

**Engineers Australia  
Engineering Heritage Victoria**

**Nomination**

**Engineering Heritage Australia Heritage Recognition Program  
for the**

**INTERSCAN Microwave Landing  
System, Melbourne, Victoria**



**February 2013**

### Front Cover Photograph Caption

**This photo shows two of the different INTERSCAN MLS Elevation Antennas<sup>1</sup> which were components of the prototype INTERSCAN landing system located at Melbourne International Airport in Tullamarine. This photograph was taken in 1977.**

***Image: Civil Aviation Historical Society's collection.***

---

<sup>1</sup> The plural of antenna adopted in this document is antennas. Both Collins and Oxford Dictionaries suggest that antennas is the correct plural expression for radio aerials whereas antennae is correct for botanical applications.

## TABLE OF CONTENTS

	PAGE
<b>Table of Contents</b>	<b>3</b>
<b>1 Introduction</b>	<b>5</b>
<b>2 Heritage Nomination Letter</b>	<b>6</b>
<b>3 Heritage Assessment</b>	<b>7</b>
3.1 Item Name	7
3.2 Other/Former Names	7
3.3 Location of Prototype	7
3.4 Address of Prototype	7
3.5 Suburb/Nearest Town of Prototype Installation	7
3.6 State	7
3.7 Local Govt. Area of Prototype Installation	7
3.8 Location of Interpretation Panel	7
3.9 Owner	7
3.10 Current Use	7
3.11 Former Use	7
3.12 Designer	7
3.13 Maker/Builder	8
3.14 Year Started	8
3.15 Year Completed	8
3.16 Physical Description	8
3.17 Physical Condition	8
3.18 Historical Notes	8
3.19 INTERSCAN Currently	11
3.20 Heritage Listings	13
3.20.1 Commonwealth Heritage List	13
<b>4 Assessment of Significance</b>	<b>14</b>
4.1 Historical significance	14
4.2 Historic Individuals or Association	15
4.3 Creative or Technical Achievement	15
4.4 Research Potential	16
4.5 Social	16
4.6 Rarity	17
4.7 Representativeness	17
4.8 Integrity/Intactness	17
<b>5 Statement of Significance</b>	<b>18</b>
5.1 INTERSCAN Historical Significance	18

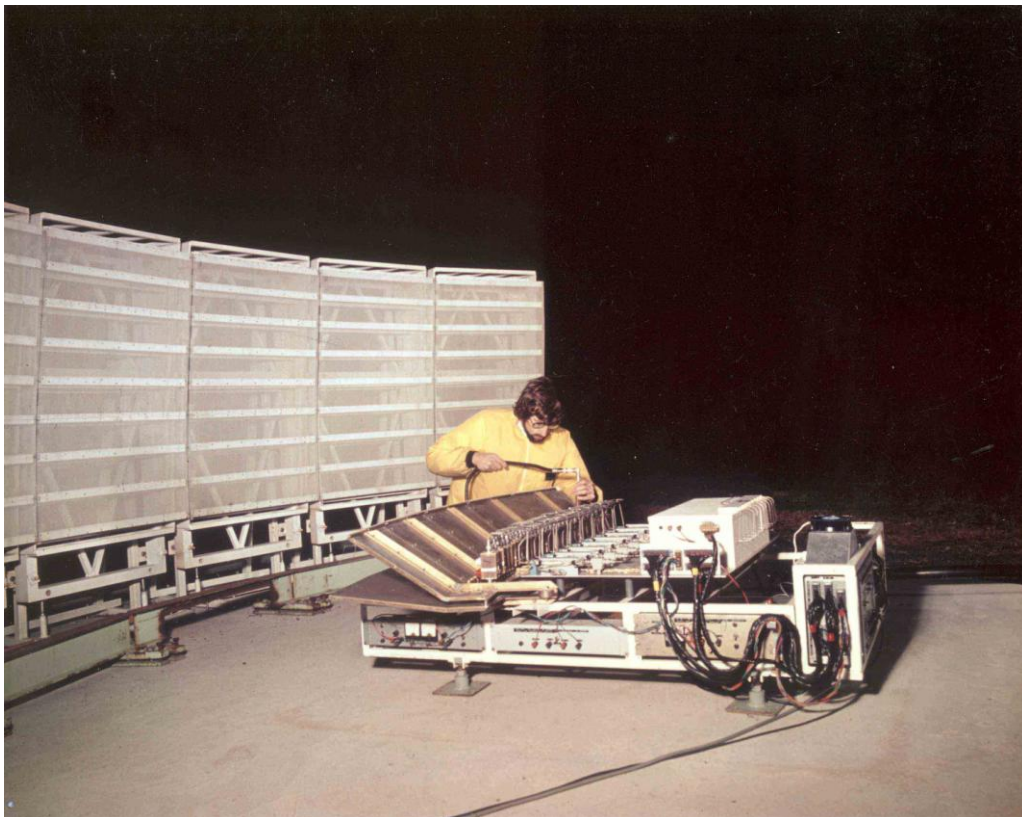
5.2 Civil Aviation Historical Society	18
6 Area of Significance	19
7 Interpretation Plan	20
7.1 General Approach	20
7.2 General Attributes of the Possible Interpretation Panel	22
7.3 The Interpretation Panel	23
7.4 Preliminary Text Blocks for Interpretation Panel	24
8 References	25
Acknowledgements	26
Appendix 1: Location of the INTERSCAN System	27
Appendix 2: Timeline for Air Services Responsibility in Australia	31
Appendix 3: Historic Individuals or Associations	32
Appendix 4: An Introduction to Microwave Landing Systems (MLS)	50
Appendix 5: Glossary of Terms	52
Appendix 6: Press release from Thales	55
Appendix 7: Additional Photographs	57

## 1 Introduction

The INTERSCAN, which is short for **Time INTERval SCANning) Microwave Landing System (MLS)** was an Australian-developed technology created in response to a competition devised by the International Civil Aviation Organisation (ICAO) and administered by the All Weather Operational Panel (AWOP) to find a replacement for the then current Instrument Landing System (ILS). The INTERSCAN system through superior design and technological diplomacy was accepted as the world standard technology for assisted landing in 1978 and is still being installed and used in airports around the world such as Heathrow Airport.

Despite the success of the technology on the international stage, in relatively recent history little has been done to acknowledge the significance of the system. The technology has mostly fallen out of the public's interest and the prototype equipment, at Melbourne International Airport has been left exposed to the elements with little care for its historical value.

This Nomination for Engineers Heritage listing should lead to greater public awareness and possible recognition with other heritage recognising bodies, allowing this Australian achievement to be remembered for posterity.



Night work being completed on an Azimuth Antenna.

*Image: Civil Aviation Historical Society's collection*

## 2 Heritage Award Nomination Letter

The Administrator  
Engineering Heritage Australia  
Engineers Australia  
Engineering House  
11 National Circuit  
BARTON ACT 2600

**Name of work:** INTERSCAN Microwave Landing System

**The above-mentioned work is nominated to be awarded recognition under the Engineering Heritage Recognition Program.**

**Location, including address and map grid reference if a fixed work:** The INTERSCAN system is located at three sites along the East-West runway (Runway 09/27) at Melbourne International Airport, Victoria.

**Interpretation Panel Location (Location):** The interpretation panel for the INTERSCAN installation at Melbourne International Airport will be installed within the Civil Aviation Historical Society and Airways Museum at Essendon Airport, upon the museum's approval.

**The owner has been advised of this nomination and a letter of agreement is attached.**

**Access to site:** The location of the INTERSCAN prototype installation is restricted, and is not accessible to the public. This is due to the location being close to the East-West runway and various taxiways at Melbourne International Airport.

**Nominating Body:** Engineering Heritage Victoria

**Owen Peake**  
**Chair, Engineering Heritage Victoria**

**Date: 24 June 2013**

### 3 Heritage Assessment

**3.1 Item Name:** INTERSCAN Microwave Landing System

**3.2 Other/Former Names:** Nil

**3.3 Location of Prototype:** East-West Runway, Melbourne International Airport

**3.4 Address of Prototype:** Melbourne International Airport

**3.5 Suburb/Nearest Town of Prototype Installation:** Tullamarine

**3.6 State:** Victoria

**3.7 Local Govt. Area of Prototype Installation:** Federal Government of Australia

**3.8 Location of Interpretation Panel:** Civil Aviation Historical Society and Airways Museum, Essendon Airport, Victoria

**3.9 Owner:** This is currently undetermined; at the time of construction the airport was owned by the Federal Airports Corporation but at the time the radio navigation equipment was installed the parcels of land belonged to the Civil Aviation Authority.

Since then the airport has changed hands to Australia Pacific Airports Melbourne Pty Ltd who is the likely owner of the site by default but this cannot be confirmed as the parcels of land may still remain in the ownership of the Civil Aviation Authority which is now known as Airservices Australia.

Contact with both parties has not cleared up the ownership issue for this site.

For the purpose of the Interpretation panel, the panel will be placed within the Civil Aviation Historical Society and Airways Museum at Essendon airport. This is due to the INTERSCAN installation at Melbourne airport being in a restricted location along the East–West Runway of the airport, as well as the INTERSCAN installation's owner being currently unknown.

**3.10 Current Use:** Prototype is no longer in use

**3.11 Former Use:** As a working demonstration and prototype of the INTERSCAN Microwave Landing System Technology for the International Civil Aviation Organisation (ICAO) as the future standard precision approach and landing system for international civil aviation.

**3.12 Designer:** Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia

**3.13 Maker/Builder:** Amalgamated Wireless (Australasia) Ltd (AWA) in association with the CSIRO, Sydney. The antenna structures were designed by Gutteridge Haskins and Davey.

**3.14 Year Started:** INTERSCAN Project began in 1971, Prototype built and installed in three separate sites within Melbourne International Airport in 1973.

**3.15 Year Completed:** INTERSCAN was made the standard signal by the International Civil Aviation Organisation (ICAO) in 1978, after all flight testing was complete in 1975.

**3.16 Physical Description:** The INTERSCAN MLS consists of three different sites along the East–West runway of Melbourne International Airport. The INTERSCAN system includes a number of different antennas (see appendix 1 for all element locations) and receivers in different positions along the length of the runway. On the approach, on the eastern part of the runway there is an antenna to detect the aircraft's missed approach, two Flare Antennas to the left on the eastern approach to determine the elevation and final guidance signal for landing on the runway. On the far end of the western side of the runway is the Azimuth Antenna to determine the glide angle the aircraft should take, and two antennas either side of the runway to determine the position of the aircraft for the Azimuth Antenna to determine the aircraft's position relative to the runway's centre line. The Azimuth information and the Elevation Flare information are combined into the guidance system to safely and accurately guide and aid the pilot to land the aircraft. The INTERSCAN system does not contain moving parts, it is stationary during operation.

**3.17 Physical Condition:** Currently the system is partially intact at Melbourne International Airport; however the remnants of the system are in poor condition as the antennas are open to the elements. All buildings and some equipment have been removed and concrete slabs remain where they once stood.

### **3.18 Historical Notes:<sup>2</sup>**

In the early 1960s the Australian Department of Civil Aviation (DCA) and various aviation administrations in Australia came to the conclusion after various upgrades were conducted on the existing Instrument Landing Systems (ILS), that an entire new system with higher accuracy was required for landing aircraft. This new system became known as the Microwave Landing System as it operated in the radio frequencies of 5000 MHz and higher, in comparison to the existing ILS system which used frequencies in the 110 to 330 MHz region during operation.

During the 1960s the United States and the United Kingdom had commenced studying alternative landing systems, each with their own objectives and were independently developed in each country. The DCA believed that the International

---

<sup>2</sup> Refer to Appendix 2 for a timeline of Air Services Responsibilities in Australia.



Civil Aviation Organisation (ICAO) should coordinate the development of the Microwave Landing System, rather than have separate countries developing separate systems in an uncoordinated method with each other, with non-universal systems.

In April 1967 during the meeting of the All Weather Operational Panel (AWOP), a proposal was made for the ICAO to begin studies on a new system to replace the older existing ILS landing system. Two years later ICAO finally agreed to commence the study for an alternative landing system, and gave the AWOP the task of producing an Operational Requirement (OR) for the system to be developed. Consequently the DoT actively participated in the task given to AWOP. In 1972 the recommendations made in the Operational Requirement were agreed to internationally by the ICAO.

In the early 1970s after the ICAO agreement with the AWOP, a worldwide competition began with the United States of America, United Kingdom, France and Germany, to study and develop a new, more accurate alternative landing system. Australia entered into this competition in 1973, to develop a submission for the ICAO.

In 1971, Dr John Paul Wild was appointed the chief of the Division of Radio Physics at the Commonwealth Scientific and Industrial Research Organisation (CSIRO) in Australia. He held discussions with the DCA in regards to applied research projects in the aviation field. As a result of these discussions the developments for the Microwave Landing System were reviewed, and in particular that the United States had reluctantly ceased development of a superior system due the lack of a suitable antenna being available for use.

Shortly after, Wild assembled a small team, which was very quick to conceptualise and develop a possible solution to the Microwave Landing System project. This solution was called 'INTERSCAN' due to its operational nature. In 1972 Wild appointed Harry Minnett as the Engineering Director for the 'INTERSCAN' Project. Wild and Harry had complementary expertise and both had enthusiasm for the project. Harry's knowledge and expertise of antennas was crucial in the conceptual and design phases; one of the antennas was an electronically scanned Torus Reflector. The technology for the Torus Reflector was earlier developed for the surface of the Parkes Radio Telescope; it was directly applicable for use in the INTERSCAN system.

In 1973 two Australian companies called Amalgamated Wireless Australasia (AWA) and Hawker de Havilland were awarded a contract from the Department of Transport (DoT) to manufacture the prototype INTERSCAN system. The prototype system installed at Melbourne International Airport was called MITAN by the two manufacturing companies, and was used for flight trials.

The operational testing of the system was undertaken by DCA and DoT.

