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LOCAL AREA AND WIDE AREA AUGMENTATIONS IN AUSTRALIA - THE VHF ALTERNATIVE

By

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SUMMARY

This paper provides advice on Airservices Australia's progress in introducing GNSS in Australia, the evaluation of local area augmentation systems and VHF as an alternative data link for a space based augmentation system.

1. Background

1.1 Global Navigation Satellite Systems (GNSS) in Australian civil aviation has been evolving mainly around the US Global Positioning System (GPS) while awaiting developments of the Russian Federation's GLObal NAvigation Satellite System (GLONASS). In the past few years, Airservices, in conjunction with the Civil Aviation Safety Authority (CASA) and industry, has introduced various levels of approval for the use of GPS by civil registered aircraft.

1.2 Airservices has been monitoring closely developments in aircraft based augmentation systems (ABAS), to meet international capability and interoperability requirements for the future eg. Boeing's FANS 1, the Airbus FANS A and Litton's AIME.

1.3 In parallel, Airservices has been evaluating ground based augmentation systems (GBAS) and space based augmentation systems (SBAS).

2. GNSS (GPS) Approvals

2.1 The following approvals are in place for civil aviation use of GPS in the Australian domestic airspace:

a. Supplemental means for enroute navigation, implemented in August 1994.
b. Primary means enroute and GPS arrivals, implemented in December 1995.
c. Primary means oceanic and in remote areas, implemented in January 1998.
d. Runway aligned, standalone, supplemental means GPS non precision approaches (NPAs), implemented in January 1998. It should be noted that the GPS NPA design standard (an Australian initiative) has since been adopted by ICAO to become the PANS-OPS standard.

2.2 The supplemental means NPAs require a conventional navigation aid at an alternate airfield (when an alternate is required). The NPAs are the result of extensive flight testing and are being implemented as quickly as the approaches can be designed.

3. Augmentation System Test Bed (ASTB)

3.1 The Augmentation Systems Test Bed (ASTB) is one of several tasks being undertaken by Airservices to determine the way ahead for air navigation in Australia. A Global Navigation Satellite System (GNSS) Technical Audit and Cost Benefit Analysis was completed in March 1997 by Booz-Allen & Hamilton (Australia) Ltd. A recommendation of that study was that augmentation systems should provide the necessary accuracy, integrity, continuity of service and availability required for satellite navigation to form the basis of navigation in Australia.

3.2 The purpose of the ASTB is to enable Airservices Australia and CASA to obtain technical and operational knowledge of GNSS augmentation systems for the Australian Flight Information Region (FIR), and in particular, local and wide area augmentation technology. This knowledge will be used in the development of the GNSS Transition Plan and the GNSS Program Master Plan for Australia and also the possible future implementation of ground based and/or space based augmentation of GNSS in Australia.

3.3 Experience and knowledge gained is also being used to promote Australia’s requirements in the development of Standards and Recommended Practices (SARPs) by the International Civil Aviation Organisation (ICAO) GNSS Panel.

3.4 The Board of Airservices Australia approved the ASTB in April 1996 and the project is managed by the Airservices’ GNSS Program Office. The Cost Benefit Analysis, the ASTB and technology advances will be assessed prior to any decision on the future air navigation system architecture for Australia.

4. Ground Based Augmentation System (GBAS) Special Category 1 (SCAT-1)

4.1 Installation

4.1.1 Melbourne Airport was selected for the installation of a Pelorus/Honeywell SLS 2000 Satellite Landing System (SLS) because of the proximity of Avalon (29 nmiles) and Essendon (5 nmiles) Airports for multiple airport evaluation and the traffic density to enable flight testing. The ground station location was not necessarily the optimum one. The Melbourne Doppler VOR (DVOR) was located within 120 meters of the ground station and the VHF Data Link (VDL) antenna height was slightly lower than the runway heights for all Melbourne runways. The location provided a test point regarding the siting of a master reference station at less than optimal position. Figure 1 shows schematically the layout of the installation.

