).

In 1949, with assistance from the Royal Australian Navy's survey sloop *HMAS Warrego*, reconnaissance work commenced on linking the Tasmanian and Victorian geodetic surveys across Bass Strait. Triangulation survey work commenced on the Eyre Peninsula in South Australia during 1951.

In 1951, Bruce Lambert became the Director of National Mapping and Chairman of the National Mapping Council. Another organisational change occurred in 1953 when the Menzies government ended the Royal Australian Air Force's role in the acquisition of aerial photography for national mapping purposes. While allocating considerable funds for that task, the government preferred that this activity be undertaken by contractors in the private sector (Lambert, 1989 and 1990).

Some major advances came in 1954. That year Nat Map introduced electronic distance measuring in Australia with the use of a Swedish AGA Geodimeter model NASM-1 to remeasure numerous triangulation base lines and triangle sides. However, weighing over 90 kilograms the early Geodimeter was not a very versatile field survey instrument. Also in 1954, renowned former Royal Australian Survey Corps Lieutenant-Colonel Howard Angas *Bill Johnson* MBE (1907-1990) joined Nat Map to head its geodetic survey operations (Ford, 1979).

In 1956, to further accelerate topographic mapping to meet national development needs the Menzies government transferred the national mapping function as the Division of National Mapping to the Department of National Development alongside the then Bureau of Mineral Resources, Geology and Geophysics.

In 1958, the first six sheets in the preliminary 1:250,000 scale R 502 topographic map series were published by the Royal Australian Survey Corps. This mostly uncontoured preliminary mapping coverage was largely controlled by astronomical determinations and barometric heighting. The last of the original 544 sheets in this series was released by 1968. However, in the absence of other suitable mapping, reprints and second editions in the R 502 series continued into the 1980s (Wise, 2011).

### **Electronic distance measuring by Tellurometer**

In July 1957 Nat Map commenced field use of the Tellurometer *Micro-Distancer* for geodetic survey traversing (Ford, 1979). This man-portable electronic distance measuring equipment was more practical and flexible than the early model Geodimeters. The Tellurometer had been envisaged by Colonel Harry Bauman of the Trigonometrical Survey of the Union of South Africa in 1954. The Tellurometer was designed by electrical engineer Dr Trevor Lloyd Wadley (1920-1981) of the Telecommunications Research Laboratory within the South African Council of Scientific and Industrial Research. The first Tellurometers and were released to the market in January 1957 (McLean, 2015A).

The Tellurometer revolutionised the ability to develop a fundamental geodetic framework across the country by principally following hilly terrain or using towers for indivisibility in flatter country. Within less than ten years Australia had an established national geodetic framework with a unique set of coordinates on a standard system. This framework was called the Australian Geodetic Datum 1966. The ADG66 was a remarkable achievement. In 1974, the British Directorate of Overseas Surveys stated that...*the Australian geodetic network, a great part of it completed in 10 years, must always remain historically one of the survey wonders of the world* (Ford, 1979).

### **Block aerial photography**

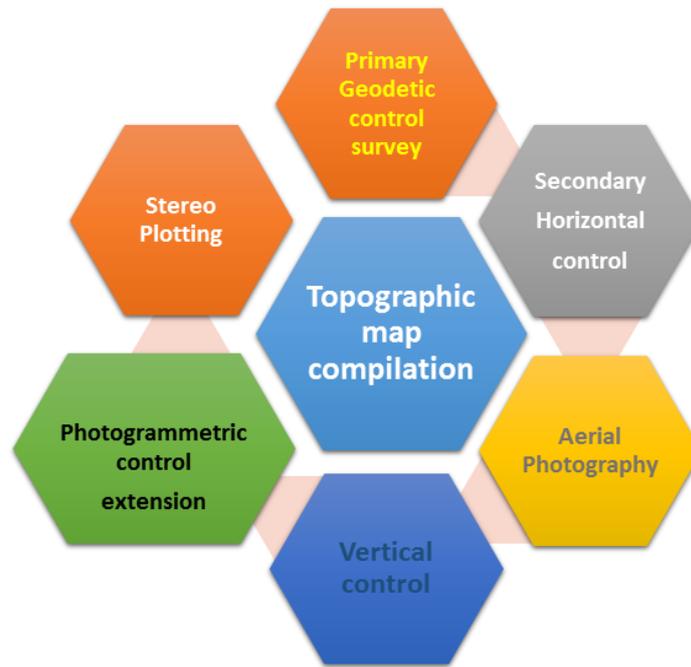
In 1960, systematic monochrome vertical aerial photography block coverage for national mapping purposes commenced being flown across the whole of Australia by a number of private sector contractor firms. This photography was flown at a nominal scale of 1:80,000 with 80 per cent forward overlap on the basis of 1:250,000 scale map sheet project areas. Generally 8 or 9 east-west flight runs each of about 50 photo frames were made for each map sheet area with occasional north-south tie runs. Thus for the 544 map sheet areas covering Australia at 1:250,000 scale, of the order of a quarter of a million photo frames were to be captured; a massive undertaking.

The contractors used several new 230 mm format aerial survey cameras supplied by Nat Map. These Swiss made Wild RC9 cameras had a 120 degree super wide angle lens with a focal length of 88 mm. To correctly plot topographic detail from the photogrammetric models, many minor control points had to be established. The *astro-fix* method for primary horizontal control and barometric heighting for vertical control used for the R 502 map series would be insufficient for the forthcoming 1:100,000 scale national topographic map series that was to have relief depicted by contours at 20-metre vertical intervals.

