Airborne Profile Recorder/Recording II (APR) Prototype and Operational Recollections

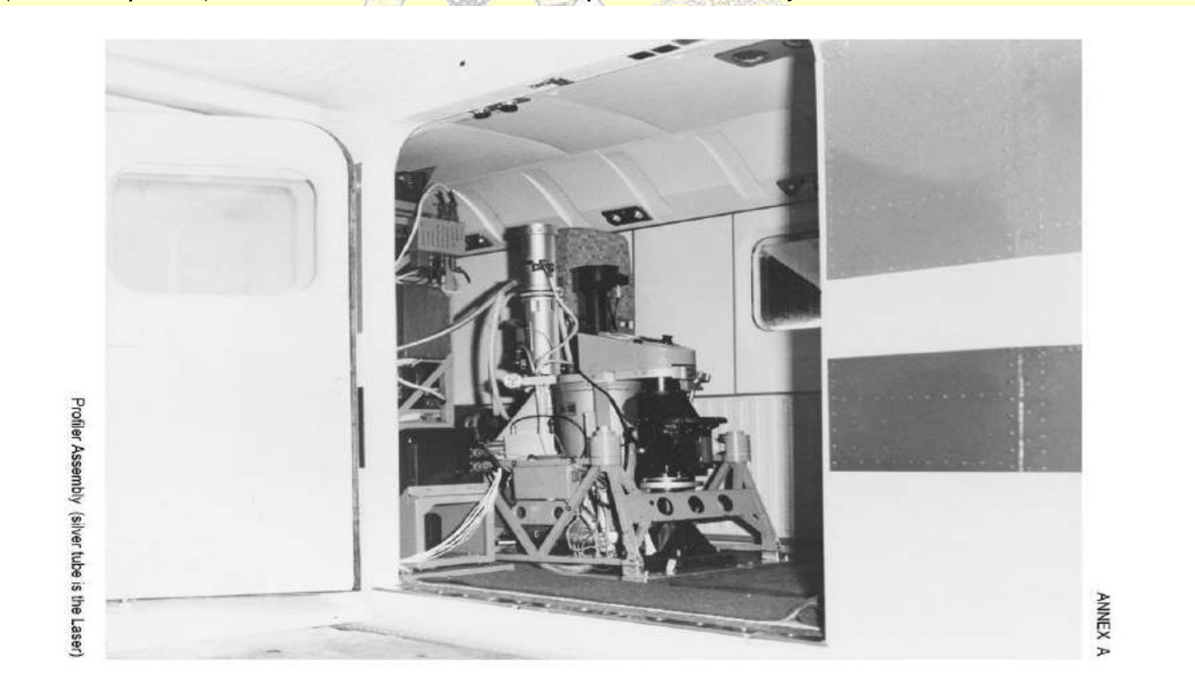
By: Peter Demaine

Military Biography

Peter Demaine graduated from Royal Melbourne Institute of Technology with a Bachelor of Applied Science, Degree in Surveying in 1978. Peter enlisted in Melbourne on 11 July 1979 as a survey cadet at the Officer Cadet School (OCS), Portsea. He graduated from OCS and was subsequently posted to most Royal Australian Survey Corps (RA Svy) units; Royal Military College of Science at Shrivenham, UK; and various non-Corps postings. Career highlights were: Officer Commanding 4th Field Survey Squadron (4 Fd Svy Sqn) the last Fd Svy Sqn prior to disbandment of RA Svy; Officer in Command of the Airborne Profile Recorder (APR) team 2 Fd Svy Sqn; Operations Officer 4 Fd Svy Sqn; Troop Commander Aerotriangulation Troop. Peter discharged from the Army as a RAE Major in Canberra on 13 July 1999.

WREMAPS, DSTO, NATMAP and RA Svy

The Laser Terrain Profiler, WREMAPS I, was developed by the DSTO Weapons Research Establishment (WRE) Salisbury SA at the instigation of the Division of National Mapping (NATMAP) to meet defined operational requirements. NATMAP flew over 250 000 kilometres of laser terrain profiles from 1970 to 1979. These profiles have provided vertical control for the photogrammetric plotting of 2.7 million square kilometres (the area of Australia is 7.7 million square kilometres) at a scale of 1:100 000 with a contour interval of 20 metres. Figure 1 (NATMAP photo) shows the WREMAPS I laser profile assembly.