The DoT determined from previous experiences that technological diplomacy was required for their bid in the competition to succeed. Australia decided to work with the United States as it moved to select its own system. If the United States was convinced of the Australian INTERSCAN systems superiority, and a system based on its principles was chosen, both countries would be a powerful force in the ICAO selection process.

In 1974 Australia decided to demonstrate the superiority of INTERSCAN to the United States; in the same year a high United States technical mission visited Australia. The officials from the United States were extremely impressed with the presentation of the INTERSCAN System and its demonstration. As Australia had a prototype at the time it was determined that it was impractical to provide equipment to the United States, instead it was determined to demonstrate that INTERSCAN would work in the United States with modified United States equipment. In mid-1974 flight tests of INTERSCAN were conducted in the United States in Atlantic City, New Jersey, with modified Transmitters for the INTERSCAN signal and Australian receivers in the aircraft. At the end of 1974 the United States used all of the core features of INTERSCAN in their landing system, this system was called Time Reference Scanning Beam (TRSB), and subsequently this was used for presentation to the ICAO.

Essentially Australia and the United States, towards the end of 1974, collaborated closely on the development of the Microwave Landing System so that the two systems from both countries were now essentially the same. The All Weather Operational Panel (AWOP) decided to deal with the entries jointly as TRSB/INTERSCAN. However the main difference between the systems was the ground system to generate the common guidance signal. This difference between the two countries' ground equipment was seen as an advantage as it demonstrated the diversity of equipment which could be commissioned in implementation of the final system.

In March 1975 INTERSCAN was demonstrated to an ICAO Working Group at Melbourne Airport. The system was so precise that the pilot of the aircraft was able to land the aircraft 60 centimetres from the centre of the runway. The original equipment such as the antennas can still be seen at Melbourne Airport.

In 1977 all the proposed systems were evaluated by the AWOP, and in February – March of the same year they chose TRSB/INTERSCAN as the signal format to be recommended to the ICAO in a worldwide meeting of its member states. INTERSCAN was installed and rigorously tested at Sydney Airport. At a further meeting of the ICAO in Montreal in 1978, 39 of the 71 member states recommended TRSB/INTERSCAN. Consequently TRSB/INTERSCAN became the standard system for implementation for the ICAO international standardisation.

The Microwave Landing System became the replacement for the older Instrument Landing System in Europe. However in the United States, the Federal Aviation Administration in 1994 halted further development of the MLS system, in favour of technology based upon the Global Positioning System (GPS). After the competition had ceased an Australian company called INTERSCAN (Australia) Pty Ltd was formed to commercialise aspects of the INTERSCAN Microwave Landing System. The company was renamed INTERSCAN International to promote the sale of its products on the international market.

### **3.19 INTERSCAN Currently**

Unfortunately INTERSCAN MLS branding is no longer being used by the government constructed vehicle for development and commercialisation INTERSCAN Pty Ltd. INTERSCAN Pty Ltd no longer constructs MLS systems as part of its product base. However as the INTERSCAN/TRSB MLS design was chosen as the world standard for Microwave Landing Systems by the ICAO, all current MLS should incorporate the principles of design which were pioneered by the CSIRO in the construction of the INTERSCAN system. MLS systems are being installed at Heathrow airport in England by an engineering company called Thales, on all of its main runways

Thales manufactures various electronic and electrical systems relating to aviation and the company produces MLS receivers and transmitters. MLS System installations under the same contract by Thales are being considered for installation at several other major airports in the United Kingdom.

In France's main international Charles De Gaulle airport in Paris and other airports in Europe, MLS systems are being considered for installation as they provide a far more efficient landing service for aircraft, especially in areas of poor visibility. As MLS Systems are still being considered for installation around Europe, it is currently unknown on how many airports have the systems currently installed. MLS systems are favoured over GPS guidance, as the satellites which make up the GPS global network are controlled by the United States military and could be deactivated or jammed at any given time. Hence MLS as a navigational aid for aircraft is favoured as each system is independent of each other and only concerns the particular runway at which they are installed.

The National Aeronautics and Space Administration (NASA) incorporated a version of the Microwave Landing System for use at its Wallops Flight Facility in Virginia and at the Space Shuttle Landing Facility in Florida. At the Wallops facility rockets are launched for science and exploration missions for NASA. When some types of space craft return they operate in a similar method to a commercial jet or heavy military transport aircraft, land on a runway and therefore an advanced landing system was required to perform the task of landing these space craft. The system installed at the Wallops Facility is designed to operate with various types of aircraft ranging from

commercial and military aircraft to different types of scientific related and experimental aircraft.

The system installed at the Wallops facility, and the Shuttle Landing Facility in Florida, is called Microwave Scanning Beam Landing System. This system is similar to the original ICAO approved INTERSCAN/TRSB system, however it is slightly different so as to accommodate the space shuttle's descent rate being 20 times higher and 7 times steeper upon approach in comparison to regular commercial aircraft.

On the 21<sup>st</sup> of August 2007, the space shuttle mission STS-118 to the International Space Station utilised the Microwave Landing System installed at the Shuttle Landing Facility at the John F Kennedy Space Center, Florida, to land the Space Shuttle Endeavour.<sup>3</sup>

Unfortunately due to the United States Federal Aviation Administration's decision to develop GPS guidance systems for aircraft, Microwave Landing System development was halted in 1994. However a small number of airports including Los Angeles International (LAX) have Microwave Landing Systems installed from the era when the TRSB/INTERSCAN was accepted as the international standard for MLS systems.

The United States Air Force is the largest user in the world of Microwave Landing Systems<sup>4</sup>, with more ground systems implemented than all other civil and military applications in the world combined. In Afghanistan, the USAF is employing six of its 37 mobile MLS systems to transmit landing guidance to Lockheed C-130 "Hercules" and Boeing C-17 "Globemaster III" transports providing support to U.S. and allied forces.

Approximately 500 Hercules of the USAF are reported to be equipped with MLS receivers<sup>5</sup>, and MLS avionics are standard on the Globemaster III, both types of aircraft are large heavy transport aircraft.

---

<sup>3</sup> NASA has released a video showing the Space Shuttle Endeavour landing after mission STS-118 at the Shuttle Landing Center at the John F Kennedy Space Center in Florida. The Video is very descriptive about the nature of Space Shuttle landings. The link to the video is: <http://www.youtube.com/watch?v=r15QlpFchbQ>

<sup>4</sup> The USAF decision to implement MMLS as a rapidly-deployable precision approach system was based upon the crash of a US military transport in Bosnia on the 3<sup>rd</sup> of April 1996. The crash occurred whilst performing a non-precision approach in adverse weather resulting in the death of 35 passengers including the then US Secretary of Commerce Ron Brown.

<sup>5</sup> Johnathon Schembri has been able to confirm from a source at the Avalon Airshow that USAF C-130s definitely have the MLS systems installed. This source had flown H model Hercules in the late 1980s and early 1990s for the USAF.

Currently testing is in progress to implement GPS based precision approach and landing system. The USAF currently has no operational GPS landing guidance equipment, as GPS is currently considered vulnerable to enemy jamming.

The Royal Australian Air Force operates Lockheed C-130H and J model aircraft, and also operates Boeing C-17 Globemaster III aircraft. Since the Hercules would require the MLS receivers to be installed for use, it is undetermined whether the RAAF Hercules do have the MLS receivers installed<sup>6</sup>. However since it is standard on the Globemaster III, the RAAF aircraft should be able to utilise the MLS systems for Assisted or Auto landing with any runway with MLS installed. The use of MLS ensures both the safety of the aircraft and the personnel on board, as in areas such as Afghanistan there is often poor visibility due to weather conditions or terrain, which increases the difficulty of landing aircraft.

Due to the characteristics of the MLS system, military aircraft landing in dangerous locations are able to make sudden sharp turns upon approach to the path of the runway so as to avoid potential enemy ground-to-air missiles, with the guidance of MLS. Each time an aircraft lands at the same runway the approach angle and direction is altered to make each flight different from the last and not predictable to avoid potential missile threats.

### **3.20 Heritage Listings** (information for all listings)

#### **3.20.1 Commonwealth Heritage List**

**Name:** Microwave Landing System Antennas at Melbourne Airport

**Nominator:** Civil Aviation Historical Society Inc.

**Place ID:** 106235

**File No:** 2/13/007/0028

**Legal Status:** Nominated Place

**Admin Status:** Not Assessed

**Date:** N/A

---

<sup>6</sup> Johnathon Schembri spoke to a RAAF C-130 J pilot at the Avalon Airshow who confirmed that the RAAF C-130s are not equipped with MLS.

## 4 Assessment of Significance

### 4.1 Historical significance:

See section 3.18 and 3.19 above for details of the history of INTERSCAN.

The historical significance of this system is due to the evolution of aircraft landing systems made possible through INTERSCAN's construction and the advancements made in Australia's ability to use diplomacy to further its technological agenda.

The basis for the INTERSCAN landing system was the Time Reference Scanning Beam system, a US Technology which was claimed at the time to be superior to other scanning beam methods; the technology was dropped by the US, however, due to the lack of a suitable antenna. In short order the CSIRO, Department of Transport and AWA Ltd were able to design and create a system using this superior method, a prototype of which was built at Tullamarine Airport which was used to demonstrate the effectiveness of the technology which lead to its acceptance as the preferred system of the US over four other competing designs.<sup>7</sup>

Several tests were performed in the US using modified Australian/US equipment until it was agreed by the US that all the essential components of the INTERSCAN system would be incorporated into the TRSB system and the two system proposals were merged into one proposal to the ICAO. The proposal competed against several of the world's most technologically advanced nations such as the UK, France and Germany with the member states of the AWOP selecting INTERSCAN as the civil aviation's world standard for landing systems to replace the older, less capable ILS.

---

<sup>7</sup> These systems were based on beam technology and Doppler technology.

#### 4.2 Historic Individuals or Association:

See Appendix 3 for biographical information on:

1. Dr. John Paul Wild
2. Harry Clive Minnett



**Mr Minnett, centre, with Mr H.B. O'Keeffe, left, of the then Department of Civil Aviation, and Dr J.P. Wild of the CSIRO, in front of the microwave landing system they helped to develop. This file photograph was taken in the early days of INTERSCAN, April, 1973, at the CSIRO Division of Radiophysics at Epping, Sydney.**

*Image: Civil Aviation Historical Societies collection*

#### 4.3 Creative or Technical Achievement:

The INTERSCAN MLS was designed as part of ICAO's invitation to member states to develop a new system capable of replacing the current ILS due to the limiting factors of this technology.

The two primary limitations of the ILS were:

1. Signal Degradation: several common landmarks around airports such as terrain, buildings and even taxiing aircraft could affect the ILS signal. Accounting for this degradation was quite expensive and time consuming and in some cases even impossible at certain sites.

2. Single approach path: The ILS provided only a single landing path directly on the centre line of the runway and at a fixed descent angle requiring the plane to be on the correct landing approach well before the airport.<sup>8</sup>

The INTERSCAN system was capable of solving both problems with the ground based equipment being comparable in cost. The primary benefits of the system were:

1. Multiple approach paths: The INTERSCAN MLS allowed planes to approach the runway from several paths including curved paths; by doing so aircraft could be diverted around noise sensitive areas and lead to simpler air traffic management as all aircraft did not need to be on the same approach path to land using the system.
2. Greater and variable descent angle: The INTERSCAN system accommodated descent angles up to 15 degrees well in excess of the 3 degrees possible with the ILS; this allowed the system to accommodate VTOL (vertical take-off and landing) and STOL (short take-off and landing) aircraft.
3. More resilient signal: the INTERSCAN MLS was not affected by terrain, buildings and aircraft in the vicinity of the airport; this made the system able to be used in more locations than the ILS and also prevented the need for costly earthworks and building considerations to make the system workable.

#### **4.4 Research Potential:**

As the device was created relatively recently by the CSIRO and was subjected to heavy scrutiny as part of its adoption as the international standard to replace the aging Instrumental Landing System, ample documentation of the devices' construction and function does exist and as such no particular areas of research appear to be pressing at this time.

#### **4.5 Social:**

Prior to the introduction of MLS technologies the single approach path offered by the then current ILS had great impacts on how airports operated and their relationships with people who lived in the vicinity of the airport.

The single flight path offered by the ILS was often responsible for the bulk of airports' traffic being sent over noise sensitive areas such as homes; the path could be changed but in the best case scenario it required realignment of the runways and at worst was impossible due to the ILS's weaknesses associated with buildings and terrain. This often led to airports being subjected to curfews which presented

---

<sup>8</sup> O'Keeffe, H.B. "INTERSCAN – The development and international acceptance of a new microwave landing system for civil aviation" as featured in Transactions of the Institution of Engineers, Australia, Electrical Engineering, Vol. EE 16, No 2, June 1980, page 78.



serious problems trying to arrange international flights around local curfews at take-off and landing.

The introduction of MLS systems allowed air traffic control to divert traffic to paths that did not pass over noise sensitive areas allowing airports to operate at expanded hours and new airports to be constructed in areas closer to population centres without being affected by curfews.

It also allowed airports to integrate better into the local environment as expensive earthworks along the approach path were no longer required and local buildings did not affect the MLS's ability to operate which allowed approach paths to be better calculated to avoid populated areas

#### **4.6 Rarity:**

Whilst the INTERSCAN MLS was chosen as the international standard by the ICAO, the installation at Tullamarine represents the very first INTERSCAN MLS in the world making the installation unique.

Due to the unique nature of the installation coupled with its lack of heritage recognition, effort should be taken to preserve the site.

#### **4.7 Representativeness:**

The TRSB/INTERSCAN microwave landing systems were accepted by the ICAO as the international standard for landing systems; as such, MLS devices implemented worldwide should follow the essential standards demonstrated in the prototype system making the device a perfect representation of the system's origin.