### **Photogrammetry**

To efficiently use the new aerial photography, modern photogrammetric plotting instruments such as the Swiss made Wild B8 stereo plotter were essential. Horizontal and vertical control values were needed to enable the stereo models to be set up and linked to adjoining photogrammetric models in these plotting machines. For each map sheet to be compiled every stereo model required photo identified points with requisite horizontal and vertical values. To allow plotting of the stereo models there was a requirement for each stereo model to have five identifiable horizontal control points. This horizontal control extension was developed by photogrammetric means either manually by slotted templates; or later, by using analytical photogrammetry techniques.

The slotted template method of radial-line triangulation was initially used by Nat Map to mechanically transfer primary control to each photo. During this photogrammetric control extension process, a plastic template was cut for each photo in the block. Common photo-control points on the sides and radials of each photo were selected and marked on the template along with any primary control points. At each marked point on the template, a slot was cut to later allow each template to move freely in relation to its neighbours. To assemble the templates in each block, base sheets on which control was plotted were laid out and carefully joined on a specifically designated large flat floor. At each primary control point a stud was fixed to the base sheet. Systematically each template was laid on top of a control base sheet with studs through applicable slots in the template and through any fixed control. With every template interconnected and constrained only at the fixed horizontal control points, the templates were allowed to adopt their own relativity. The stud positions of photo-control points were pricked through to the base sheets and as the templates were lifted all points were annotated on the base sheet for later identification (Hocking, 1987; Menzies and Wise, 2011). The overall topographic map compilation sequence is depicted in Figure 1 below.



**Figure 1: The topographic map compilation sequence.**

By the late 1970s as the computational power and speed of enterprise-level computers grew, analytical aero triangulation techniques evolved for calculating the horizontal positions and the elevations of photo-control points using programs such as the *Modblock* software developed by Dr CWB *Claude* King (Nat Map 1972-1985). However, these analytical photogrammetric methods still required a standardised network of topographic survey points on the ground to infill the loops of the national geodetic survey network.

### **Horizontal ground control intensification by Aerodist**

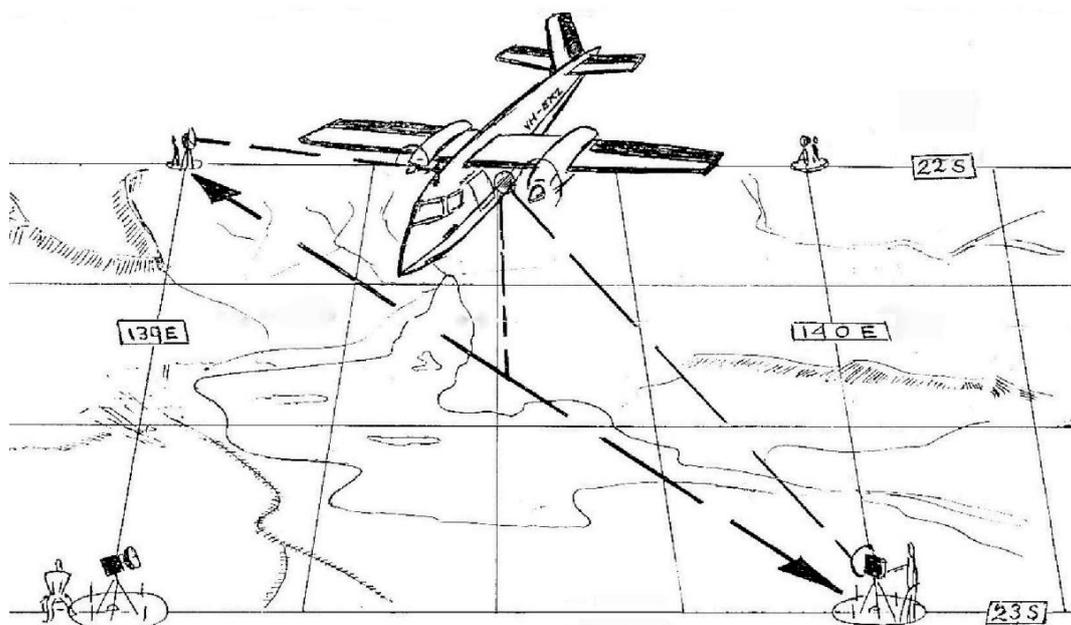
With steady progress being made in establishing the national geodetic survey loops, Nat Map's Director Bruce Lambert pondered the best means of intensifying survey ground control to obtain the horizontal points needed for each stereo model within the various aero triangulation blocks. For this horizontal ground control, a survey point needed to be established at an interval of no more than one degree of latitude and one degree of longitude within the geodetic survey loops (Lines, 1992). In some cases horizontal ground control was later needed at 30 minute intervals.

To find a feasible horizontal control solution Lambert sought the advice of his Melbourne based topography and technology specialists Supervising Surveyor George Robert Lindsay *Rim* Remington and Senior Surveyor John Dunstan *Joe* Lines; both were highly experienced former Australian Survey Corps officers. Ultimately it was decided to employ *Aerodist*; a new and as yet untried airborne version of the Tellurometer. Lambert obtained funding approval for the purchase of an *Aerodist* system in October 1961 (McLean, 2015A).