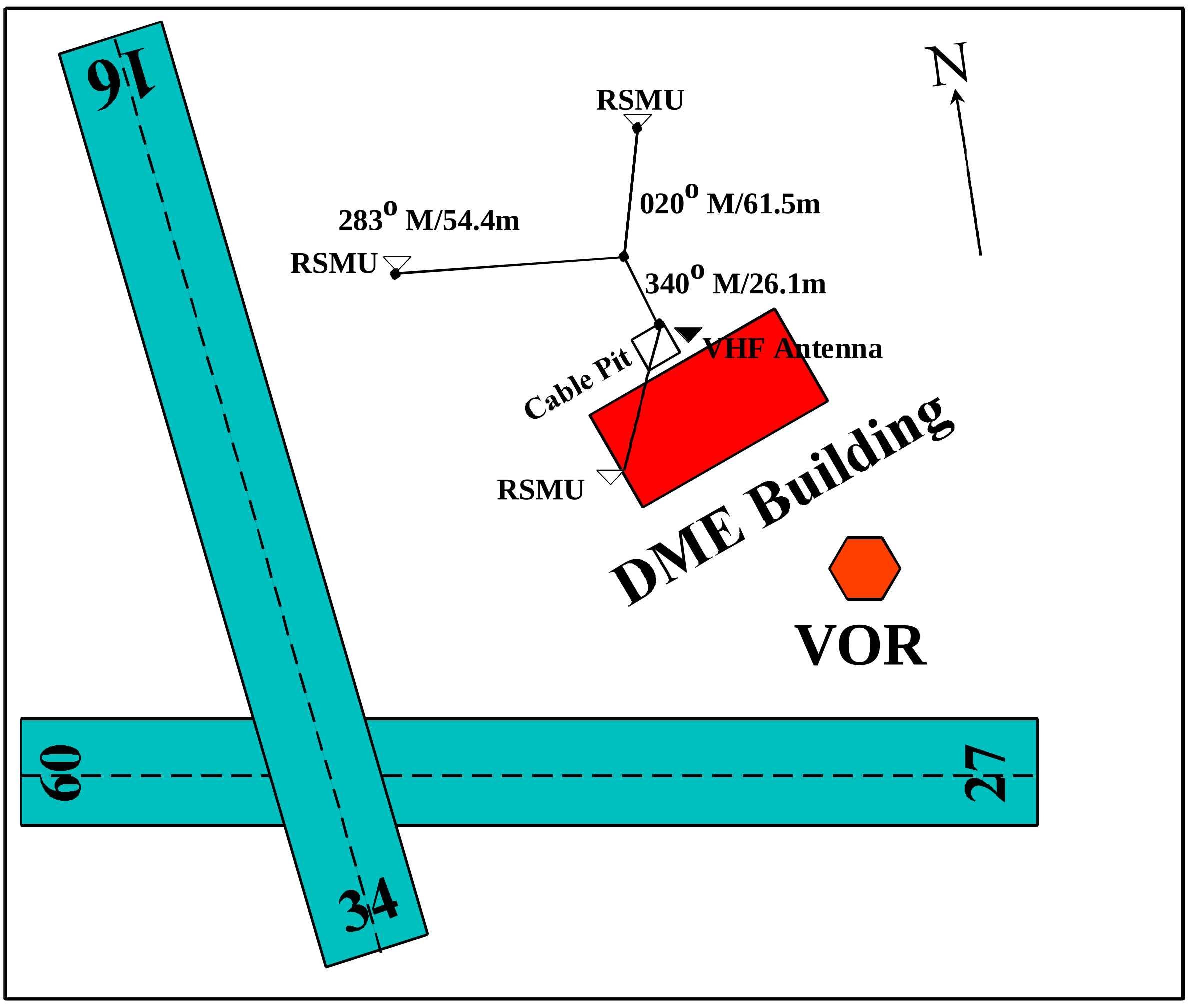

Figure 1. - GBAS (SCAT-1) Installation Layout Melbourne Airport

4.1.2 Airfield surveys of Melbourne and Essendon were completed by the Australian Survey and Land Information Group (AUSLIG). An evaluation of any interference between the SLS-2000 and the DVOR was completed. No interference to either system by the other was found and operations were allowed to commence.

4.2 Ground Station

4.2.1 The ground equipment consisted of a Pelorus Navigation Inc (Canada) SLS 2000 master reference station connected to three remote sensor monitoring units (RSMUs). The ground system used a carrier-smoothed code-tracking Differential GPS (DGPS) approach to achieve a Special Category 1 (SCAT-1) precision approach capability. The SLS-2000 ground system gained Type Acceptance by the FAA in August 1997. It was also commissioned at Newark NJ and Minneapolis-St Paul MN in early 1998 and is awaiting Operational Approval for use by a US carrier. Other cities are also installing the SLS-2000 within the USA. Within Canada, installations have occurred at Regina and Winnipeg.