#### **4.8 Integrity/Intactness:**

Quite a few of the components of the device are still in place at Melbourne airport with their exact locations available in Appendix 1. According to anecdotal evidence the remaining antennas have been left exposed to the elements without maintenance and are in a poor condition although components may be able to be restored if necessary. In addition to the antenna components, a transmitter used for the guidance signal is currently being held at the Airways Museum in Victoria which has been well preserved.

## 5 Statement of Significance:

### 5.1 INTERSCAN Historical Significance

The INTERSCAN Microwave Landing System installation at Melbourne International Airport was used as a prototype in March 1975 to conduct a demonstration of its operation for the ICAO. The INTERSCAN prototype installation was proven to be extremely precise in that it aided the pilot to land the aircraft within 60 centimetres of the centre of the runway.

Initially, in 1971 to early 1974, the INTERSCAN system was developed by the CSIRO, as a potential alternative to the aging Instrument Landing System. The INTERSCAN Microwave Landing System is very significant to Australia nationally and internationally, as the guidance signal used by INTERSCAN became the international standard for this type of landing system in 1978. The significance of the INTERSCAN System is that it was initially completely designed in Australia and a working prototype was installed and successfully tested locally at Melbourne International Airport, as well as at Sydney Airport.

Internationally the INTERSCAN system is significant in that the United States and Australia jointly developed a Microwave Landing System based on the principles of INTERSCAN and certain components of the American Time Reference Scanning Beam (TRSB); consequently in 1978 the system was recommended by 39 of 71 member states of the ICAO, and the combination of the Australian INTERSCAN system and the United states TRSB became the international standard for the Microwave Landing Systems.

### 5.2 Civil Aviation Historical Society

The INTERSCAN project was Australia's response to the ICAO's challenge for member states to develop a microwave landing system to replace the many non-standard ILS installations at civil airports around the world. INTERSCAN was the Australian name patented for its version of the MLS. The name is a neologism, derived from the words **Time INTERVAL SCANNING** system. It was the result of collaboration between science (The Commonwealth Scientific and Industrial Research Organisation – CSIRO), design and precision manufacturing (Amalgamated Wireless (Australasia) Ltd (AWA) and civil aviation navigation aids engineering (Department of Civil Aviation until 1973, and then the Department of Transport Air Transport Group [DCA/DoT]). The signal format and antenna design were based on CSIRO Radio Astronomy research work. As a result of the success of the project a company, INTERSCAN Navigation Systems Pty Ltd, was created to manufacture and market INTERSCAN and other radio navigation aids. For example, Distance Measuring Equipment (DME) was also a joint venture between the Council for Scientific and Industrial Research (CSIR) – the forerunner of today's CSIRO, AWA and DCA between 1948 and 1965. The optical tracker, used in the flight testing

of INTERSCAN was also an Australian development. Several elements of the development of INTERSCAN resulted in Australian patents being granted.

## **6 Area of Significance:**

National and International

## 7 Interpretation Plan

### 7.1 General Approach

The ceremony should be held on **Saturday 9<sup>th</sup> of November 2013**. As the Civil Aviation Historical Society and Airways Museum Essendon are holding an Open Day with the theme of Melbourne International Airport history; it would be most appropriate to hold the ceremony at the museum on this date.

Preliminary discussions have been held with Roger Meyer of the museum. We are thinking of a ceremony at 10 AM with speakers at least from the Civil Aviation Historical Society and Engineers Australia. Roger thinks we might be able to get one of the people involved in the development of INTERSCAN to speak. There might also be merit in asking a VIP from Melbourne Airport to speak as a part of the process of getting their support for a sustainable future for the INTERSCAN relics at Melbourne Airport.

The ceremony could be held in the room where the INTERSCAN exhibit is located. This space would comfortably hold 30 - 50 people. Morning tea and nibbles can be provided. The museum has suitable kitchen facilities.

The interpretation panel and marker can be located within the Airways Museum at Essendon Airport in the INTERSCAN display already in place in the museum. The museum is planning to rearrange the INTERSCAN display to better integrate the elements and have agreed that an Engineering Heritage Australia marker and “mini” panel could be included.

This exhibit currently includes:

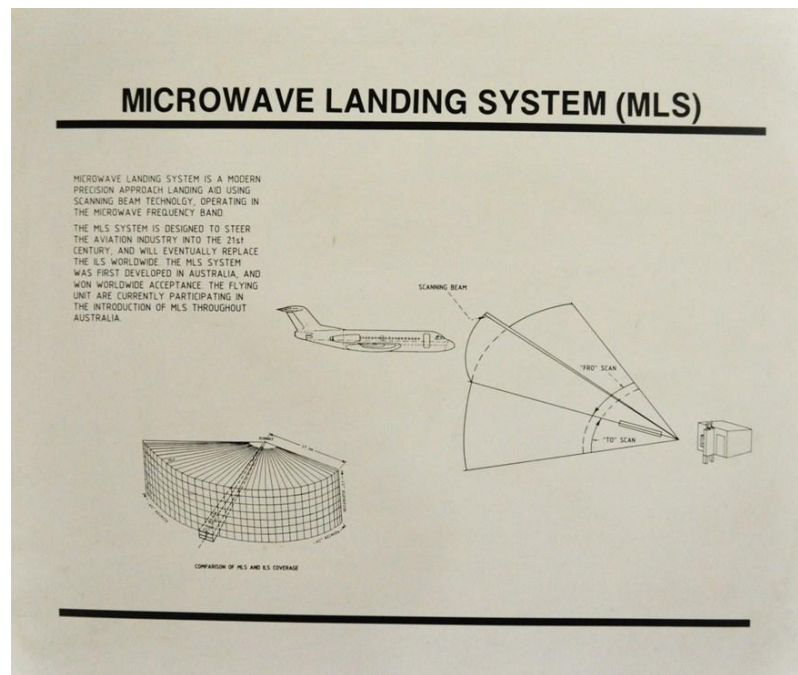
- An interpretation panel with the story of INTERSCAN/MLS (see image below). This panel is of good quality and well illustrated. **Because of this there is no need for a full EHA standard interpretation panel**, which, in any case, would be difficult to accommodate.



- A 19" rack of INTERSCAN electronic equipment (see image below).



- A freestanding diagram on a portable stand showing the basic operation of a MLS system (see image below).



The museum plans to incorporate all this material plus the EHA “mini” panel into a new display on the other side of the room. The new display will most likely be mounted on self supporting office screen system components. Similar material was sighted in the museum and it is suitable for the proposed purpose.

Note that it is not feasible to recognise INTERSCAN at the actual site at Melbourne International Airport as the equipment is not easily visible or accessible to the public. There are long term tentative plans for relocation of some of the antenna elements to a publically accessible area at the airport in which case EHA could review the possibility of adding interpretation at the airport as well as that at the Airways Museum.

## 7.2 General Attributes of the Proposed “mini” Interpretation Panel:

A title **“INTERSCAN Microwave Landing System prototype – Melbourne International Airport, Victoria”**.

- 1) Images of the EHA marker (full size 300 mm diameter).
- 2) Logos of EA and the Airways Museum.
- 3) Shorty description of the INTERSCAN Project (approximately 180 words).
- 4) The date and other details of the marking ceremony.

### 7.3 The Interpretation Panel:

- 1) Size to be nominally 350 mm wide by 600 mm high (similar style and size to the Yallourn panel copy reproduced below).
- 2) The panel will be located indoors in as secure environment so it can be constructed of reflective vinyl-on-aluminium sheet with flanges to facilitate hidden fixings.
- 3) Text should be 24 point Arial Bold.



#### Yallourn Power Station

##### *Engineering Heritage Significance*

**Yallourn Power Station demonstrated several important technological developments which were of national significance in power station practice in Australia.**

It was the first major power station to be located on the coalfield which supplied its fuel. Early power station practice had placed power stations within cities supplying energy at quite low voltages to customers without an intervening transmission system. This invariably meant transporting the coal by rail and/or ship to the power station. Yallourn was placed immediately adjacent to the coalfield using dedicated mechanical handling equipment to deliver coal to the power station. Power stations located on coalfields require high voltage transmission systems. At Yallourn 132 kV transmission was adopted initially to transmit power to Melbourne.

The engineers of Yallourn overcame the problems of converting their rich brown coalfields into electricity and minimising transport costs. Victorians have since enjoyed a cheap and plentiful source of power which also gave their industries a major advantage in terms of production efficiency.

Yallourn was an early adopter of pulverised coal as the method of delivering fuel to the boiler. This innovation paralleled efforts to develop more efficient pre-drying of the very high moisture content coal mined at Yallourn. Pulverised coal fuel for large utility boilers later became universal.

Yallourn represented five stages of power station development, constructed over a period of 40 years and operated for 65 years, during which enormous increases in the size of boilers and turbo-generators occurred. All five stages of development were operational simultaneously at Yallourn between 1961 and 1968.

*Engineering Heritage Australia has recognised Yallourn Power Station as having national engineering heritage significance. Representatives of Engineers Australia and PowerWorks unveiled this marker on 26 October 2011.*

#### **7.4 Text Block for the Interpretation Panel:**

“The INTERSCAN Microwave Landing System (MLS) was an Australian developed technology created in response to a competition devised by the International Civil Aviation Organisation (ICAO) to find a replacement for the then current Instrument Landing System (ILS).

The INTERSCAN installation at Melbourne International Airport was used as a prototype in March 1975 to conduct a demonstration of its operation for the International Civil Aviation Organisation (ICAO). The INTERSCAN prototype installation was proven to be extremely precise in that it aided the pilot to land the aircraft within 60 centimetres of the centre of the runway. The system was adopted as an international standard by ICAO.

The system was designed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and built by Amalgamated Wireless (Australasia) Ltd (AWA) in close collaboration with the CSIRO.

Whilst MLS did not replace ILS universally as planned in the 1970s the technology which grew out of INTERSCAN is now being used at busy airports in Europe and by the US Air Force at front line airfields such as in Afghanistan. The technology was never adopted in Australia”.

**(181 words)**

Aim for 180 words



## 8 References:

1. CSIRO 2012, INTERSCAN aircraft Landing System, Australia, Viewed: 10 December 2012, <[www.csiropedia.csiro.au/display/CSIROpedia/INTERSCAN+aircraft+Landing+System](http://www.csiropedia.csiro.au/display/CSIROpedia/INTERSCAN+aircraft+Landing+System)>
2. Airways Museum, 2012, The INTERSCAN Microwave Landing System, Egon Stern, Australia, Viewed: 10 December 2012, <[www.airwaysmuseum.com/MLS%20INTERSCAN%20article%20Stern%2078.htm](http://www.airwaysmuseum.com/MLS%20INTERSCAN%20article%20Stern%2078.htm)>
3. Avionics Today, 3 April 2003, MLS Back to The Future?, United States of America, Viewed: 9 January 2013 <<http://www.aviationtoday.com/av/issue/feature/807.html#.UO44229QH4Z>>
4. Thomas, B & Robinson, B 2005, 'Harry Clive Minnett 1917-2003', Historical Records of Australian Science, vol. 16, no. 2, pp. 199-220
5. Bollard, J.R 1989, 'Introduction of Microwave Landing Systems to Australia', Civil Aviation Authority.
6. Edwards, Ekers & Frater 2011 'JOHN PAUL WILD', Proceedings of the American Philosophical Society vol. 155, no. 3, pp. 377-381
7. O'Keeffe, H.B 1980, 'INTERSCAN – The Development and International Acceptance of a New Microwave Landing System for Civil Aviation', Transactions of the Institution of Engineers, Australia, vol. EE 16, no. 2, pp. 78-81
8. CSIRO 2012, *Harry Clive Minnett [1917-2003]*, CSIRO, Viewed: 28 January 2013, <<http://www.csiropedia.csiro.au/display/CSIROpedia/Minnett,+Harry+Clive>>
9. AINonline 2013, by: John Sheridan, May 15, 2008, Viewed: 12 February 2013, <<http://www.ainonline.com/aviation-news/aviation-international-news/2008-05-15/european-airports-choice-mls-doesnt-mean-ils-dead>>
10. Wikipedia 2013, Microwave Landing System, Viewed: 10 December 2012, <[http://en.wikipedia.org/wiki/Microwave\\_landing\\_system](http://en.wikipedia.org/wiki/Microwave_landing_system)>
11. Armada International, June 2002, Landing aids for bare bases, Viewed: 20 February 2013, <<http://www.thefreelibrary.com/Landing+aids+for+bare+bases%3A+the+war+in+Afghanistan+has+seen+US...-a090256992>>

## **Acknowledgements**

The authors of this nomination would like to take the opportunity to express our warmest appreciation for the assistance provided by the Civil Aviation Historical Society and in particular Roger Meyer. Their assistance has proven invaluable in the drafting of this nomination.