Aerodist was part of the family of microwave distance measuring systems (together with the ground-based Tellurometer and the Hydrodist system for marine applications) that were invented by South African electrical engineer Dr Trevor Lloyd Wadley. Aerodist overcame the *line of sight* constraint of the ground based Tellurometer which necessarily reduced the length of line measurements and impacted on survey station site selection options.

Australia and Canada were the only countries to use the Aerodist system in major national surveying programs (Tuttle, 1967; Lines, 1992). The Royal Australian Survey Corps obtained an Aerodist system in 1964. This system was initially deployed in western Papua New Guinea and later in northern Australia including Arnhem Land and the Kimberley. The last deployment of the Corps' Aerodist system was in 1975 in the Cape York area during a major 1:100,000 and 1:50,000 scale mapping project *Operation Sandy Hill* (Anderson, 1967; Lines, 1992; McLean, 2015A).

The Aerodist system allowed dynamic slope distances from two ground transponder (or *remote*) stations to be measured by the master equipment in an aircraft that would fly between the two ground stations. By using these measured slope distances, the known aircraft antenna separation distance, the height of the ground stations, aircraft height at the line crossing point, and by taking meteorological observations to determine atmospheric refraction, a sea level distance between the two ground stations could be determined. A typical Nat Map Aerodist measuring flight is depicted in Figure 2 below.



**Figure 2: A typical Aerodist measuring flight (from Else 1972).**

In Aerodist measurements, the *A* pattern was the primary measuring wave and was almost continuously recorded on an analogue paper chart. The *A* pattern indicated the final two digits of the slope distance from the aircraft to the remote station on the ground; the tens and units of metres. The *A* pattern was switched out at about 6 second intervals and the three remaining patterns *B*, *C* and *D* were switched in for a fraction of a second. The *B*, *C* and *D* patterns provided the coarse distance readings, namely the initial digits of the line measurement (the tens of thousands, thousands, and hundreds of metres). For each Aerodist line a minimum of seven good runs would be flown with the *goodness* of the run being determined by the quality of the trace that recorded the measurements on to the chart (Lines, 1965).

While it may sound simple, Aerodist was an embryonic system that was inherently unstable and often unreliable. Nat Map's first Aerodist system was supplied in July 1962 but failed bench acceptance testing and was returned to the supplier eight days later. A second MRC2 Aerodist system was delivered in January 1963. After vehicle-mounted and helicopter-borne acceptance testing mainly in western Victoria, Nat Map accepted this system in early June 1963. Nat Map then undertook several weeks of Aerodist trials during which work procedures were established, master and remote operators trained and various teething problems addressed. The use of electronics technicians in the Aerodist measuring field parties was later found to be essential for operational continuity.

In 1963 and 1964 Nat Map's Aerodist system master units were mounted in Bell 47-J2 helicopters (VH-INM and VH-INZ respectively) chartered from Ansett-ANA. In 1965 the system was mounted in a Rockwell Aero Commander 680E fixed-wing aircraft (VH-EXY) chartered from Executive Air Services. Between 1966 and 1974 the Aerodist system was mounted in a Rockwell Grand Commander 680FL aircraft (VH-EXZ) also chartered from Executive Air Services; an image of this aircraft is shown in Figure 3 below.



**Figure 3: Aerodist measuring aircraft VH-EXZ at Caiguna 1972 (Paul Wise image).**

### **Aerodist system components**

Aerodist master units essentially comprised: a klystron oscillator that set the carrier signal frequency that allowed voice communication with remote units and later broadcast the measuring pattern frequency signals; a triode power amplifier that amplified carrier and measuring signals for transmission through the aircraft antenna system; and ovens for the crystals that determined the pattern frequencies that were automatically switched over the carrier frequency to give the measuring signals for relevant distant components. Each master unit weighed about 15 kilograms. Nat Map eventually had three master units of differing frequencies rack mounted in the measuring aircraft.

The master units were frequency coded Red, White and Blue and could only measure to a remote unit with the corresponding frequency colour code. Other major Aerodist components in the aircraft included an externally mounted antenna system that allowed any of the three masters to be switched to either the port or starboard (or to the forward) antenna; a power supply to provide the 10 amperes of current at 28 volts required by the master units; and a pen marked paper chart on which the distance measurements were graphically recorded.

Ancillary master equipment included imperial and metric altimeters, a psychrometer with an externally mounted sensing head linked via a thermocouple device through a direct current amplifier to a switched display readout meter mounted with the master units; an aircraft heading indicator; an *over-Aerodist* communications headset for the master and remote operators to communicate when not in measuring mode; an in-cabin intercom for three-way communications between the master operator, booker and aircraft pilot; and a high frequency radio transceiver to allow radio communications between the booker, remote parties and other field party components (centre party, helicopter support party, etc).

Nat Map eventually deployed six Aerodist remote units, namely four single frequency remotes (Red 1, Red 2, Blue 1 and White 1) and two dual frequency remotes (White 2/Red 3 and Blue 2/White 3). Typically four remotes were deployed on a routine basis; one was used on an *ad hoc* stand-by basis; and one was retained in the centre party as a spare for ready replacement of a defective unit or to be deployed when operationally convenient.