4.2.2 The SLS-2000 DGPS ground station comprised equipment to perform three major functions:

a. to determine ground-based differential corrections
b. to transmit these corrections to the aircraft using a DO-217 defined datalink
c. to transmit pathpoints for runway approach path

4.3 Equipment Setup

4.3.1 The system went through an installed system performance check. This covered such items as power tests, equipment functionality, power supply transfer operation, interference tests, datalink RF power levels, RSMU operation, satellite coverage tests (in accordance with RTCA Document DO-217) and database verification. The system was initiated and transmitted “dummy” test information in April 1997.

4.4 Airborne Installation

4.4.1 An Airservices’ flight inspection F-28 was the host aircraft. Honeywell Australia provided an HT-9100 flight management system avionics equipment. The equipment was installed during routine maintenance.

4.4.2 Data recording equipment was specially devised by Airservices’ staff. An Ashtech Z-12 dual frequency GPS receiver was installed as the truth reference system after verification that the Time Space Position Indicator (TSPI) system using differential GPS was accurate enough for the trials (< 1.0m). Some of this work was completed by Royal Melbourne Institute of Technology undergraduates.

4.5 VHF Data Link

4.5.1 The VHF Data Link for the Melbourne installation operated on 112.025 MHz for test purposes only. The system operated initially with a power of 10 Watts but was increased to 20 Watts for evaluation. The modulation type was D8PSK.

4.6 Approach Design

4.6.1 The precision approaches programmed into the equipment emulated ILS approaches for test purposes. That is, they had a Glide Slope of 3° and a Threshold Crossing height of 50 ft or 15.2 meters. Approaches to the following 10 runways were inserted into the single SLS-2000:

Melbourne Runway 09	Melbourne Runway 16
Melbourne Runway 27	Melbourne Runway 34
Essendon Runway 08	Essendon Runway 17
Essendon Runway 26	Essendon Runway 35
Avalon Runway 18	Avalon Runway 36

4.7 Test Flying Program

4.7.1 Specific tasking was used to validate the TSPI system during the initial week of testing in September 1997. Six days of testing occurred with over 16 hours of recorded data collected. Tests evaluated the flight characteristics and accuracies:

a. on glidepath,
b. 2½ dots (half scale deflection) left and right of centreline,
c. 2½ dots high and low of glidepath,
d. 5 dots (full scale deflection) left and right of centreline, and
e. 5 dots low of glidepath.

4.7.2 Other tests included orbits at 30 nmiles at 6,000 feet AGL and 15 nmiles at 3,000 feet AGL around the ground transmitter to determine the signal power levels. Flight testing was completed in late November 1997.

4.8 Test Results to Date

4.8.1 Approaches were made to all runway ends at Melbourne, Essendon and Avalon. GBAS SCAT-I equipment is designed to cover multiple airfields within 20 - 30 nmiles of the reference station. RTCA Doc 217 Change 2 requires the GBAS to provide a signal power level of -77 dBm. The measured results at 10W were -72.7 dBm at 30 nmiles and -65.0 dBm at 15 nmiles, showing the power level exceeded the specification.

4.8.2 All approaches on the centreline at each airport were within 3 metres of the required track and displayed a highly stable indication to the pilot. Flights to Avalon Runway 18 and Runway 36 determined the range at which a reliable signal could be received. The data corrections were lost at 850 feet AGL at 29 nmiles descending into Avalon. This is a sheer physics problem. The antenna at Melbourne was only 9 metres high and just on the planar level of Runway 16/34. With a higher, or better placed, antenna, there is no doubt a usable signal could easily reach Avalon at touchdown.

4.8.3 The test report will be available by October 1998.

4.9 Future Plans

4.9.1 Airservices will install a Raytheon DIAS 3100 LAAS SCAT-1 system at Canberra Airport, Australian Capital Territory, to evaluate another architecture. Additionally the effects of high terrain and consequent masking will be evaluated. All levels of civil pilots from general aviation to B-747 pilots will be able to fly the LAAS SCAT-1 approaches and provide valuable feedback to Airservices Australia.

4.9.2 Airservices will make recommendations to the regulator CASA on the acceptance and commissioning of LAAS SCAT-1/LAAS CAT-1 systems when the systems become available commercially.