### **Nomination prepared by:**

#### **Johnathon Schembri**

Victoria University, Bachelor of Electrical and Electronic Engineering, Student  
115 Market Street  
Essendon, Victoria 3040  
Phone: +61 03 93510954  
Mobile: 0407208410  
Email: mel\_jcs@hotmail.com

#### **Anthony Slattery**

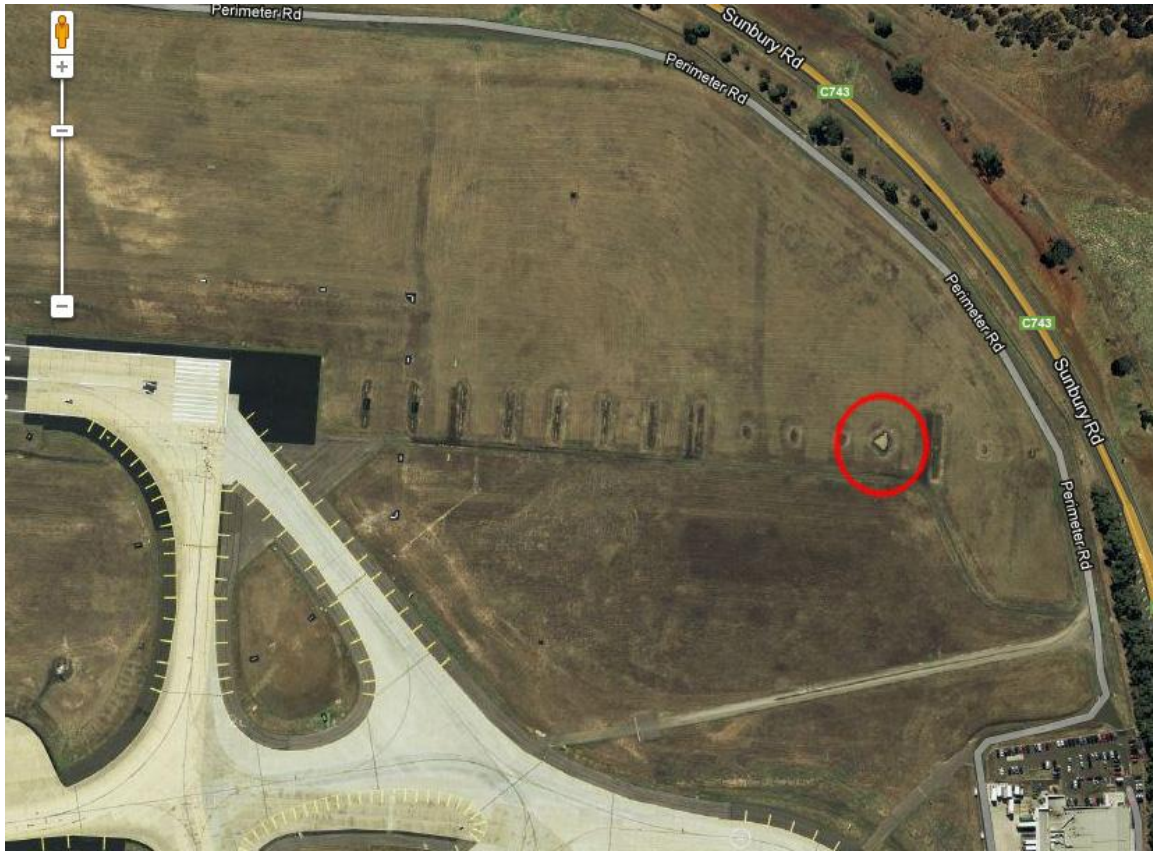
Victoria University, Bachelor of Electrical and Electronic Engineering, Student  
3 Strang Street  
Hoppers Crossing, Victoria 3029  
Phone: +61 03 97347844  
Mobile: 0466065834  
Email: anthonysslattery@hotmail.com

## Appendix 1: Location of the INTERSCAN System



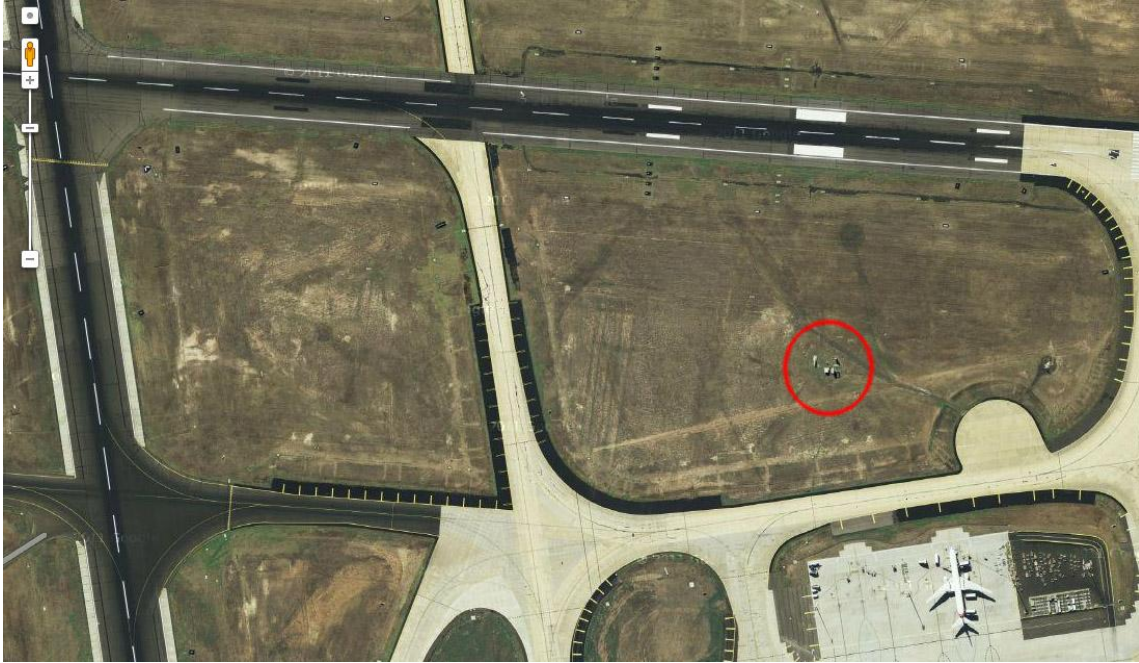
In the image above Melbourne International Airport is shown. The red circles indicate the three different sites for the INTERSCAN system. Each are labelled one to three, and the following images are in order of how they are listed in the satellite image of the airport.

**Image: Google Earth**



Shown in the image above is the approach antenna to indicate the presence of an approaching aircraft for the East-West runway. The plane is detected and effectively the other systems will begin to determine the aircraft's elevation from the ground and the vertical position of the aircraft in reference to the centre line of the runway.

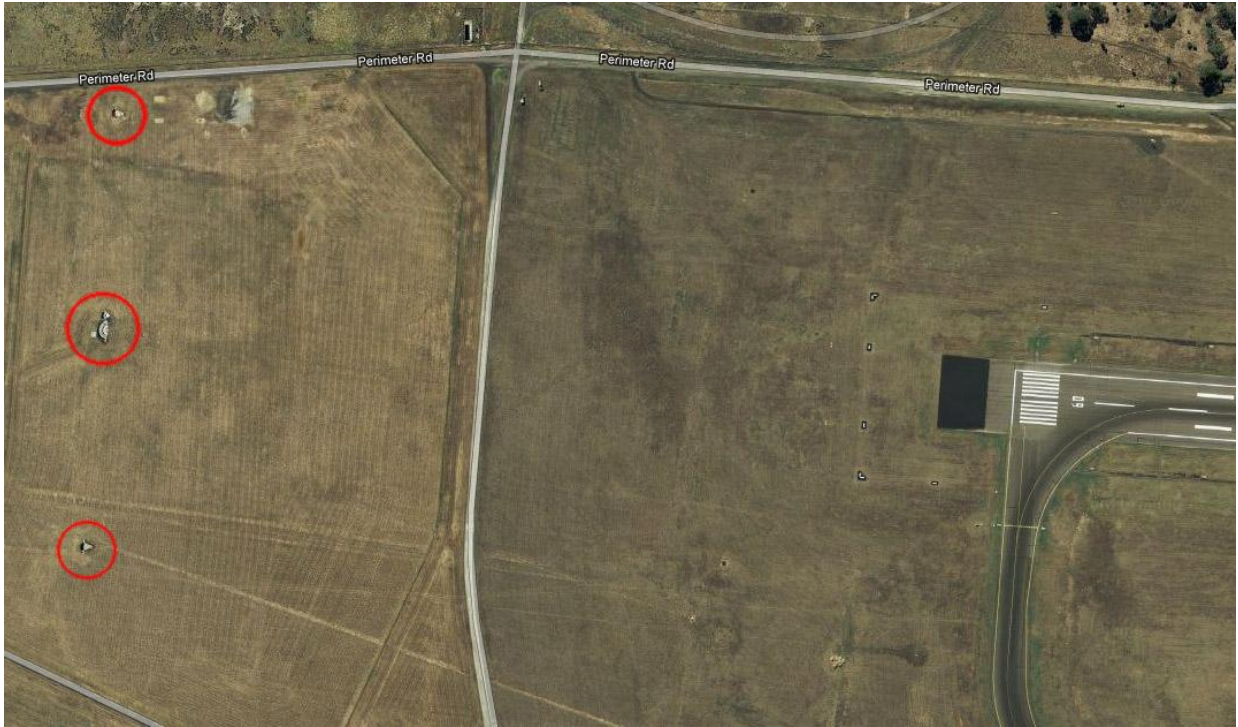
**Image: Google Earth**



In the image above, the Elevation and Guidance Flares are shown. The Elevation Flare determines the height above the runway, and the Guidance Flare combines the information from the Azimuth Antenna and the Elevation Flare and sends a combined guidance signal to the approaching aircraft to aid the pilot in landing the aircraft.

**Image: Google Earth**





Shown in the image above are the Azimuth Antennas. The two outer antennas detect the vertical position of the approaching aircraft in relation to the centre line of the runway. They use a 'to and fro' beam to establish how far from the centre the aircraft is, by using positive 40 degrees and negative 40 degrees for the top antenna and the bottom antenna respectively. The centre antenna combines the information and relays it back to the Guidance Flare, as shown in the previous image.

**Image: Google Earth**

## Appendix 2: Timeline for Air Services Responsibilities in Australia<sup>9</sup>

2 December 1920	The Air Navigation Act, which established the Civil Aviation Branch in the Department of Defence, was passed.
28 March 1921	The Civil Aviation Branch began to function, with the appointment of Superintendents of Aerodromes, Flying Operations and Aircraft.
8 April 1936	The Civil Aviation Board established within the Department of Defence.
14 November 1938	The Department of Civil Aviation (DCA) was created.
30 November 1973	The Department of Civil Aviation was amalgamated with the Department of Shipping and Transport to form the Department of Transport (DoT), Air Transport Group.
7 May 1982	The Department of Aviation was created.
24 July 1987	The Department of Aviation was amalgamated with the Department of Transport and Communications.
1 January 1988	The Federal Airports Corporation was created.
1 July 1988	The Civil Aviation Authority was established.
6 July 1995	Airservices Australia was created.
1 July 1995	The Civil Aviation Safety Authority was created.

The functions performed by the Department of Civil Aviation since its creation in 1938 continue to be performed by Airservices Australia, The Civil Aviation Safety Authority and the Federal Airports Corporation. The only exception is that the responsibility for Domestic and International Policy reverted to the Department of Transport and Communications from July 1988.

---

<sup>9</sup> Sourced from the Civil Aviation Historical Society, November 1995.

## Appendix 3: Historic Individuals or Associations

### Dr. John Paul Wild (1923 - 2008)



**Dr. John Paul Wild**

John Paul Wild<sup>10</sup> was born in Sheffield, England, the son of a cutlery manufacturer who lost everything in the Great Depression. Paul's father went to the U.S. when Paul was three months old and Paul did not see him for the next thirty-three years. Paul had an early love of mathematics that he attributed to the enthusiasm and encouragement of his school mathematics teachers. He went to Cambridge University in 1942 and studied mathematics and physics before joining the navy in July 1943. This two year period was to be his only period of university study.

Paul served as a radar officer on the flagship HMS *King George V* in the British Pacific Fleet for two and a half years. On one of the many visits the fleet made to Sydney, Australia, Paul met Elaine Hull, and their friendship grew with subsequent visits. Paul returned to England after the war and taught radar to naval officers, corresponding frequently with Elaine. In 1947, he obtained a job at the Radiophysics Laboratory of Australia's Council for Scientific and Industrial Research (CSIR) and moved to Sydney, his proposal of marriage by mail having already been accepted. Paul's first role was the relatively mundane maintenance and development of test equipment, but after a year he was able to join Joe Pawsey's radioastronomy group. Paul was a great admirer of Pawsey, who provided "an ideal environment to allow everyone to use their own initiative." CSIR became the Commonwealth Scientific and Industrial Research Organisation (CSIRO) in 1949.

Paul worked with Lindsay McCready to build, at Pawsey's suggestion, the first spectrograph to study the frequency dependence of solar bursts. This instrument

---

<sup>10</sup> Known as Paul Wild for short.



provided a display of frequency versus time covering a swept frequency range from 40 to 70 MHz. Paul travelled to Penrith, 50 km west of Sydney, by train each day with a technician and a hand-cranked movie camera to record the cathode ray screen showing the variation of intensity with frequency of the solar radio emission. Paul recalled, "Every now and then a great burst would come from the sun and we were very excited and we photographed everything that went on. ... After four months we got so much data that we just closed everything down and came back and I analysed the data at very great length; the results were spectacular."

Three types of bursts were identified—which they named Types I, II, and III — distinguished by the way the frequency changed with time. In a series of papers published in 1950, they presented their data and the conclusion that Type II bursts were associated with shock waves coming out through the solar atmosphere at 1,000 km/sec that were associated, about a day later, with aurorae visible near the Earth's poles. The more frequent Type III bursts were associated with streams of electrons being ejected one hundred times faster—at a third the speed of light—and taking only an hour to reach the earth. This was one of the first realisations that astrophysical phenomena could result in the production of particles travelling at relativistic speeds. The interpretations proved to be correct, and their naming of the burst types became the standard.

The success of these observations led to the construction of three rhombic spectrograph antennas at Dapto, 100 km south of Sydney, to conduct further studies of the sun at frequencies between 40 and 240 MHz, which confirmed and extended the Penrith work. Paul likened this research to the study of taxonomy that preceded Darwin's *Origin of Species*. His analysis of the anatomy of the solar flares and his development of the physical interpretation culminated in a unified model that integrated the apparently complex radio flare phenomena in the solar chromosphere, in the solar corona, and in the interplanetary space.

In the course of this solar work, Paul became interested in the radio spectrum of hydrogen and wrote up an internal report related to the potential for spectral lines in the solar bursts. When Ewen and Purcell in the USA first observed the 1420 MHz hyperfine transition of hydrogen in 1951, Paul went back to his report, generalized it to include the interstellar medium, and six months later published the first detailed theoretical paper on the microwave spectral lines from the hydrogen atom—a classic in the field. After ten years of research, Paul's collected papers gained him a doctor of science degree from Cambridge. The group was the pre-eminent group in the world for solar radioastronomy and would continue its work for three decades.