Defence Science and Technology Organisation (DSTO) pioneered the application of laser research to terrestrial mapping for a system to aid topographical survey of land surface profiles in Australia. This followed from research led by Fred F. Thoneman into the use of laser technology soon after the discovery of lasers in 1960. The airborne laser terrain profile recorder (APR) that was fundamental to the system was designed by Mike Penny from the WRE and developed during 1968 to 1974. Mike's work for the Department of the Army, the APR developed under the WREMAPS-II program, went into service with RA Svy from 1974 to 1985 to replace barometric heighting. APR was able to measure and record ground profiles from aircraft flying at altitudes up to 5,000m above ground level. These altitudes are particularly useful for APR operations in Indonesia and PNG due to the height of terrain and mapping requirements. *(Editor: An earlier Airborne Terrain Profile Recorder, radar based, was used by RA Svy to map the Territory of PNG/Indonesia border in 1963.)*

The WREMAPS-II APR prototype was developed and tested in Australia by DSTO. Note that a production version of the APR was never made. The APR consisted of a mechanically still structure with a low power laser transmitter, a receiving telescope, barometric reference unit (BRU), UV chart data recorder, digital data recorder and a 70mm strip camera to photograph the ground immediately below the aircraft. The receiving telescope looked at the same patch of ground that the transmitter illuminated and collected an extremely small fraction of the laser light scattered from the ground. By measuring the time taken for the laser light to make the return trip from the transmitter to the ground and back to the receiver, the distance between the aircraft and the ground was measured. The strip camera recorded the precise track of the laser beam across the ground on 70-millimetre film. The prototype also included a Wild RC10 super-wide angle air survey camera to assist with matching the vertical profiles to mapping photography.

The APR laser generated short duration pulses of green light at a rate of 25 pulses per second. These light pulses were directed vertically downward from the aircraft in a narrow beam. Each pulse was scattered by the terrain, and a small proportion were detected by the optical receiver located in the aircraft. When the transmitted pulse left the aircraft, a 300 MHz counter was started, and when a reflected pulse was received the counter stopped. The number of pulses counted within this period corresponded to the number of half metres between the aircraft and ground.

It was necessary to determine the aircraft position with respect to sea level for the profile plot to yield true ground height information. This was achieved by flying the aircraft along an isobaric (constant pressure) surface using the BRU. Any deviation of the aircraft from this pressure surface was recorded and used to correct ground-height information. If a profile run (typically 120 kilometres) could be made between two points of known height, correction could be made for any slope in the isobaric surface. See Figure 2 (NATMAP diagram) below.

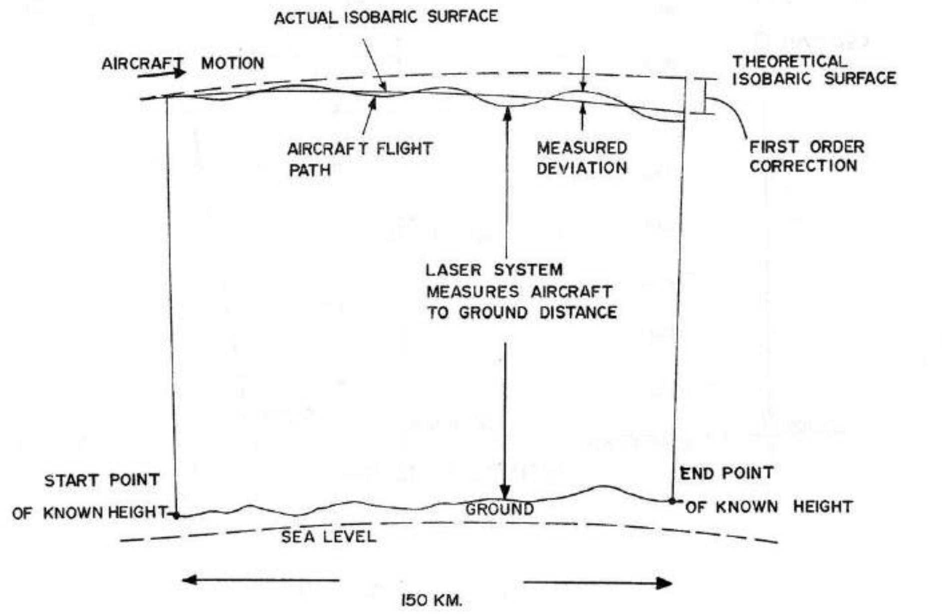


Figure 2: Principle of Airborne Profiling

Another innovation developed by Australia's defence scientists was the Weapons Research Establishment Laser Airborne Depth Sounder (WRELADS) program see Annex A.