5. Satellite Based Augmentation System (SBAS)

5.1 Current Situation

5.1.1 SBAS is commonly thought of as the US FAA's wide area augmentation system (WAAS). However Airservices has embarked on an investigation of the capability of VHF to provide a suitable alternative data link for transmitting wide area correction messages to aircraft. The US WAAS uses a network of monitoring stations throughout the US and lower provinces of Canada to assist in the generation of correction messages. These messages are uplinked via the Inmarsat III satellites for broadcast to an aircraft which applies the corrections to a GPS derived position to improve the accuracy of the position. The Inmarsat satellites also have navigation packages on board from which an aircraft's avionics can range, thereby providing additional satellites in space from which to obtain ranging information.

5.1.2 Airservices is using a VHF retransmit capability via the Optus satellite to provide the correction messages to an aircraft. Thus the ASTB is transmitting an SBAS message format on a GBAS data link. It is emphasised this is only a proof of concept by Airservices. Other concepts might involve networking a series of GBAS stations to provide a wide area network or utilising other frequency bands. The Stanford University VHF system and the United Kingdom's C-band trials are examples of similar investigations. Additionally, the Swedish Civil Aviation Authority's VHF Data Link (VDL) Mode 4 is another possibility. For a truly international system, the data link needs to be internationally interoperable. Airservices Australia will not be promoting an Australian only solution.

5.2 ASTB Space Based Augmentation System

5.2.1 The original ASTB test plan called for an interconnection to the Santa Paula CA Navigation Land Earth Station for uplink of the Australian generated SBAS message to the Inmarsat III Pacific Ocean Region (POR) satellite. However, for various reasons, that test data link route became unavailable.

5.2.2 At that time, Airservices conducted a pragmatic evaluation of what an end user would need and what areas of coverage would be required. It should be noted at the outset, that there are about 10,000 registered aircraft in Australia, of which some 7,000 aircraft navigate using Visual Flight Rules (VFR) only. The traffic density in Australia is significantly different to that in North America or Europe. The majority of air traffic movement occurs on the eastern seaboard in the so called J-curve, a line running from Cairns in north-east Queensland to Adelaide in South Australia. Other major air traffic route exist from Sydney and Melbourne to Perth, from Sydney north west to Singapore and Bangkok, and east across the Pacific.

5.2.3 An assessment of the VHF voice communications coverage area in Australia was made. Air Traffic Service (ATS) VHF voice communications above 20,000 feet utilise the Optus domestic communications geostationary satellite. There is almost 100% VHF coverage over Australia above 20,000 feet. An evaluation was completed for VHF coverage at 10,000 feet, 5,000 feet and 2,000 feet. The coverage areas are shown at Annex A. It can be seen that by overlaying the most frequently used air traffic routes, there are vast areas of Australia that probably do not need augmentation. The debate on that, and any subsequent decision, is still well in the future. However it was decided to test the viability of generating a wide area message and transmitting it to an aircraft via VHF rather than on the L1 frequency available via INMARSAT satellites.

5.2.4 There are two main elements of the satellite based wide area component in the ASTB, the ground infrastructure and the airborne testing. L1/L2 GPS receivers were installed by AUSLIG around Australia and off-shore as part of the Australian Fiducial Network. These GPS receivers are capable of providing some of the required information for the ASTB and are referred to as the Test Reference Stations (TRSs). An MOA was signed between Airservices Australia and AUSLIG in April 1996 for the provision of data from these sites. These stations form the basis of the ASTB. Sites at Darwin, Alice Springs, Ceduna, Brisbane and Hobart are being used in addition to the Master Control Station reference station in Canberra. NovAtel Millenniums were installed at each site except Ceduna which has a TurboRogue.

5.2.5 A contract was signed with Stanford Telecommunications (STel) Ltd in June 1997 to provide technical assistance with the implementation of the wide area component of the ASTB. The US FAA provided Australia with the international TRS to TMS (Test Master Station) Interface Control Document. The Airservices' G-1000 aircraft is the test aircraft.