Each remote unit system comprised the unit itself (about the size of a Tellurometer), a reflector dish, a dipole antenna, a communications headset and a power lead for connection to a 12 volt lead acid battery power source. (Dual frequency remote units also had an auxiliary back section with separate klystron oscillator and triode power amplifier and related cabling.) Other remote party equipment included a mounting tripod, a petrol generator for battery charging, a spare 12 volt battery, a high frequency radio transceiver, clinometer, prismatic compass, plumbobs, box measuring tape, field books, survey station summaries, measuring scheme diagram, protractor, and ruler etc as well as a mechanism barometer and a psychrometer. At survey stations, data recorded for each measuring run during remote unit operation included: barometric pressure readings; wet and dry bulb temperatures; and instrument performance readings. In addition, a remote instrument identifier (its frequency code), the height of the instrument and its standpoint in relation to the survey station mark were also recorded for each line measured.

### **Aerodist charts**

Aerodist line measurement in the aircraft was depicted by traces of the ranges to each ground station that were recorded graphically on a paper chart by the automatic chart recorder. The chart provided for up to three simultaneous records (when photo trilaterations were measured). As an in-the-field quality control check each chart was test *broken* to verify it was useable prior to dispatch to the Melbourne office for full computation.

For simple two station line-crossing reductions (as in Figure 4 below) the charts were examined back in the office and pairs of distances, one from each ground station, were extracted and summed for the same number of intervals on either side of the actual line-crossing. The sums of the distances measured on a line-crossing were then graphed as a parabola. Twenty-one sums, ten on either side of the adjusted minimum were graphed and then computed by the method of least-squares to obtain the theoretical minimum line distance (Lines, 1965). Each minimum distance was then reduced to a sea-level distance by applying corrections for atmospheric refraction, antenna separation, aircraft and remote station heights, and earth curvature. These reductions were undertaken using a computer program developed by Frank Leahy (Nat Map 1961-1965) who was later at the University of Melbourne.

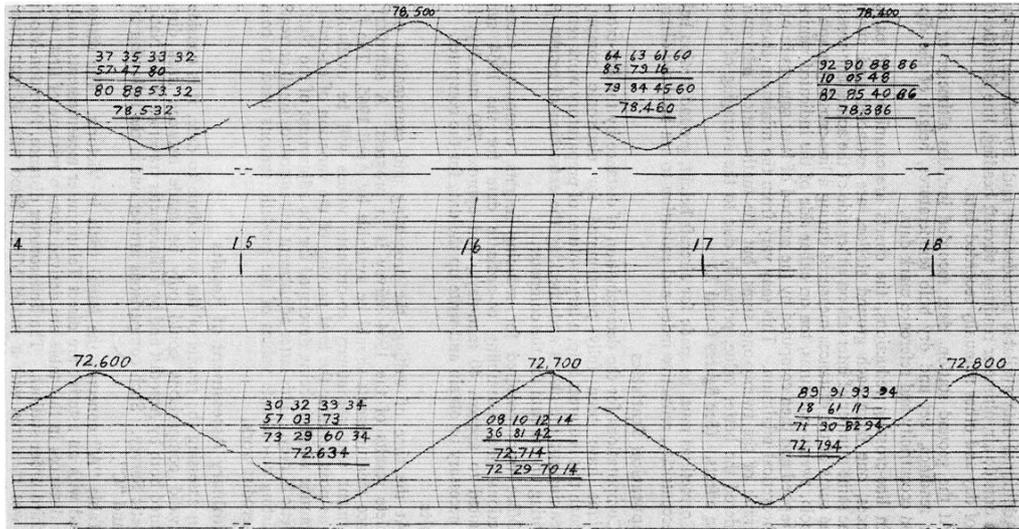


Figure 4: Sample Aerodist chart (from Lines, 1965).

### Accuracy of Aerodist surveys

The Aerodist network blocks were strengthened by Tellurometer measurements to any conveniently located higher order survey stations during ground marking operations. In the earlier years of operations, Aerodist measurements were also made to any higher order survey stations located within the Aerodist blocks. In addition, *comparison lines* over known distances between some of the geodetic survey stations surrounding the Aerodist network blocks were routinely measured as the Aerodist surveys progressed.

Where differences between the geodetic and Aerodist distances over comparison lines exceeded five metres the reasons were usually because of poor quality signals during the measurement due to marginal Aerodist equipment performance; excessively long lines being measured; steep outlooks from remote stations located at high geodetic control points causing large ground swings (reflections); errors in eccentric station connections; inaccurate meteorological observations; or misreading of the aircraft altitude at the line crossing, which was later addressed by reading two altimeters: one imperial and the other metric (McMaster, 1980).

The final coordinates for Aerodist stations were computed using *Varycord*; a FORTRAN program that used the *method of least squares* adjustment technique. The *Varycord* program was developed by Anthony Gerald *Tony* Bomford (1927-2003), who was the Director of National Mapping from 1977 to 1982.