All these results had been inferred from spectral observations, and there was a growing desire to be able to image the sun at the same range of frequencies with an angular resolution comparable to the human eye. This dictated the need for an instrument more than a million times the size of the aperture of the human eye. With Pawsey's help, a grant of US\$500,000 (later increased to \$630,000) was received

from the U.S. Ford Foundation to build a radio-heliograph at Culgoora, near the town of Narrabri, in northern New South Wales. Paul acknowledged his friend Kevin Sheridan, chief electronics engineer, as the key figure in this development.

The radio-heliograph consisted of 96 steerable parabolic antennas, each 13.7 m in diameter, and spaced at 100 m intervals around a circle of diameter 3 km. More than 320 km of copper wire was used to form open transmission lines to transport the signals to the central control building. Operating initially at 80 MHz (a wavelength of 3.75 m), the radio-heliograph was able to produce a detailed image of the sun each second, and to record both senses of polarization of the radio waves. This unprecedented capability yielded its first surprise in its first days of operation: a series of bursts, previously assumed to all be originating from the same part of the sun, were found to be coming from two locations separated by more than 800,000 km but connected, it was subsequently realised, by solar magnetic field lines.

The radio-heliograph, which was later extended to frequencies of 40, 160, and 327 MHz, stayed in operation for seventeen years from 1967, providing a tremendous amount of data and insight into the way the solar corona works and the relationship between solar and terrestrial phenomena. Paul published more than seventy papers in this area, and his achievements brought him the Balthasar van der Pol Gold Medal of the International Union of Radio Science for contributions to radioastronomy “including completion of a notable high-resolution radio-heliograph” in 1968; the Hendryck Arctowski Gold Medal of the U.S. National Academy of Sciences in 1969; the Herschel Medal of the Royal Astronomical Society in 1974; and the Hale Prize of the American Astronomical Society for Solar Astronomy in 1980.

In 1971, Paul took over from E. G. (“Taffy”) Bowen as chief of CSIRO’s Division of Radiophysics. While continuing his interest in solar studies, he also looked for opportunities to use the skills gained from the radioastronomy work and to provide a balance of pure and applied work in the division. Discussions with the Department of Civil Aviation identified a replacement for the existing commercial aircraft all-weather Instrument Landing System as a key opportunity, which was taken up with great enthusiasm by Paul. This work led to the INTERSCAN microwave landing system, which was accepted as the new global standard in 1978, and was used until cheaper GPS-based systems became available. Paul was awarded the Royal Medal of the Royal Society in 1980, “In recognition of his conception of the basic principles of the INTERSCAN instrument landing system and the guidance of its development to a successful conclusion.”

Paul was appointed chairman and chief executive of CSIRO in 1978. As chairman of CSIRO from 1978 to 1985, he was Australia’s national science leader. He led the organisation through a restructuring to modernise it and bring it closer to the industries and community it serves. Recognising that CSIRO needed to adapt and provide scientific and technological leadership in a changing world, he wrote in 1984, “Yet, whatever the changes, one characteristic must remain inviolate: a high

standard of excellence and originality. Without excellence and originality, research achieves nothing.” During this period he was instrumental in securing funding for major national research facilities including Australia’s National Oceanographic Research Vessel, the Australian Animal Health Laboratory, and the Australia Telescope, and he established a new Division of Information Technology. The Australia Telescope Compact Array was built on the site of the radio-heliograph.

Another project that started in this era was his Very Fast Train (VFT) project. He envisaged a fast train linking Sydney, Canberra, and Melbourne, noting, “We’re trying to take Australian railways out of the 19th century and into the 21st in one leap.” He became chairman of the VFT consortium, but the project collapsed in 1991 when the government rejected proposals to provide tax benefits for infrastructure projects.

Progress in science requires “big-picture” people who can see their way through the complexity to set the path forward. In this arena, as illustrated from his earliest work, Paul was absolutely first class. He clearly had an exceptional intellect, wide knowledge, appreciation of technical issues, and unquenchable interest in new projects and ideas.

Paul’s work was recognized by many awards: he was made a fellow of the American Academy of Arts and Sciences in 1961, a foreign member of the American Philosophical Society in 1962, a fellow of the Australian Academy of Science in 1964, and a fellow of the Royal Society in 1970. He was made a Commander of the Order of the British Empire (CBE) in 1978 and a Companion of the Order of Australia in 1986.

Paul died a week before his eighty-fifth birthday. At his funeral service the casket was covered in red, orange, yellow, green, blue, and indigo flowers—the colours of the sun’s spectrum. Some of Paul’s ashes were sealed into a memorial sundial near the Visitor Centre at Culgoora, which is now known as the Paul Wild Observatory.

Paul outlived Elaine and his second wife, Margaret, and is survived by his children, Peter, Penny, and Tim.

## Harry Clive Minnett (1917-2003)<sup>11</sup>



**Harry Clive Minnett**

Harry Minnett was born at Hurstville in Sydney on 12 June 1917 and lived there until he married in 1955, just prior to being posted to London in 1956. His parents were Frederick Harry Brook Minnett, a nurseryman (born in Paddington, September 1887) and Elsie May Garnsey (born in Dubbo, July 1891). Following their marriage, they established a delicatessen business at a time when Hurstville was expanding.

Harry attended Hurstville Primary School and was Dux in his final year in 1929. He then attended Sydney Boys' High School, 1930-34. Harry had a brother Bruce who was nine years younger. At an early age Harry was captivated by technology, and at around the age of 15 built a short-wave radio set to listen to overseas stations. This more than anything is seen to have sparked the passion that marked out his future career and dominated so much of his life.

He studied science and engineering at the University of Sydney, where the Professor of Electrical Engineering was the far-seeing JPV Madsen. Harry graduated in Science (Mathematics and Physics) in 1939 and in Engineering (Mechanical and Electrical) with First-Class Honours in 1940.

### **At CSIR/CSIRO 1940-81**

In April 1940, Harry Minnett joined the Council for Scientific and Industrial Research (CSIR, renamed CSIRO in May 1949), soon after the establishment of the

---

<sup>11</sup> Thomas BM, Robinson BJ, 2005, Biographical memoirs: Harry Clive Minnett 1917-2003, Australian Academy of Science.

Radiophysics Laboratory for research into advanced radar systems. He remained with the organisation until his retirement in 1981.

In September 1978, Harry was appointed Chief of the Division of Radiophysics for a period of three years, after which he would reach retirement age. In addition to his normal duties as Chief, Harry played a major role in guiding a preliminary proposal for the next-generation radio telescope then called the 'Australian Synthesis Telescope'. He was also involved in the search for a new Chief who would not only carry forward the concept of the new telescope, its implementation and funding, but would take a lead in initiating new research directions for supporting Australian industry. The position was filled by RH Frater.

Harry retired on 26 June 1981 and was appointed a Senior Fellow in the Division of Radiophysics until 23 October 1981, when he was made an Honorary Fellow until 30 June 1982.

Harry died on 20 December 2003 after a short period of illness.

## **Research contributions**

### **Radar equipment**

On joining Pawsey's radar research group at CSIR in 1940, he was to play a significant role in developing radio-frequency and antenna-related technologies for radar equipment (or RDF - radio direction finding - the term that was often used at the Laboratory). Harry contributed not only to the design of radio-frequency components such as waveguides, antennas and high-isolation receive-transmit switches for very high-power operation, he also participated in the testing of the radar systems with which he was associated (see Radar). The war-time projects were:

- the antenna system for Shore Defence (ShD) operating at a frequency of 200 MHz
- the first Light-Weight Air-Warning equipment (LW/AW Mk1) which incorporated the design principles for the ShD system, and of which over 200 were built for the support of Australian and US Forces in the south-west Pacific region
- the development of appropriate antennas and related radio-frequency components for a new system of air-warning radar operating at the higher, microwave frequency of 1.2 GHz. The final outcome was the highly successful high-performance Australian Light-Weight Air-Warning set (LW/AW Mk2). Although this system was later described as perhaps the outstanding technical war-time achievement of the Laboratory, the quantity production order of 47 units was cancelled because of the cessation of hostilities.

Following the war, the technology developed for radar systems, particularly the advanced research carried out for the final version of the Light-Weight Air-Warning set operating at microwave frequencies, placed Harry in a sound position to contribute to new fields of research.

### **Radio astronomy at microwave frequencies**

In 1947, he teamed up with JH Piddington to carry out the first significant radio astronomy observations at microwave frequencies. While Piddington tended to concentrate on the theoretical aspects of the new, microwave radio astronomy program, Harry's main efforts were directed to developing the observing equipment and in observing, although he also participated in the analysis of the results.

The radiometers that Harry had developed were, at that time, the most sensitive and stable in existence and made possible the first systematic observations of the Moon, Sun and Galaxy in the microwave region of the spectrum.

### **The radio navigation group**

In 1952, Harry was appointed leader of the Microwave Navigation Group. He made an experimental study in collaboration, with Don Yabsley, on the feasibility of long-range automatic distance measuring equipment for aircraft navigation using ionospheric propagation. He was also responsible for the development of microwave radar for the measurement of vehicle speed for the New South Wales Police Department. This development would be interesting to review, given the current interest in such devices; perhaps the work was done before all the underpinning technologies were available to give adequate portability?

Harry's ability as a meticulous engineer with a thorough understanding of the related underlying scientific principles was recognised by his being appointed to leading roles in a number of significant projects which were to have a long-term impact on Australian science and technology. These were:

- his role in guiding the design of the Parkes 64 m radio telescope to successful completion
- the establishment of a world-recognised research group on antenna design to support radio telescope design and upgrades
- his contributions to the construction of the 3.9 m Anglo-Australian optical telescope at Siding Spring Mountain, New South Wales
- his contributions to the INTERSCAN aircraft Microwave Landing System developed by the Division of Radiophysics in collaboration with industry.



**Harry Minnett on the Parkes radio telescope, May 1964. [Source: CSIRO ATNF]**

### **The Parkes 64 m radio telescope**

At a conference held in Parkes in 1991 to celebrate the thirtieth birthday of the radio telescope, RH Frater, a past Chief of Division, stated:

“This telescope was Taffy Bowen's vision, a vision taken up enthusiastically by Ian Clunies Ross [Chairman of CSIRO] and Fred White, carried to its initial fulfilment by the efforts of people like Harry Minnett working with Freeman Fox and Partners, and then carried to fame by John Bolton”.

### **The Antenna Group at Radiophysics**

From 1962, Harry's initial interest centred on satisfying the requirements of the NASA contract, which required the provision of regular reports. One aspect of the contract was the supply of engineering data to NASA on the performance of the Parkes antenna. In addition Harry, with the support of D Cole, carried out tracking measurements for NASA of the Mariner II spacecraft on its mission to Venus (1962) and of the Mariner IV spacecraft on its mission to Mars (1964-65). Further tracking of NASA's spacecraft under separate contracts were to be made at Parkes in 1969 (Apollo 11, made famous in the movie *The Dish*), 1986 and 1989 (Voyager II), 1996-97 (Galileo) and 2003-04 (Mars tracks). The earlier measurements were used by NASA to help justify the design and building of the three 64-m antennas for their Deep Space Network. Other projects included:

- reflector performance studies and surface upgrades
- high-performance feed research.

## **The Anglo-Australian optical telescope project**

An Anglo-Australian Joint Policy Committee (JPC) recommended that the UK and Australia jointly fund the construction of a 3.9 m optical telescope in Australia, to be called the Anglo-Australian Telescope (AAT). The project office for the AAT was established in Canberra in 1967.

In November 1967 Harry, having gained extensive experience with the design of the Parkes radio telescope, became a consultant, together with RL Ford of the Royal Radar Establishment (Malvern), for the design of the drive and control system for the AAT. It was initially intended to follow well-established design concepts for the telescope, but Harry found that the requirements for the drive and control system were initially lacking. He also considered that optical telescope design had not kept pace with the opportunities that could be provided by technological advances. As Harry related:

“Together we visited the major astronomy centres in Britain and listened to the conflicting and often discouraging requirements of the optical observers. I persuaded the Science Research Council that Ford should accompany me to Kitt Peak where we found a proposal for a digital servo drive to the traditional worm gear system”.

Harry became convinced that the only way to make a major advance in optical telescope drive systems was to eliminate the inefficient worm gears from the servo loop, together with the reverse-torque spur gear system that had gradually evolved for anti-backlash purposes. His proposal was to replace these with a precision spur-gear driven by a balanced pair of motors and pinions in the push-pull anti-backlash arrangement that had become common in radio telescopes. Harry's experience with the design of the Parkes servo system also suggested that the struts connecting the horseshoe structure to the north-end bearing were too flexible and would lead to a low-resonant frequency. The AAT strut structure was completely redesigned for greater rigidity by consultants in Canada.

Harry and Ford recommended to the JPC that the AAT should use a photo-electric guiding system integral with the telescope to relieve the astronomer of this traditional chore. They also recommended a modified digital on-line computer for automatic setting, correction of systematic errors, monitoring and data logging. As Harry stated:

“All these changes represented a major rethink in optical telescope drive and control practice and in such a large project could only be advocated after a good deal of anxious soul searching. A great amount of effort by myself and ultimately by many others was needed with the gearing manufacturers and the Japanese drive and control contractors to achieve the high precision required.”



Mike Jeffery, the Project Manager for the AAT, died suddenly in September 1969 and Harry was seconded to the JPC as Project Manager. He was responsible for supervising all aspects of the project design and construction, and contracts with local and overseas contractors. This included the optical structure, mechanical and electrical design and manufacturing work on the telescope, its building together with ancillary equipment, and the civil works on Siding Spring Mountain, New South Wales, that were carried out by MacDonald, Wagner and Priddle Pty Ltd. Harry travelled to England and the USA in April-May 1969 and in July 1970. When a new Project Manager took up duty in the last half of 1970, Harry overlapped as an adviser for a further year. He then returned to his consulting role on the drive and control system.