5.2.6 Figure 2 is a schematic diagram of the wide area augmentation components.

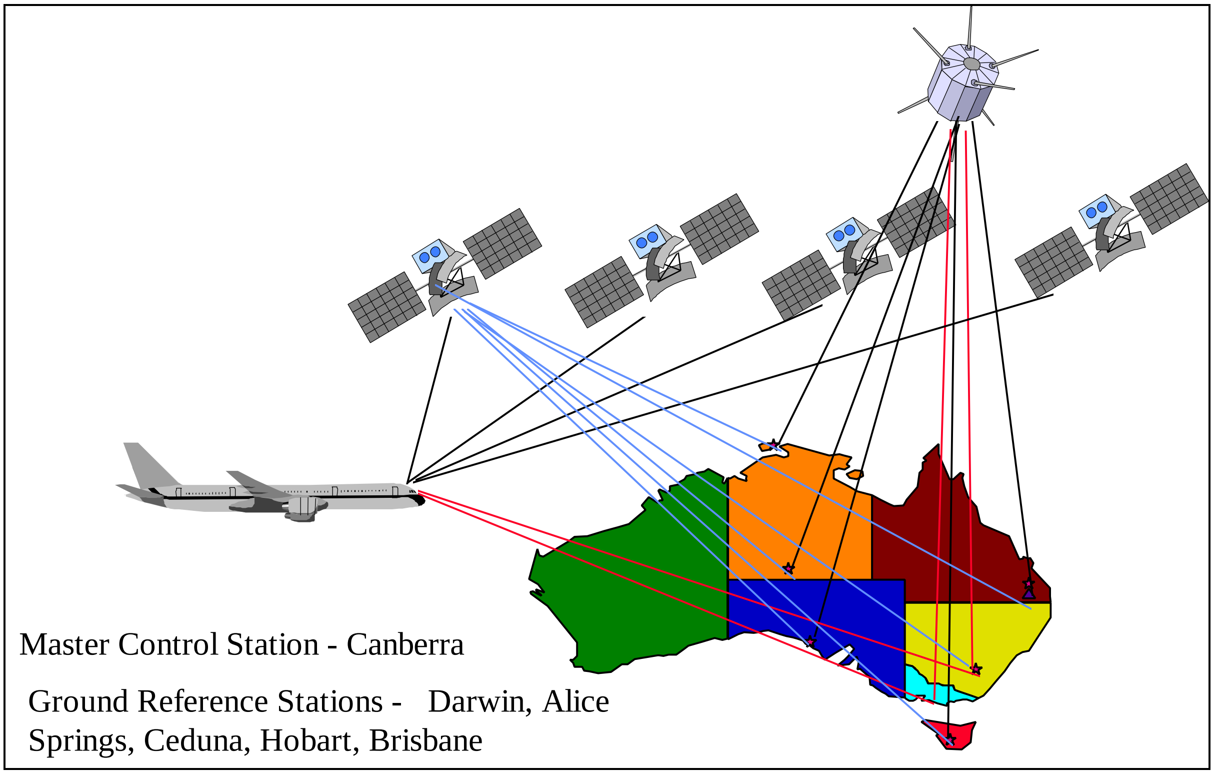

Figure 2. Space Based Augmentation System Components

5.3 **Data Link**

5.3.1 The data from each TRS site is linked via the Optus satellite to the Master Control Station in Canberra. The data is processed and a wide area correction message is generated. That data is then sent via modem to VHF stations in Canberra and Melbourne, for uplink to the G-1000 test aircraft. In fiscal year 1998/99, the data will be broadcast to the Optus satellite which will act as a "bent pipe" to retransmit the data to the test VHF transceivers which lie within the Optus footprint. The data will be retransmitted automatically by the transceivers. Static testing has already been completed on this element of the ASTB.

5.4 Phased Approach

5.4.1 The wide area component of the ASTB is divided into two main phases:

a. **Phase 1.** Procurement of equipment for TRSs, TMSs, G-1000 aircraft and integration testing of the components at STel.
Installation of TMS and TRSs.

b. **Phase 2.** Static Tests
Flight Tests - enroute, non precision approaches, CAT-1

5.5 Current Status

5.5.1 All the AUSLIG stations are transmitting data back to Canberra. The first two TRSs were installed in late October 1997 and the Master Control Station became functional in late November 1997. The first wide area message was generated on 23 February 1998. The ASTB is using a grid matrix of 10° by 10° which may be changed to 5° by 5° next year. Flight testing will commence in early April 1998.

5.5.2 The static tests have generated correction messages with an accuracy of 0.6 meter CEP with no diversions beyond 2 meters. Flight testing will evaluate the errors due to retransmission. Static data latency from the TRS to the MCS is 375 milliseconds. Transmission of the correction message to the Optus satellite and return has a 250 millisecond latency. The processing time is still being measured fully.