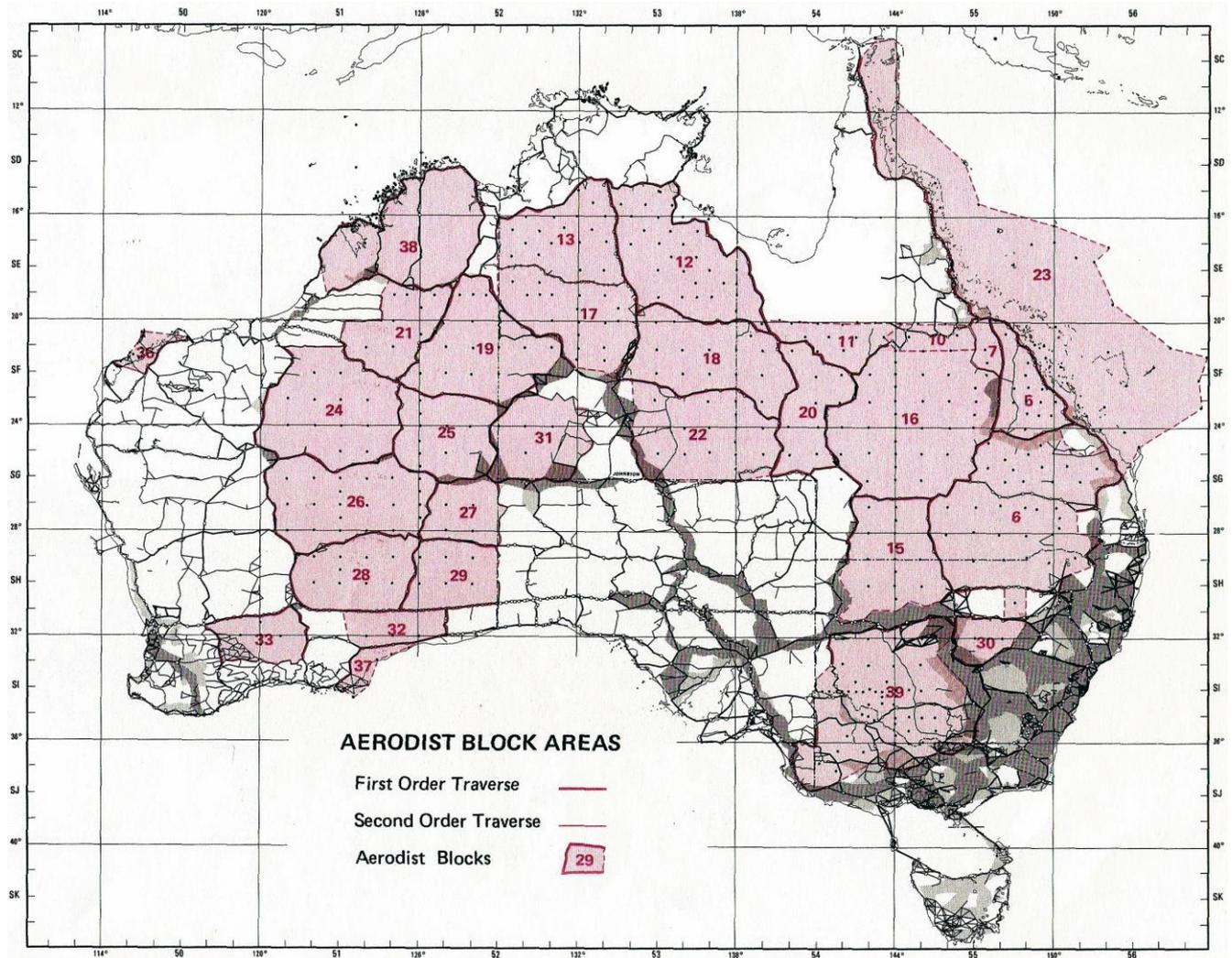
From all the Varycord adjustments used to determine final coordinates of Aerodist survey stations, the average difference (residual) between observed and adjusted distances was 1.49 metres for an average line length of about 100 kilometres. For the thirty Varycord adjustments of Aerodist blocks, the average maximum residual was 6.3 metres (McMaster, 1980). Subsequent Tellurometer traverses and position *fixes* by JMR Doppler satellite receivers at a number of Aerodist stations verified that the coordinates of Aerodist stations were usually accurate to better than 5 metres (McMaster, 1980).

### **Aerodist ground marking arrangements**

The ground marking undertaken to establish Aerodist control stations was a significant task. In the early days of the Aerodist program from 1963 to 1964 this ground marking was undertaken in conjunction with measuring activities. Lines (1965) noted that Aerodist station reconnaissance, ground marking, air photo identification, and barometric heighting absorbed something like 40 per cent of the manpower requirement in those first two Aerodist field seasons. In 1965, Aerodist control stations were established by semi-autonomous marking field parties. In 1966, stations were established by dedicated marking field parties; some with helicopter support. From 1967 to 1970 separate Aerodist station marking field programs were undertaken; all using helicopter support. These marking programs were usually a year or so ahead of the related measuring operations. From 1971 to 1974 various Aerodist marking arrangements were used; either ahead of or in conjunction with measuring operations. Details of Nat Map's Aerodist ground marking operations are provided in Jenny (2013 and 2013A) and Wise (2014A).

### **Aerodist field operations**

Helicopter-borne Aerodist measuring operations commenced in the Bowen Basin of central Queensland in the second part of 1963 and continued in the Surat Basin of southern Queensland and northern New South Wales in 1964. Fixed-wing aircraft mounted Aerodist measuring operations commenced from Emerald in central Queensland during August 1965. Between 1966 and 1970, Aerodist measuring operations progressed steadily northward and westward through Queensland and the Northern Territory. The extent of Nat Map's Aerodist measuring field operations between 1963 and 1974 is shown in Figure 5 below.



**Figure 5: National Mapping Aerodist Blocks at December 1974 (from McMaster, 1980).**

**National Mapping Aerodist operations in Western Australia 1971-1974**  
 Aerodist measuring operations in Western Australia commenced in Blocks 19 and 21 located to the south of the Kimberley and into the Great Sandy and Gibson Deserts. These initial operations ran from June to August 1971. Field operations continued in Western Australia in following years until Nat Map’s Aerodist measuring activity was complete in November 1974. Aerodist measuring operations in Western Australia are summarised in Table 1 below.