Vertical Control

The APR recorded a height profile over the land as the aircraft flew a grid pattern of sorties to capture height profiles. APR was used by the RASvy Corps in Defence Cooperation Programme mapping projects in PNG and Indonesia in the 1970's. RASvy deployed the APR across northern parts of Australia, western NSW, and around the Lake Hume region of northern Victoria, through the 1970's and 80's.

Principle of Airborne Laser Profiling

The distance between ground and aircraft is determined by comparing the phase of the transmitted and reflected laser light, which is continuously recorded on the UV chart and digital data recorder.

By flying over points of known elevation at the start and finish of each flight line and applying an accurate correction provided by the Barometric Reference Unit which continuously senses small changes in the flying height of the aircraft, the height datum is established and misclosure calculated and proportioned along the line. The heights of any intermediate points can then be derived, see Figure 2 above.

In practice, heights are obtained from profiles flown in a rectilinear pattern (i.e. N-S and E-W profiles) over the area to be mapped. As the levelling control net is marked on the ground only at intervals of some kilometres road profiles between known heights are used to connect to each intersecting profile. Profiles ending over the coast use sea level data interpolated between 2 tidal gauges.

The bench marks, road profiles and sea level heights provide the datum for the profiles and enable heights of the intersection points to be calculated. These intersection points are used to calculate loop closures across the entire network. If loop closures associated with a profile are too large, the profile is reflown.

RA Svy APR Equipment

The RASvy APR equipment consisted of a narrow beam laser distance measuring system, a barometric reference unit (BRU) to establish a height datum at the start of each profile and sense small changes in pressure along the profile, a special continuous-strip 70 mm camera to record the track, gyroscopes to sense pitch and roll of the aircraft, and associated support equipment, including a UV paper chart recorder for displaying all relevant data and a Texas Instruments digital profile recorder. A Wild RC10 super-wide angle air survey camera was used to connect APR profiles to current mapping photography. The APR equipment and RC10 camera were fitted into a leased Queenair aircraft. The crew consisted of a civilian pilot; and a RA Svy team consisting of a navigator, APR operator and RC10 air camera operator. On the ground there was a mobile darkroom with facilities to develop RC10 and 88mm photography. A Texas Instruments digital computer was used to extract APR digital data. UV chart data was extracted directly from the chart.

Profiling by RA Svy in Australia

The Lake Hume region was used for training APR teams and calibration of equipment, and at the start of APR operations coastal waters were used for calibration of equipment. RAEME technicians serviced the APR at Mascot Airport and in the field with limited spare parts provided by DSTO. RC10 cameras were serviced under a commercial contract. The Navy's WREMAPS development was aided by lessons learnt from the APR.

In Australia the aircraft would fly at a constant pressure height of around 10,000 feet above Mean Sea Level (MSL) when profiling. The pilot would aim to keep the aircraft at a fixed altitude referencing the BRU, and minimising pitch and roll. Profiling was usually done in the morning, where possible, to avoid turbulence and cloud build up (consequently dry season operations in northern Australia). The aim was to establish a network of North/South and East/West profiles, covering one or more 1:250K mapping areas tied into existing vertical ground control (e.g. Bench Marks, sea level heights interpolated from tidal gauges, etc.) at each end of the profiles and within profiles. The APR team would aim to fly profiles over open country avoiding forests so the laser beam could obtain the clearest profile of the ground. Intersection points (IPs) between N/S and E/W profiles were planned to be in open country.

Profile height differences at IPs were used to calculate errors within the network, and reject profiles causing errors greater than tolerances set in the APR Standard Operating Procedures. The APR navigator would direct the pilot to the location of the profiles, keep the pilot on track for the duration of the profile and advise the APR team when nearing IPs. The APR operator, looking down through strip camera, would advise when IPs were crossed and the air camera operator would take a photograph. The air camera operator also ensured that suitable aerial mapping photography was taken of each profile. After returning to base at the end of profiling each day the APR team would ensure that UV charts, digital cassettes, 88mm strip films and mapping photography were readable and within APR data and mapping photography standards.