5.5.3 One issue that had to be addressed was the near/far issue. Because the correction messages are emanating from a VHF antenna, the WAAS receivers being used, which are the same as the National Satellite Test Bed receivers, needed a delay built into the ground transmission to enable the cycle of the WAAS receiver to accept the correction messages at the same time slot that the US WAAS timing uses.

5.6 Future Activity

5.6.1 In the next fiscal year (July - June), subject to funding approval, the system may be extended to evaluate the use of other data link methods. The full retransmit capability from test VHF transceivers will be evaluated. Linking to other countries may also be attempted.

5.6.2 A detailed study will need to be undertaken to determine if VHF or other data links provide the availability, integrity and continuity of service sufficient to be considered a viable alternative mechanism for providing wide area augmentation.

5.6.3 The requirements for wide area augmentation capable avionics will also need to be addressed in considerable detail. Such issues as whether avionics or aircraft can accommodate two data link sources of wide area correction messages need to be addressed with manufacturers.

5.6.4 A Ground Based Regional Augmentation System (GRAS), based on an SBAS message being transmitted on a separate data broadcast frequency than the current ICAO GNSS Panel SBAS Standards and Recommended Practices, will become a ICAO GNSS Panel future work item. Airservices will be participating actively in that work.

5.6.5 Airservices has commenced the development of a GNSS Transition Plan involving key personnel from Airservices, CASA, Defence and Industry, which formed as a team to undertake this important task. When completed, during the first half of 1999, the Plan will be supported by sustainable safety and business cases.

6. Conclusion

6.1 The ASTB is a progressive initiative by Airservices Australia. The GBAS program will ensure that Airservices and CASA are in a position to certify the public domain GBAS CAT-1 equipment when it becomes commercially available. The results to date in Melbourne, show that the 20 runway ends at Melbourne, Moorabbin, Essendon and Avalon could be serviced by one ground system.

6.2 The wide area augmentation evaluation is examining the requirements for, and capabilities of, such augmentation in Australia. The use of VHF, while for testing a proof of concept only, could result in an alternative methodology for implementing wide area augmentation. Other data link methods should also be investigated so that a full understanding of alternative systems is available for a fully integrated, internationally interoperable wide area augmentation. A pragmatic approach to what is required by individual countries should be undertaken so that an affordable international system can be implemented.

6.3 Airservices will be seeking the most cost effective satellite and/or radio navigation mix architecture that provides the best aid to navigation that is affordable and internationally interoperable into the 21st century.