The AAT was, at that time, the largest scientific project undertaken in Australia. Its ease of use and high level of performance put British and Australian astronomers into the forefront in many areas of astronomy. It contrasted very much with the performance of a telescope of similar size built in Chile by the European Southern Observatory Consortium. Harry wrote of the AAT: Its design and construction involved almost all branches of engineering, and at crucial points in its evolution, I believe I helped to shape the outcome.

### **INTERSCAN - a precision microwave landing system**

When Paul Wild was appointed Chief in 1971, he took the opportunity to participate in an international competition by the International Civil Aviation Organisation (ICAO) to design and construct a microwave landing system (MLS) for aircraft. Wild assembled a small team to propose and develop a new system. The project had financial support from the Commonwealth Department of Transport. Other competing groups were three large teams in the USA and groups from the UK, France and Germany. For decades the aircraft approach system used worldwide had been in the VHF frequency band. The ICAO required a much more precise system operating near 5 GHz. The system was required to define appropriate landing paths that could also automatically land the aircraft. If landing was aborted, it would need to guide an aircraft away safely.

Wild, who had an outstanding grip on the basic principles of physics, was quick to come up with a time-reference scanning-beam system as a possible solution to the MLS; this was called 'INTERSCAN'. In 1972, he appointed Harry as Engineering Director for the INTERSCAN MLS project. Wild and Harry had complementary expertise and both had enthusiasm.

Harry's role as Engineering Director continued through the feasibility studies in 1972, and during the design definition phase in 1973 when the Australian company AWA was awarded a contract from the Department of Transport to engineer and manufacture a system for flight trials at Tullamarine airport, Melbourne.

Harry's antenna expertise was called on particularly for the conceptual and design phases. One of the antennas was an electronically scanned Torus Reflector. He wrote: The vertical profile of an azimuth reflector was shaped by synthesis techniques to produce a very sharp cut-off along the ground and an optimum shape at other vertical angles. The technology developed for the new surface of the Parkes radio telescope was directly applicable to all the reflector antennas for INTERSCAN.

During 1974, Harry travelled widely to advocate the INTERSCAN MLS system. At the end of that year, the US Government conducted a four-month evaluation of the British Doppler system and the Australian INTERSCAN system. Through negotiation, the US would collaborate with the country that they saw as having the best system. This would then undergo further development prior to submission to ICAO. The US decided in favour of the Australian time-reference scanning-beam technique, giving the US and Australia a common technical platform in preparation for the final submissions to ICAO.

As part of the program to improve the INTERSCAN system, Harry proposed a concept for correcting the cylindrical aberration of the Torus Reflector. The correction was implemented in the electronic modulation and switching system that produced the quasi-continuous beam scan. This reduced the overall size of the antenna by almost one-half.

The Department of Transport entered the INTERSCAN MLS system into the international competition conducted by ICAO, and in 1976 it was selected as the winning entry. Unfortunately international politics was later to plague the project, resulting in a reduced role for Australia.

One significant spin-off was the formation of a company to commercialise aspects of the INTERSCAN MLS system. This Australian company was called INTERSCAN (Australia) Pty Ltd but was later renamed INTERSCAN International to promote the sale of its products, including phased-array antennas, on the international market.

### **In retirement**

In 1982, Harry became consultant to INTERSCAN (Australia) Pty Ltd at the invitation of the Managing Director (J Drennan). The INTERSCAN (Australia) engineering team had just spent two years in Kansas City, USA, working with Wilcox Electric developing an MLS using phased-array antennas, which had displaced the original CSIRO reflector antennas. This joint effort was aimed at satisfying the Federal Aviation Administration (FAA) specifications followed by submission of a formal response to the FAA's Request for Tender. It was then a matter of urgent commercial necessity for INTERSCAN to obtain other engineering work to support the team while the tender was being evaluated. As it later transpired, INTERSCAN (Australia) was unsuccessful in being awarded a contract and the need for new contracts became more pressing. Although INTERSCAN (Australia) was

unsuccessful in its bid to the FAA for MLS, it was successful in selling the systems in Spain, China and Taiwan, and in the USA to non-FAA customers.

Harry's task was to search for suitable opportunities. His first success came with a proposal for a long-range VOR (Very-high-frequency Omni-Range) antenna. This was the first task outside MLS to be undertaken by INTERSCAN (Australia). Some twenty systems were subsequently sold to the DCA.

An additional task undertaken by Harry was the design of a precision ground-reflection antenna range using the old landing strip at Fleurs, Badgery's Creek, New South Wales.

This range was intended to be used for production testing of MLS antennas. The units were tested on the range to a precision of 0.001 degrees in guidance accuracy.

Another project in which Harry was involved, this time in association with BB Jones, was the conceptual design of an electronically scanned TACAN (Tactical Air Navigation) antenna for use by the Royal Australian Air Force. This antenna consisted of a cylindrical array fed from a 36-way Butler Matrix using electronic phase shifters. It was a very successful project both commercially and technically.

Harry became Deputy Chief Executive of INTERSCAN International in 1985 and retired from that position in July 1986 at age 69.

## **Tribute**

In their biographical memoir of Harry Minnett, former CSIRO colleagues Bruce Thomas and Brian Robinson wrote:

“... Harry was very thorough in every task that he undertook and was analytically precise. He would invariably follow the subject through with extreme attention to detail, often to the frustration of those working around him. Of course, this was to stand him in good stead when the need arose”.

Harry was a person of the highest integrity, had professional competence of a high order in many different fields of engineering and science, and made outstanding contributions to science through engineering. Harry was never the 'centre of attention' at staff parties, preferring to discuss engineering in the corner of the room with colleagues. He had very little time for 'small talk'.

## **Honours and awards**

Fellowships:

1980	Fellow, Institution of Engineers Australia
1979	Fellow, Australian Academy of Technological Sciences and Engineering

1976	Fellow, Australian Academy of Science
------	---------------------------------------

## Awards:

2001	Centenary Medal - for service to Australian society and to the science of radiophysics
1982	Australian Medal of the Guild of Air Pilots and Air Navigators
1972	Officer (Civil), Order of the British Empire (OBE) - for services to science

## Adjunct Professor Brian O'Keeffe AO ( - )<sup>12</sup>



Adjunct Professor Brian O'Keeffe Hon LLD (Monash), BE (Qld), FIE Aust, FAIN, can rightly be described as one of the giants of Departmental history, having played a major part in making Australia's reputation for excellence in aviation on the world stage.

Brian O'Keeffe graduated as Bachelor of Engineering (Electrical) from the University of Queensland in 1956 and joined the Department of Civil Aviation (DCA) where he was engaged in the design and supervision of radio installations and special electronic investigations. From 1957 to 1959 he carried out Navigation Aids research at the University of Adelaide under sponsorship from DCA.

**Left: Brian O'Keeffe in 1997 at the time of his retirement from Airservices Australia.**

***Image: Brian O'Keeffe collection***

In 1959 Brian joined the Department's central office, Airways Engineering Branch, advancing to the position of Senior Assistant Secretary, Planning Research & Development in 1975. The period began with his design of a new ILS localiser antenna which became the standard for Australia for many years. In conjunction with the Departmentally sponsored Air Navigation Group at Sydney University, an ILS model range and a new glide path antenna were developed. He carried out some of the first measurements of the detailed structure of the ILS signal-in-space. He used the computing facilities of Monash University to investigate the systems being developed for the automatic landing of aircraft which were of great interest to the designers of aircraft systems.

During this period, Brian O'Keeffe was one of the co-developers of a high accuracy, optical/electronic tracking system for aircraft engaged on flight calibration, which was a vital part of the later Microwave Landing System (MLS) development. The results of all this work over many years were contributed to the ICAO All Weather Operations Panel. He was also the Australian member of the ICAO Study Group on the updating of the Manual of Testing of Navigation Aids. Thus began a long line of contributions to ICAO.

---

<sup>12</sup> The Civil Aviation Historical Society, [www.airwaysmuseum.com](http://www.airwaysmuseum.com), downloaded 8 Sept 2013.

He took a leading role in the international development of the MLS, writing the first paper presented to ICAO in 1967 proposing that the ILS be replaced and was then involved actively in the development of what came to be known as MLS. He was responsible for the then Department of Transport's (the successor organisation to DCA) MLS program, which, together with other research and manufacturing bodies in Australia, produced and tested a complete MLS for presentation to ICAO. He promoted the benefit of international collaboration and eventually a combined multi-State proposal was put to ICAO using essentially the Australian signal format. Thus, the Time Reference Scanning Beam system was adopted by ICAO as the international standard in 1978.



In the late 1960's Brian was involved in the early studies of the application of satellite systems for civil aviation and carried out ranging measurement experiments using the ATS-1 satellite and pseudo-random code techniques. He was the aviation representative on the Australian Government Task Force on the National Communications Satellite System and presented a cost effective design for a satellite system for civil aviation in Australia. With the Government acceptance of a national satellite system, this aviation system was implemented and has provided a high quality service for Australian civil aviation from the mid 1980s.

Brian O'Keeffe was appointed head of the restructured Airways Division in 1982 which carried out the planning, research and provision of communication, navigation, surveillance facilities as well as the provision of air traffic control, flight services, rescue and fire fighting services. In this position, he was able to initiate and pursue a plan for the complete modernisation of the airways system which would vastly increase the productivity of the system by the use of modern technology.

In 1984, he became the Australian member of the ICAO Special Committee on Future Air Navigation Systems (FANS). He took an active role in the FANS Committee and was elected Vice Chairman. In particular, he organised the preparation of material on "institutional arrangements" which can be described as how to put together a global system, based on satellites, with components provided by civil aviation authorities, international organisations, service providers and aircraft operators. In this period, the FANS Committee developed what was probably the first truly integrated system of communication, navigation, surveillance and air traffic management capable of international acceptance. With the completion of FANS Phase I in 1988, he was elected to lead the interim Committee and then elected Chairman of the FANS Phase II Committee in 1990. He then lead the Committee to have the system accepted at a worldwide ICAO meeting in 1991 and to develop the detailed institutional arrangements and the global co-ordinated plan. The plan was completed in 1993.

Following the establishment of the Australian Civil Aviation Authority in 1988, he was appointed General Manager, Advanced Systems Development to allow him greater involvement in international matters and in particular, international technical developments.

He initiated the development of a general purpose aircraft position display system based on "off-the-shelf" computer equipment. In particular, this was used for Automatic Dependent Surveillance (ADS) developments and copies of the equipment were loaned to several countries in the Asia/Pacific Region in the spirit of international cooperation. At this time, he was involved in

organising the Pacific Engineering Trials (PET) to demonstrate ADS, as a joint collaborative project between Australia, US and Japan. He persuaded other States in the Asia/Pacific Region to become involved and finally lead to the certification of the FANS 1 package for the Boeing 747-400 aircraft in 1995.

In 1991, Brian O'Keeffe was appointed General Manager, R & D and ICAO Affairs in the Civil Aviation Authority.

In 1992 he became the Australian member of the Asia Pacific Air Navigation Planning and Implementation Regional Group (APANPIRG) and was elected Chairman of its Communications, Navigation, Surveillance and Air Traffic Management (CNS/ATM) Sub group. Under his leadership, the Subgroup developed, in two years, a plan for the transition to CNS/ATM in the Region. With the completion of this plan, the Subgroup was re-formed in 1994 to co-ordinate the implementation of CNS/ATM. Again, he was elected Chairman and pursued a vigorous campaign to proceed with detailed implementation plans for nine geographical areas representing the major traffic flows in the Asia/Pacific. As a result, detailed plans were agreed and implementation has proceeded rapidly.

He has long recognised the importance of the internationalisation of civil aviation and has pursued this through ICAO and bilaterally. He has contributed to ICAO through numerous panels and divisional meetings. He was elected First Vice President of the ICAO General Assembly in 1992 and First Vice Chairman of the Asia/Pacific Regional Air Navigation Meeting in 1993. He has negotiated bilateral Memoranda of Co-operation on technical matters with a number of countries in the Asia/Pacific Region.

With the establishment of Airservices Australia 1995, Brian was appointed General Manager International & ICAO and, in 1996, Special Technical Adviser to the CEO.

In 1996, Brian O'Keeffe was nominated by Australia as a technical expert to serve on the ICAO Panel of Legal and Technical Experts on the Establishment of a Legal Framework with regard to the Global Navigation Satellite System and was invited to make an introductory presentation to the first meeting of the Panel. Also in 1996, at the invitation of the President of the ICAO Council, he became a member of the ICAO CNS/ATM Implementation Advisory Group (ALLPIRG).

In 1997, he was invited to make a presentation on the "Implementation of the FANS CNS/ATM Systems in the Asia/Pacific Region" to the US Vice President's White House Commission on Aviation Safety and Security. He was a member of the US Government-Industry Free Flight Steering Committee until 1998.

Since 1992 he has organised Workshops and Seminars on CNS/ATM, GNSS and ADS-B at the Singapore Aviation Academy for middle level managers responsible for the planning, implementation, operation, and management of CNS/ATM from airlines, civil aviation and airport authorities, government transport and military agencies.

Over many years, he has been invited to speak on CNS/ATM by technical bodies world-wide. In recent times, the US Institute of Navigation invited him to be the Technical Chairman of the Aviation sessions at their International Technical Meeting of the Satellite Division in 2003.

He has been a consultant to various Government and Industry bodies, such as Honeywell (USA), Airports Fiji Ltd and the Australian Civil Aviation Safety Authority (CASA). In 2001 he completed an analysis of the performance of currently used and proposed navigation systems involving GPS for Australian airspace for CASA. Following on from this, he is currently a consultant on Global Navigation Satellite System (GNSS) to the Australian Government/Industry Strategic Air Traffic Management Group, examining the performance of the new generation of GPS receivers

for aviation.