**Table 1: National Mapping Aerodist measurements in Western Australia 1971-74**

<b>Year</b>	<b>Aerodist Blocks</b>	<b>Lines Measured</b>	<b>Stations Fixed</b>
1971	19 and 21	130	22
1972	21, 24, 25, 26, 27, 28, 29, 32, 33, & 37	517	80
1973	36 (offshore)	57	4
1973	37 (offshore component)	13	3
1974	38 (Kimberley)	100	15

### **Nat Map Aerodist field party composition**

During operations in Western Australia, the Nat Map Aerodist measuring field parties typically comprised around 20 men. While the overall field party member numbers varied from time-to-time, Aerodist field staff were usually organised in the following components:

- **centre party** comprising the field party leader-surveyor, another surveyor, one or two electronics technicians, measuring aircraft pilot, and two or three other Nat Mappers; a typical centre party camp is shown in Figure 6 below
- **remote sub-parties** comprising four teams each of two persons
- **helicopter support party** comprising a sub-party leader, fuel truck driver, one or two helicopter pilots and a helicopter engineer.



**Figure 6: Typical Aerodist centre party camp-Blyth airstrip 1972 (Oz Ertok image).**

Typically an Aerodist field party was equipped with the following motor vehicles. The centre party had: either a Land Rover or a Toyota 4X4 station wagon for personnel transport; an electronics workshop/office mounted on an International C1600 4X4 truck; and a 4 ton Bedford RLCH 4X4 supply truck. There were four Land Rover 109 inch wheelbase 4-cylinder 4X4 vans for the remote parties.

The helicopter support party vehicle was an International C1300 4X4 utility and another 4 ton Bedford RLCH 4X4 truck was attached to this party for the positioning of aircraft fuel, water and motor spirit; an image of a fuel truck in operation is shown in Figure 7 below. Often there would be another one or more light four-wheel drive motor vehicles within the overall field party.



**Figure 7: Bedford fuel truck in operation Gunbarrel Highway 1972 (Laurie McLean image).**

### **Helicopter support**

Aerodist onshore operations in Western Australia during 1971, 1972 and 1974 were supported by helicopters that were used to position the remote unit parties. The helicopters were all Hughes 500 369HS light turbine aircraft. In 1971 a single helicopter was used. It was chartered from Sydney based Helicopter Utilities Pty Ltd. In both 1972 and 1974 two helicopters were used in the field. These aircraft were chartered from Melbourne based Jayrow Helicopters Pty Ltd. During two-helicopter operations each aircraft operated independently to position remote parties but generally worked from the same helicopter base camp. The 1971 helicopter camp at survey station NM/F/366 in the Great Sandy Desert south of Christmas Creek homestead is shown in Figure 8 below.



**Figure 8: Helicopter VH-UHO at NM/F/366 in the Great Sandy Desert 1971 (Ted Graham image).**

The helicopters were contracted to lift 800 pounds over 80 nautical miles and return to base without refuelling. After loading the required technical equipment into the helicopter there was only limited space and weight allowance for the two remote sub-party personnel and their camping equipment and supplies. Personal effects and spare clothing were kept to a minimum. Camping equipment and supplies were: a spade and an axe, a tightly rolled swag and collapsible stretcher for each person, a metal bucket, saucepan and billycan, plastic wash-up bowls, crockery and cutlery, a can opener, a 20 litre jerry can of water and a cardboard box of canned and dried food. There was no room for chairs or tentage. With this meagre loading, remote party members would usually operate from and camp at one or more survey control stations on hill tops or in the valleys between sand ridges for six days per week. Remote parties were mostly returned to the helicopter camp for a rest day on Sunday. Only then could they have a shower and wash their clothes. This rough living went on for the duration of the helicopter support contract; that is for periods of four to seven months duration. A helicopter supported Aerodist remote station is shown in Figure 9 below.