Performance Observations of APR Equipment on RA Svy Operations

APR equipment and parts had become worn and temperamental by the early 1980’s after years of operations in Australia, PNG and Indonesia. RAEME technicians were able to keep the equipment serviceable with spare parts provided by DSTO.

Lag between aircraft pitch, roll and isobaric height; and data recorded by the APR system induced errors. Experienced pilots were used to minimise these lag induced errors.

APR teams generally consisted of experienced operators and those who had recently graduated from School of Military Survey APR training courses. This approach meant that new members got valuable operational experience under the watchful eye of seasoned members, and operational lessons learned were passed onto them.

I was very privileged to work with many fine RA Svy APR team members, RAEME technicians and civilian pilots during my career. I got paid to do a job I loved doing and to see vast regions of Australia that I had never seen. I met many interesting characters wherever I was based for APR operations, but they are stories for another day.

Key Personnel

Bob McHenry led APR operations in PNG and possibly Indonesia. Bob was a great font of APR knowledge for me from my days as Troop Commander Aerotriangulation Troop. Others who gave me a deeper understand of APR, vertical control and mapping photography requirements were Mick Dempster, Rusty Williams, Phil Boyle, Don Musgrave and Bruce (Happy) Hammond.

I led three APR operations and assisted in another one. These were:

- Op NERVOSE 84 in the Arnhem Land based at Ngukurr, Barkly Tablelands and Elliott regions of the NT;
- Op ARIGHT 83 in Gulf of Carpentaria and Cape York Peninsula of Queensland based at Normanton;
- 1984 operation in Western NSW operation based at Narromine in 1984; and
- Assisting Pete Clarke for Op MIZMAZE 83 in the Kimberley region based at Kununurra.

Andy McLeod led the APR course that trained Pete Clarke and I at SMS. Derek Stanmore a member of my APR team at 2 Fd Svy Sqn, was very experienced and helped me better understand the APR operational aspects. I had good APR teams for operations including people like: Doug Gay, Wolfgang Thun, Marty George, Simon (Andy) Capp, Roger Rees, Steve Hill, Hutch Hunter, Neil Jones, Peter (Spoon) Lefel, Steve Gloster and Dave Longbottom. Civilian pilots Keith Meggs and Jim Miller? Apologies to anyone I have missed due to my failing memory.

Operation work taught me a lot about myself and the need to always work as a team. Clear communication between all members of the team and a thorough understanding of the mapping control and photography requirements to be used by Aerotriangulation Troop were essential.

Videre Parare Est

Annex

WRELADS Program and DSTO

References:

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ANNEX A - WRELADS Program and DSTO

Another innovation developed by Australia's defence scientists was the Weapons Research Establishment Laser Airborne Depth Sounder (WRELADS) program that has had a wide application beyond strictly defence needs. This is a self-contained, transportable bathymetric survey system that uses a pulsed laser mounted in a fixed-wing aircraft. It is the fastest and most cost-effective tool for surveying in coastal waters to a depth of 70 metres and in areas too shallow or otherwise hazardous for navigation. The Royal Australian Navy's Hydrographic Service had estimated that it would take 80 years to complete hydrographic surveys of Australia's continental shelf using shipborne acoustic depth sounders and sought another means of conducting the surveys.

Under the leadership of Mike Penny, a prototype was constructed (WRELADS I) and installed in a 'Beechcraft' Queenair aircraft. Test flights were conducted over South Australian and Queensland littoral waters between November 1976 and June 1977 to test basic design concepts. WRELADS II followed. This upgraded model, installed in a 'Dakota' aircraft, underwent 550 hours of flight trials over north Queensland, West Australian and South Australian waters between August 1979 and May 1984.

Tenders were called in 1987 for the construction and trial of an operational version, with BHP Engineering and its partner Vision Systems Ltd being awarded the contract in May 1989. On 28 January 1992, the Minister for Defence Science and Personnel Gordon Bilney launched the LADS optimisation trials and acceptance tests program at Adelaide airport. The Navy accepted LADS on 8 October 1993.