Brian O'Keeffe left Airservices Australia in 1997 and is presently (c.2006) the Managing Director of FANS PLANS P/L where he provides high level advice on the planning and implementation of the new CNS/ATM System as developed by the Future Air Navigation Systems (FANS) Committee of the International Civil Aviation Organisation (ICAO). He is also Adjunct Professor in Engineering at the University of Canberra. He continues to organise Seminars on CNS/ATM at the Singapore Aviation Academy and is a member of the Singapore Minister for Transport's International Advisory Council. With nearly 50 years experience in the planning, research and development of electronic systems for civil aviation, Brian still consults for government and industry organisations, both nationally and internationally.

Awards for his service to civil aviation have been :-

1990 Certificate of Commendation from the US Federal Aviation Administration in recognition of "numerous leadership contributions enhancing the safety and efficiency of civil aviation on a global basis and for fostering 21st century civil aviation technologies".

1992 Appointed an Officer in the Order of Australia "for service to civil aviation, particularly international civil aviation".

1992 Special Medallion of the Air Traffic Control Association of USA "for outstanding achievement and contributions which advanced the science of air traffic control and enhanced the professions of the ATC system".

1993 Elected Fellow of the Institution of Engineers, Australia in recognition of "high achievements and the level of responsibility which you have assumed over an extended period for important engineering decisions, activities and programs".

1994 Honorary Membership of the Royal Institute of Navigation of UK "for services as Chairman of the ICAO FANS Committee. The work of ICAO FANS over this period has now resulted in actions being taken to implement the most significant advance ever made in worldwide civil aviation. Mr O'Keeffe's dedication and skill have been major factors in the success of this work".

1995 Aviation Week's Aerospace Laureate in Electronics "for substantial contributions in the global field of aerospace in 1994" and in 1997 was inducted into their Hall of Fame at the Air and Space Museum of the Smithsonian Institution in Washington DC.

1995 Appointed as Adjunct Professor in Communications Engineering at the University of Canberra.

1996 Special Commendation from the Air Traffic Control Association of USA "In recognition and gratitude of the adult life contributions and dedicated services of Brian O'Keeffe which enhanced the National and International Air Traffic Control Systems and in further recognition of his outstanding support of ATCA".

1997 Award from the Civil Aviation Authority of Singapore "In appreciation for outstanding contribution to the Singapore Aviation Academy".

1997 The US Federal Aviation Administration's Award for Distinguished Service "in advancing international aviation in the public interest and achieving outstanding results in enhancing the global aviation system".



1997 The Clifford Burton Medallion from the US Air Traffic Control Association.

1997 Elected Fellow of the Institute of Navigation, Australia.

1998 Conferred with the degree of Doctor of Laws honoris causa by Monash University at the graduation ceremony in the Faculty of Engineering

1998 The US Institute of Navigation's Capt. PVH Weems Award "recognising continuing contributions to the art and science of navigation".

2002 Elected to the Canberra Engineering Hall of Fame of the Institution of Engineers, Australia

2004 Received the highest award of the International Civil Aviation Organisation, the Edward Warner Award, "in recognition of your eminent contribution to the development of international civil aviation, in particular your leading role in the field of air navigation systems."



**Image: Brian O'Keeffe collection**

2007 Received *Aviation Week & Space Technology* magazine's L. Welch Pogue award for his work on FANS (L. Welch Pogue joined the US Civil Aeronautics Board in 1938 was appointed Chairman in 1942. In 1944, along with Edward Warner, he was a member of the US delegation at the international conference in Chicago which set up ICAO).

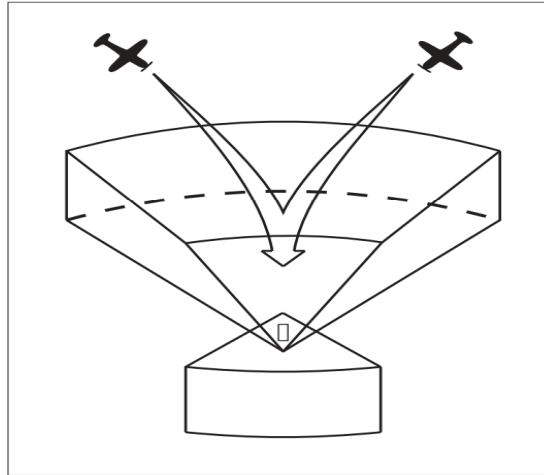
## **Appendix 4: An Introduction to Microwave Landing Systems (MLS).**

Microwave Landing Systems provide precise navigation guidance necessary for exact alignment and descent of aircraft. MLS are capable of being used to perform Category III landings which allow a decision height (height at which a missed approach must be initiated) of 30m and a runway visual range of 200m; this allows MLS systems to perform landings in low visibility conditions.

The MLS system consists of several pieces of ground based equipment with the standard configuration including:

- An Azimuth Station: This station provides the landing aircraft with azimuth navigation guidance as well as data communications to the aircraft which can include 3d locations of the MLS equipment, waypoint coordinates, ground equipment performance levels, DME status, runway conditions and weather conditions.
- Back Azimuth Station: This station provides the aircraft with guidance for missed approaches and departures
- An Elevation Station: This station provides the aircraft with the approach elevation angle
- DME/P (Precision Distance Measuring Equipment): this piece of equipment provides range guidance. The accuracy of the DME equipment is improved when paired with MLS installations; to account for the accuracy of the azimuth and elevation stations the accuracy of the systems range information is around 30m.

As the name suggests guidance information is provided to the aircraft in the microwave frequency range, operating between 5031 and 5091 MHz with 200 possible channels. Both the azimuth station and the elevation station share a single frequency with angle and data functions time shared. The DME/P operates on a different frequency band of 962 to 1105 MHz but each DME/P channel is paired with one of the 200 microwave channels for consistency.



### **3D Volume Representation**

In its standard configuration the MLS provides a landing window of 40 degrees on each side of the runway centreline and 15 degrees above the runway, the range of the equipment extends 37km along the landing path.

When pairing all of the information from the various stations the system is able to accurately identify the aircraft's 3D position in space, this allows the system to provide standard landing guidance to MLS equipped aircraft. Other benefits of the system include curved or segmented landing approach paths and selectable glide paths.

Combining 200 separate channels, higher than the foreseeable requirements of any airport and low susceptibility to interference from weather conditions, airport ground traffic and other environmental factors, the MLS is a highly robust and accurate landing system that has been described by the FAA as "precision three-dimensional navigation guidance accurate enough for all approach and landing manoeuvres."

## Appendix 5: Glossary of Terms

### A Technology

**MLS:** An acronym for Microwave Landing System: these systems use Microwave beams to determine an aircraft's location in space relative to the runway and provide navigation information necessary to land in low visibility conditions. The technology was developed to supplement or replace the then current Instrument Landing Systems providing several benefits over the older system.

**ILS:** An acronym for Instrument Landing Systems: prior to the acceptance of INTERSCAN/TRSB as the world standard of ICAO, ILS was the preferred low visibility precision landing aid; the system provided aircraft with navigation information required to align the aircraft with a single pre-set landing path directly down the centre line of a runway on a glide path of 3 degrees. Despite being replaced as the world standard for all weather landing systems ILS is still used heavily today and is capable of performing a Cat III landing.

**DME:** An acronym for Distance Measuring Equipment: this is another Australian developed technology and is used to provide aircraft with their distance from the device.

**TRSB:** An acronym for Time Reference Scanning Beam: this was the name selected by the US for the technology behind the combined bid for the INTERSCAN/TRSB landing systems.

**GPS:** An acronym for Global Positioning System: this is a spaced based navigation system that uses a series of satellites. When the ground based system has line of sight with at least 4 satellites a pulse is sent from each which contains the exact time it was sent; by comparing the time the pulse is received with the time it was sent the distance from each satellite can be determined and from this the user's exact position.

**VTOL/STOL:** An acronym for Vertical Take Off and Landing/Short Take Off and Landing: these aircraft differ from common aircraft due to the much higher angle at which they land and take off. In the case of VTOL this is all the way up to an elevation angle of 90 degrees due to the fact that they land vertically down instead of gliding into a runway on a low descent angle like traditional aircraft.

## B Organisations

**ICAO:** an acronym for the International Civil Aviation Organisation

**AWOP:** an acronym for ALL Weather Operations Panel, AWOP is a Part of the ICAO

**CSIR/CSIRO:** Acronyms for the Commonwealth Scientific and Industrial Research/ Commonwealth Scientific and Industrial Research Organisation, currently the organisation goes by the name CSIRO

**AWA:** an acronym for Amalgamated Wireless (Australasia) Ltd

## Concepts

**Azimuth:** this is an angular measurement used in spherical coordinate systems and represents the angle between a reference point and an object on a reference plane.

In the case of INTERSCAN, the object of interest would be the landing aircraft, the reference plane would be the horizon and the reference point would be the centre line of the runway.

**Microwave:** these are waves in the electromagnetic spectrum with wavelengths varying from 1mm to 1m and a frequency range from 300 MHz (0.3 GHz) to 300 GHz. The term microwave comes from the smaller wavelength in comparison to radio waves.

**Categories of Precision Approach and Landing Operations:** These are guidelines set down by civil aviation organisations around the world as minimum safe landing conditions; the various landing aids are rated by their performance through rigorous testing and are assigned a category based on their performance to the guidelines below which come from Australia's Civil Aviation Safety Authority:

Category I (CAT I) operation. A precision instrument approach and landing with a decision height not lower than 200 feet and a visibility not less than 800 meters, or a runway visual range not less than 550 meters.

Category II (CAT II) operation: A precision instrument approach and landing with a decision height lower than 200 feet but not lower than 100 feet, and a runway visual range not less than 300 meters.

(iii) Category IIIA (CAT IIIA) operation: A precision instrument approach and landing with a decision height lower than 100 feet, or no decision height and a runway visual range not less than 175 meters.

(iv) Category IIIB (CAT IIIB) operation: A precision instrument approach and landing with either a decision height lower than 50 feet, or with no decision height and a runway visual range less than 175 meters but not less than 50 meters.

(v) Category IIIC (CAT IIIC) operation: A precision instrument approach and landing with no decision height and no runway visual range limitations.

**Decision Height:** depending on the landing category this is the minimum height at which a missed approach must be initiated.

**Australian Government Agencies responsible for Civil Aviation:** Refer to Appendix 2.

## Appendix 6: Press Release from Thales

### **Thales sets a world-first through partnership in providing the MLS for civil aircraft**

29 April 2009

Thales today announced that its Microwave Landing System (MLS), aimed at increasing aircraft efficiency on airport approach, has received UK approval for ground installations to Cat IIIb (low visibility conditions) operations at Heathrow Airport.

Thales had already received European certification for its onboard aircraft installations to Cat IIIb (low visibility conditions) operations in November 2007.

British Airways is the first airline worldwide to implement this new system and has been proving the system on its Heathrow Airbus Single Aisle fleet throughout 2008. The new system was fully operational from 25 March 2009 and is the result of intelligent partnerships and significant international joint development between Thales and major industries including Airbus, British Airways and the UK and French national airport and air transport authorities.

100 automatic landings, with Thales's Microwave Landing System (MLS) functioning on both the ground and onboard the aircraft, were required to gain official UK approval and certification for the system. British Airways has performed automatic landings on both runways at Heathrow. This application of the MLS technology is a world-first and means that more flights will be able to land safely in difficult weather conditions, where air traffic is dense and where interference from buildings or objects including moving aircraft on taxiway around the approach to the airport is extensive.

*"We are delighted with the latest certification, which has enabled British Airways to become the first airline to benefit from a system that will simultaneously increase capacity and safety, whilst also providing key environment enhancements", said Paul Kahn, Managing Director of Thales's Navigation & Airport Solutions business. "These synergies have enabled us to develop a world-class solution in which we are confident other airlines and airports will see a valuable opportunity."*

The use of MLS technology will have a positive impact on the environment - every minute gained on a flight represents a saving of the equivalent of 160Kg in CO<sup>2</sup> emissions.

With its transverse capabilities and "systems of systems" approach, Thales has the capacity to bring together both ground systems and onboard systems providing a global solution to meet the requirements of all users.

## **Notes to editors**

### **Microwave Landing Systems**

With an average of 10 or 19 days of low visibility per winter, bad weather is a significant cause of arrival delay in Heathrow. Low visibility produces an average of 35-50% reduction in the landing rate. MLS-equipped airports and consequentially the airlines using MLS will be able to maintain their traffic flow during bad weather conditions. MLS reduces the need for air traffic control to provide extra spacing between landing and departing aircraft in low visibility, because the MLS signal is less sensitive to aircraft and obstacles at the airport. This also has the benefit of reducing the overall delay for all airport users.

As the name suggests, MLS uses a microwave signal (5Ghz). This technology is less susceptible to interference, for example from another aircraft moving on the airport surface or surrounding buildings, than traditional solutions like ILS. The system has two separate parts - a ground station and an onboard system - that function together. Onboard the aircraft a multimode receiver computes the aircraft position with the ideal approach path using a C-Band (5Ghz) digital signal sent by the MLS ground transmitters.

### **About Thales**

Thales is a leading international electronics and systems group, addressing Defence, Aerospace and Security markets worldwide. The Group's civil and military businesses develop in parallel and share a common base of technologies to serve a single objective: the security of people, property and nations. Thales's leading-edge technology is supported by 22,500 R&D engineers who offer a capability unmatched in Europe to develop and deploy field-proven mission-critical information systems. The Group builds its growth on its unique multi-domestic strategy based on trusted partnerships with national customers and market players, while leveraging its global expertise to support local technology and industrial development. Thales employs 68,000 people in 50 countries with 2008 revenues of €12.7 billion.

Thales UK employs 8,500 staff based at more than 50 locations. In 2008 Thales UK's revenues were over £1.4 bn.