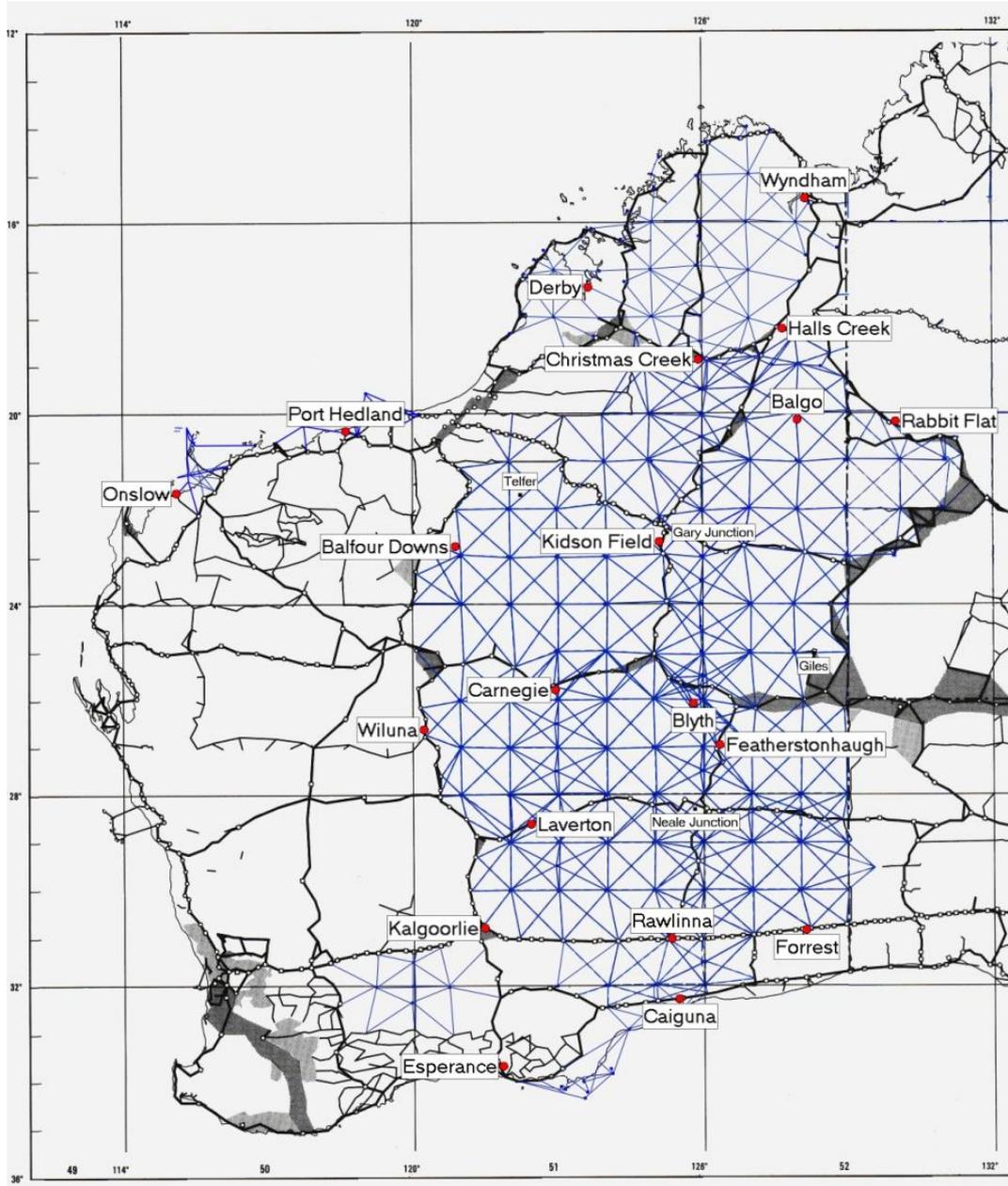
**Figure 9: Helicopter supported Aerodist remote station 1972 (Ted Graham image).**

Generally the helicopter support camps were located near the centre of measuring operations to minimise flight distances and flying times. Typically camps were in remote areas *out in the bush* in the Great Victoria, Gibson, Little Sandy and Great Sandy Deserts, on the fringe of the Nullarbor Plain or in the Kimberley. Thus helicopter support camps had to be fully self-sufficient. The helicopter camps used in Western Australia are shown in Figure 10 below.



**Figure 10: Nat Map Aerodist helicopter camps in Western Australia 1971-1974.**

The centre party of necessity had to be based at an airstrip. Thus it tended to be located more often in towns or other settlements such as near station homesteads. However, when necessary the centre party also operated from remote airstrips out in the bush; such as from former oil search strips at Featherstonhaugh, Kidson Field and Blyth Strip in 1972. The centre party bases used in Western Australia and the Aerodist lines measured in that State are shown in Figure 11 below.



**Figure 11: Aerodist centre party bases and lines measured in Western Australia during 1971-1974.**

### **Western Australian offshore Aerodist operations**

During 1973 operations in Western Australia, Nat Map measured Aerodist lines to survey stations on offshore features around Onslow and out to Barrow Island and the Montebello Islands. Based from Onslow and Port Hedland some 57 Aerodist lines were measured and a number of Tellurometer connections made in this Block 36. Later in 1973 based from Esperance, Aerodist lines were measured and Tellurometer connections made to Block 37 offshore features in the Archipelago of the Recherche. During offshore operations Aerodist remote and Tellurometer parties were positioned by locally chartered fishing boats.

The 1973 Aerodist measuring in Block 36 included 8 photo trilaterations to determine the positions of four points on Tryal Rocks and points on Geographe Shoals, Little Turtle Islet, North Turtle Island, and Bedout Island. Using the photo trilateration procedure, *air coordinates* were obtained for near vertical photo frames captured by a motorised 70 mm Vinten reconnaissance camera. These air coordinates were determined by simultaneous Aerodist measurements to three control stations with known positions while vertical photos were being captured by the Vinten camera. The air coordinates were then related to ground features identified on the Vinten images to determine the ground coordinates for the 8 offshore features. (The Vinten camera was mounted in both of the Nat Map fixed-wing Aerodist measuring aircraft; VH-EXY and VH-EXZ. It was used to spot photograph control stations as part of normal Aerodist operations.)

### **The last Nat Map Aerodist line**

Aerodist measuring was undertaken in Block 38 in the Kimberley region from early September to early November 1974. The centre party was based from Wyndham, Halls Creek and Derby. Nat Map's last Aerodist line was flown from Derby on 2 November 1974. It was between Nat Map survey station NM/F/694 and Royal Australian Survey Corps survey station R160.

Nat Map's Aerodist system was used to measure some 3,020 lines that fixed the positions of 480 survey stations and provided horizontal control for topographic mapping over more than 50 per cent of Australia's mainland area (McLean, 2015A). Some 817 of these Aerodist lines were measured in Western Australia during 1971-1974. The National Topographic Map Series coverage relied on the horizontal ground control provided by the Aerodist measuring system. This map series provided the cornerstone of our nation's topographic data infrastructure (Menzies and Wise, 2011).