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ANNEX A

Figure 1.   VHF Coverage at 20,000 Feet

A - 2

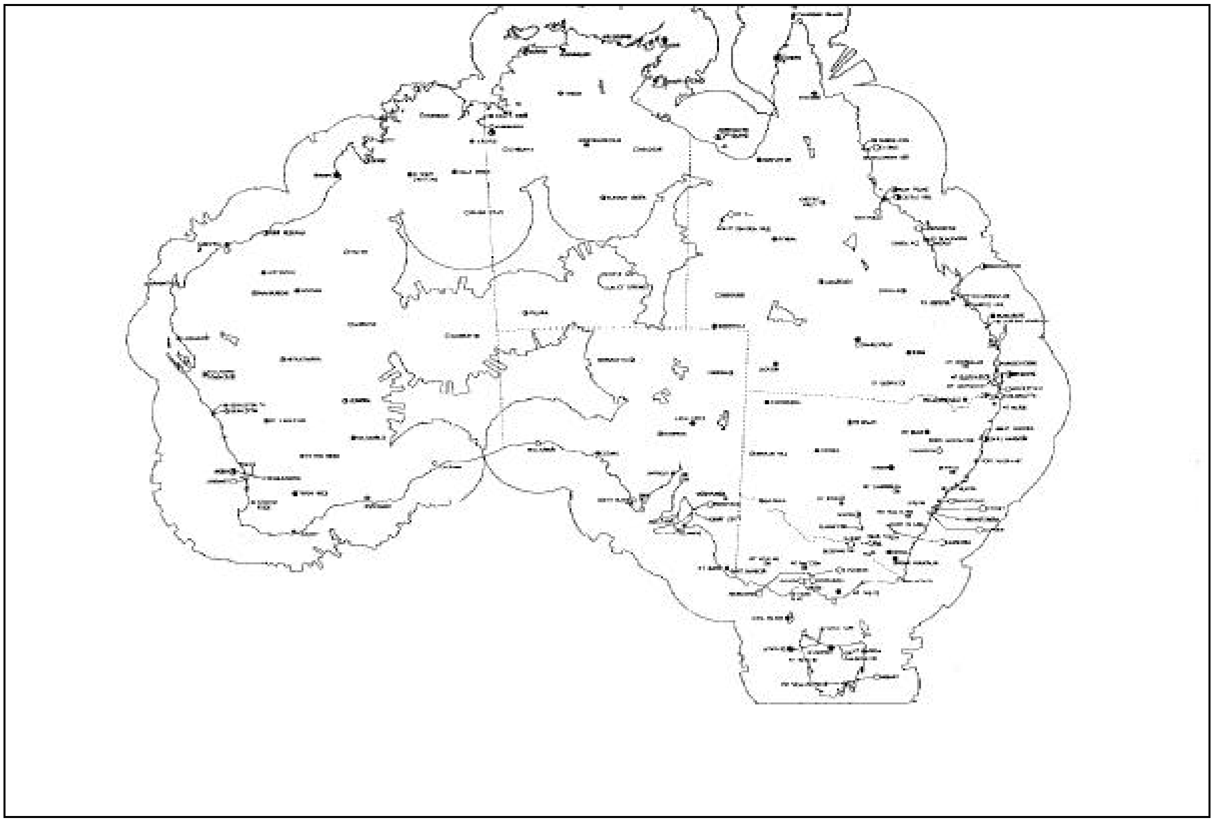

Figure 2. VHF Coverage at 10,000 Feet

A - 3

Figure 3. VHF Coverage at 5,000 Feet

A - 4

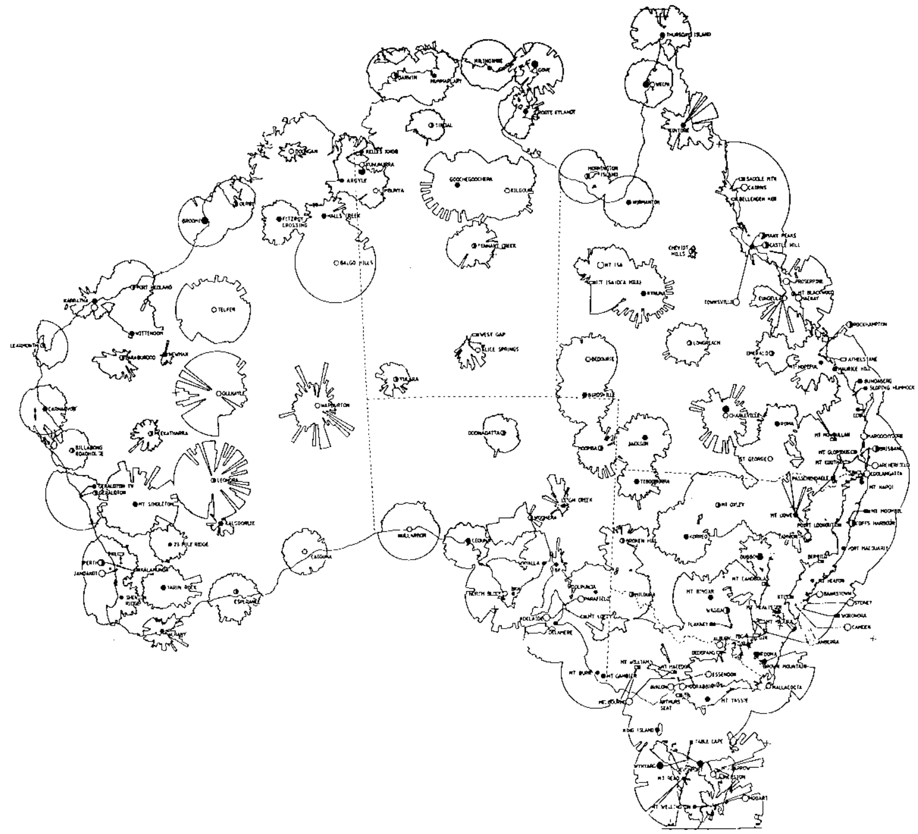

Figure 4. VHF Coverage at 2,000 Feet