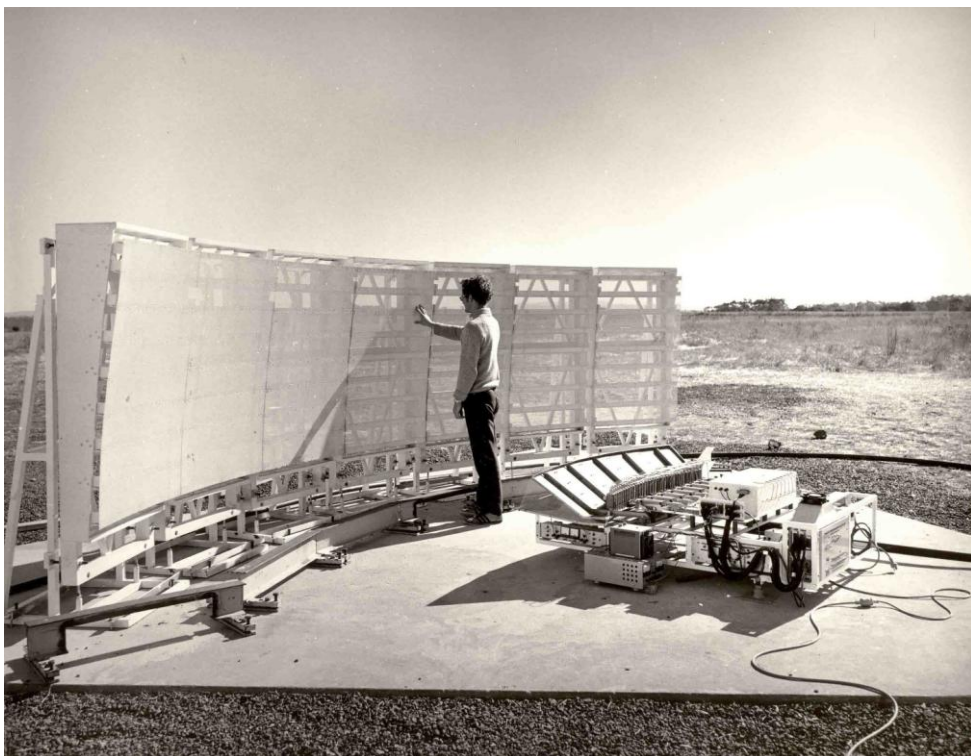


## Appendix 7: Additional Photographs



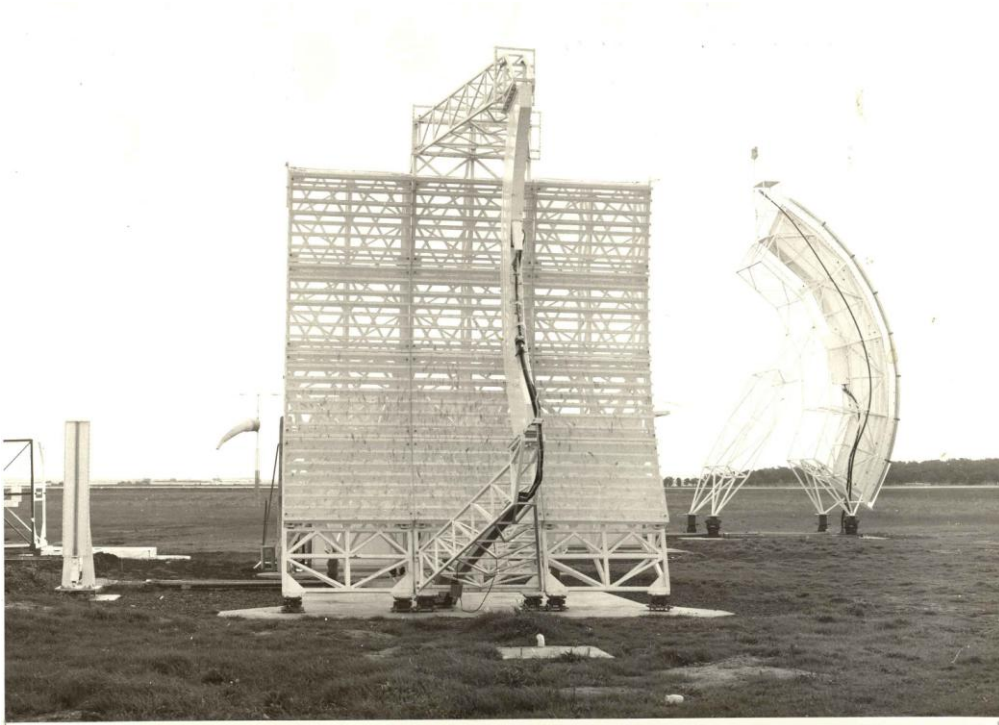
A view of one of the Azimuth Antennas

*Image: Civil Aviation Historical Societies collection.*

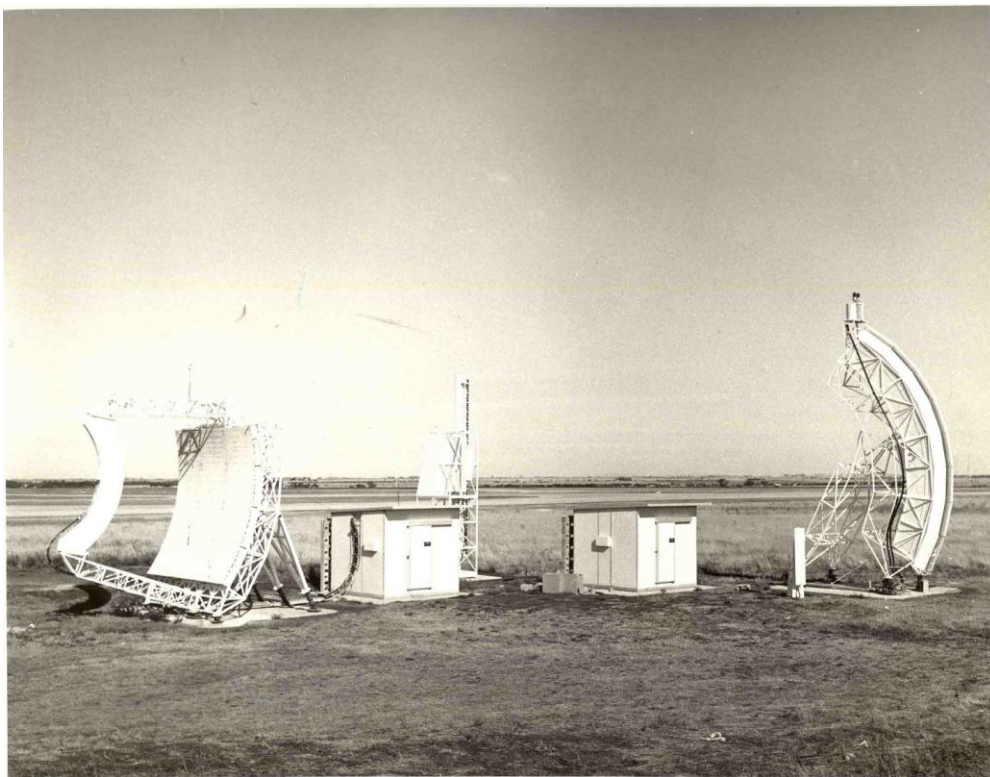


Work being performed on one of the Azimuth Antennas

*Image: Civil Aviation Historical Societies collection.*



**Front View of the Elevation Antenna, the Flare Guidance Antenna can be seen in the background the flare was not included in the final standard system**  
*Image: Civil Aviation Historical Societies collection.*



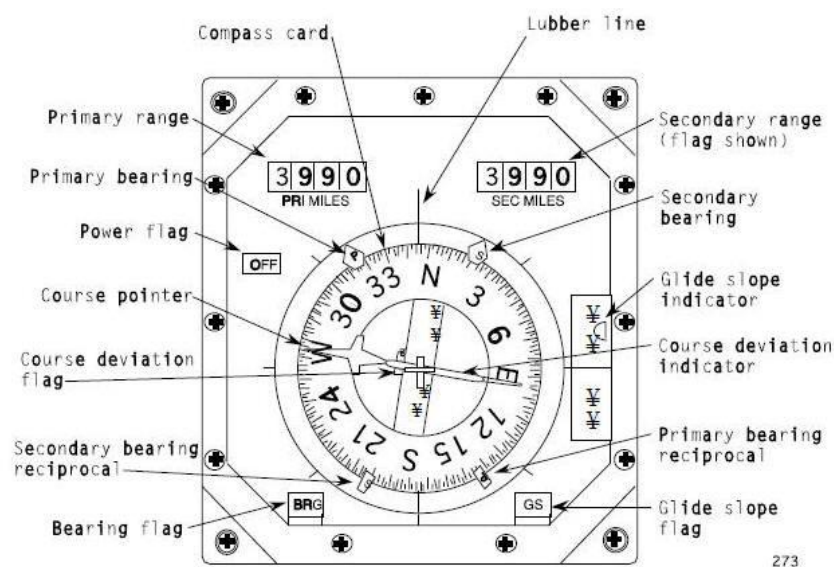
**Side view of the Elevation Antenna and Flare Guidance Antenna**  
*Image: Civil Aviation Historical Societies collection.*





The NASA Boeing 737 research aircraft on the Wallops runway in 1987 with the Microwave Landing System equipment in the foreground. This system is currently used to also land Space Shuttles.

*Image: Wikipedia.org, Original Image was from NASA*



Horizontal Situation Indicator

The image shown above is a Horizontal Situation Indicator. When MLS mode is chosen via a switch on the dash of the cockpit and the frequency is matched with the MLS on the NAV1 radio equipment, within the centre of the compass area a line will appear. The pilot must then proceed to line the aircraft directly up with this line as it is the marker for the MLS system.

*Image: Space Shuttle Guide Link:*

*[http://www.spaceshuttleguide.com/system/dedicated\\_display\\_systems.htm](http://www.spaceshuttleguide.com/system/dedicated_display_systems.htm).*



**Mobile MLS equipment made by Textron Defence Systems; these systems are currently used by the United States Air force**

*Image: Textron Defence Systems*

**CHANGE CONTROL**

<b>VERSION 1</b>	<b>14 Dec 2012</b>	<b>1132 WORDS</b>	<b>Commenced Drafting</b>
<b>VERSION 1.1</b>	<b>3 Jan 2013</b>	<b>2554 WORDS</b>	<b>Refining of information in document</b>
<b>VERSION 1.2</b>	<b>9 Jan 2013</b>	<b>3680 WORDS</b>	<b>Refining of information in document and adding of location images</b>
<b>VERSION 1.3</b>	<b>10 Jan 2013</b>	<b>4150 WORDS</b>	<b>Finalisation of the first draft, Section 2 requires ownership information</b>
<b>VERSION 1.4</b>	<b>25 Jan 2013</b>	<b>8500 WORDS</b>	<b>Finalisation of the second draft, second biography will be in draft 3</b>
<b>VERSION 1.5</b>	<b>01 Feb 2013</b>	<b>8550 WORDS</b>	<b>Finalisation of the second draft, second biography will be in draft 3</b>
<b>VERSION 1.6</b>	<b>08 Feb 2013</b>	<b>11500 WORDS</b>	<b>Finalisation of the third draft, second biography added</b>
<b>VERSION 1.7</b>	<b>10 Feb 2013</b>	<b>11500 WORDS</b>	<b>Very minor changes by OP</b>
<b>VERSION 1.8</b>	<b>10 Feb 2013</b>	<b>11500 WORDS</b>	<b>Image file size reduced, slight modifications made to document.</b>
<b>VERSION 1.9</b>	<b>14 Feb 2013</b>	<b>11750 WORDS</b>	<b>Addition of information in INTERSCAN Currently section and Photos</b>
<b>VERSION 2.0</b>	<b>16 Feb 2013</b>	<b>12700 WORDS</b>	<b>Additions to section 3.19, addition of an attachment and photos</b>
<b>VERSION 2.1</b>	<b>20 Feb 2013</b>	<b>13150 WORDS</b>	<b>Slight modifications to make the document ready for proof reading</b>
<b>VERSION 2.2</b>	<b>28 Feb 2013</b>	<b>13214 WORDS</b>	<b>Very minor changes by OP</b>
<b>VERSION 2.3</b>	<b>5 March 2013</b>	<b>13214 WORDS</b>	<b>Proof Reading added in Track Changes</b>
<b>VERSION 2.4</b>	<b>5 March 2013</b>	<b>13085 WORDS</b>	<b>Proof reading comments incorporated</b>
<b>VERSION 3</b>	<b>24 March 2013</b>	<b>13151 WORDS</b>	<b>Incorporated footnotes 3 &amp; 4 pp12-13 re MLS equipment in USAF &amp; RAAF Hercules aircraft</b>
<b>VERSION 4.1</b>	<b>31 March 2013</b>	<b>13184 WORDS</b>	<b>Changed spelling of antennae to antennas throughout. Refer JS email of 28 March 2013</b>
<b>VERSION 4.2</b>	<b>31 March 2013</b>	<b>13184 WORDS</b>	<b>Changes technical terms to capitals at beginning of each word e.g. elevation flare becomes Elevation Flare. Refer JS email of 28 March 2013</b>
<b>VERSION 4.3</b>	<b>28 April 2013</b>	<b>13184 WORDS</b>	<b>Corrected "Schembri" p12, footnote 4</b>
<b>VERSION 5</b>	<b>24 June 2013</b>	<b>13143 WORDS</b>	<b>Incorporated editorial suggestions from Roger Meyer inc Appendix 2</b>
<b>VERSION 6</b>	<b>24 June 2013</b>	<b>13385 WORDS</b>	<b>Modified Interpretation Plan in line with discussions with Roger Meyer</b>
<b>VERSION 7</b>	<b>8 Sept 2013</b>	<b>13385 WORDS</b>	<b>Added Prof Brian O'Keefe to Appendix 3</b>