### **Vertical control for topographic mapping**

The primary focus of this paper has been on the use of the Aerodist airborne distance measuring system to obtain horizontal ground control for the 1:100,000 scale national mapping program. However, for completeness of the topographic map compilation sequence, a brief summary of the methods used to obtain vertical mapping control is given below.

As with the majority of vertical control used for the earlier R 502 map series, the initial heights for Aerodist survey control stations were determined by the barometric heighting method. This heighting was undertaken during Aerodist ground marking operations. However, by the end of the 1970s, third order spirit levelling connections had been made to the overwhelming majority of Aerodist stations including those in the remotest parts of the Western Australian deserts.

The ability to run spirit level connections to Aerodist stations was due to the immense amount of work undertaken on the national levelling survey between 1965 and 1970. The national levelling survey allowed the determination of the Australian Height Datum in 1971 (Wise, 2014B). To obtain vertical control for its later topographic map compilation, Nat Map used three height value acquisition methods: a radar-based airborne profile recorder, a vehicle-based ground elevation meter, and an airborne laser terrain profiler (Manning and Menzies, 1988).

Adastra Airways was contracted to provide National Mapping with vertical control for 1:100,000 scale mapping. Between 1962 and 1971 Adastra supplied about 200,000 kilometres of terrain profiles. These chart-based vertical profiles were provided from a Canadian sourced radar profiling system that was flown at some 3,000 metres above ground level to help avoid turbulence. At that height the radar sampled an area on the ground of about 50 metres in diameter. This sample was then considered sufficient for inland areas of generally low relief (McLean, 2013).

From 1964 to 1969, National Mapping used a Johnson Ground Elevation Meter to obtain around five per cent of the vertical control needed for topographic mapping at 1:100,000 scale. The Elevation Meter was built by Sperry-Sun in the United States and was used only by government mapping agencies in Australia and North America. It was a vehicle-based system that provided level traverse results with errors of less than 10 feet in 50 miles at an average traversing speed of about 15 miles an hour on reasonably good road surfaces. On average, about 100 miles per day of level traversing could be achieved. The Nat Map Elevation Meter was a specially modified General Motors Corporation four-wheel drive van that had four-wheel steering, power assisted brakes and air conditioning. The vehicle had a small fifth road wheel on the right side that was connected to an electronic pendulum system; this is shown in Figure 12 below.

Together with an on-board computer, the overall system allowed distances travelled and changes in height to be measured and provided on paper printouts. Spirit level connections were made to level traverse bench marks at the start and finish of each Elevation Meter traverse. Tyre pressures for the three road wheels on the measuring side of the vehicle were critical for measurement accuracy. An engine operated air compressor and a tyre pressure control system was used to continually maintain the required tyre pressures during measuring operations (Manning and Menzies, 1988; McLean, 2015).



**Figure 12: Nat Map's Johnson Ground Elevation Meter (Frank Leahy image).**

In the late 1960s, to achieve greater vertical control accuracy by sampling a much narrower footprint on the ground than could be achieved with radar, Nat Map instigated the development of an airborne laser terrain profiler. This WREMAPS I profiler was developed by the Weapons Research Establishment of the then Department of Supply. Nat Map operated this laser terrain profiler between 1970 and 1979 with over 250, 000 kilometres of laser terrain profiles being flown. These profiles provided vertical photogrammetric control for plotting an area of some 2.7 million square kilometres at 1:100, 000 scale with a contour vertical interval of 20 metres (Wise, 1979).

### **Beyond the Aerodist era**

Completion of the first standard topographic mapping coverage of Australia was not achieved until late in the 20<sup>th</sup> century. This National Topographic Map Series involved the compilation of 3,062 sheets at 1:100,000 scale with contours at 20-metre vertical intervals and was completed in 1988. However, only 1,602 of these sheets (generally covering the more populated areas) were printed as 1:100,000 scale topographic maps.

Nevertheless, the total 1:100,000 scale compilation coverage was used to derive an updated 1:250,000 scale National Topographic Map series (Menzies and Wise, 2011). In this updated and contoured (with a 50-metre vertical interval) 1:250,000 scale series, the 544 map sheets on standard sheet lines (one degree of latitude and one and a half degrees of longitude) in the earlier R 502 series were reduced to 513 sheets which were completed by 1991 (O'Donnell, 2006). The reduction in overall sheets was achieved by the use of special editions that spilled over standard sheet lines in coastal areas.

The post World War II period in Australia saw some major technology changes and outstanding achievements in securing our nation's first standard topographic mapping coverage. Technological change in this period was immense as we went from the steel measuring band to the Geodimeter, Tellurometer, Aerodist and other electronic distance measuring systems and then to satellite-borne positioning and imagery acquisition systems. Space-age geodesy commenced with the launch of the United States *Vanguard* satellite in 1958 even before the Aerodist system had been developed. In 1967, the United States Navy Navigation Satellite System was made available for civilian use (Brinker and Minnick, 1994). The Doppler NNSS was already being used for position fixing in Australia around the time Nat Map's Aerodist measuring was complete in late 1974. The launch of the United States' Earth Resources Technology Satellite (later renamed Landsat I) in July 1972 saw the start of the systematic acquisition of imagery by space-borne vehicles.

Of course the Aerodist era is now in the past and technology continues to advance. Nevertheless, the journey ahead may be more pleasant when the road already travelled is understood.

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