75 years of scientific accident investigation support at the Bend

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Mr. Molent has worked in the fields of aircraft structural integrity, structural mechanics, structural and fatigue testing, advanced bonded repair, aircraft vulnerability and aircraft accident investigation. He has over 200 publications in these technical areas and is a qualified aircraft accident investigator. He has been attached to both the then Civil Aviation Department (1985) and the US Navy (NAVAIR, 1990-1991) in Washington D.C. as an airworthiness engineer. Mr Molent is currently the Defence Science and Technology Organisation's Head of Emerging Aircraft Structural Integrity. In 2010 he was awarded with the Minister's Award for Achievements in Defence Science.

Mr Athiniotis is Head of Aircraft Forensic Engineering and Accident Investigation. He commenced at DSTO in 1989 and has amassed extensive knowledge and experience in metallurgical investigations of aircraft structures, components and systems, and investigations of military accidents and incidents. In 2008, Mr Athiniotis was awarded a Chief of Defence Commendation for his investigation support into the Sea King accident in 2005, and a Chief of Air Force Commendation for his investigation support into the recovery of the Canberra aircraft that went missing in Vietnam in 1970.

Abstract : Like other nations, early Australian attempts at powered flight fared poorly. The first recorded accident was when Colin Defries tried to coax a Wright Flyer into the air at Victoria Park Racecourse in Sydney on 4 December 1909. The attempt terminated abruptly when the aircraft struck logs hidden by long grass. Whilst early aircraft accident investigation' causal findings such as "a lack of lift in the air[1]" were a useful meteorological observation, they provided little assistance for making the aviation system safer. As at the time, there was no formal system or infrastructure for the investigation of air accidents; these were often left to the discretion of the pilot or owner (or another generally non-expert body) to investigate. The net result was a wide variation in approach and little in the way of science. The need for an aeronautical science system in Australia was recognised by the 1938 Wimperis Report to the Australian Government which led to the establishment of the then Aeronautical Research Laboratory (ARL) in 1939 at Fishermans Bend, Port Melbourne, Victoria. The ARL then provided the foundation to the conduct of independent and scientific aircraft accident investigations in support of Defence Aviation, and to the wider community, which is a staple to the present day.

This paper presents a brief history of 75 years of systematic scientific support to aircraft accident investigation at the now Defence Science and Technology Organisation at the Bend.

[1] WW1 Royal Flying Corps Monthly Safety Report December 1917.

1. Introduction

"In the 1920's, there was growing public disquiet at what was seen, probably correctly, as officialdom's rather elementary approach to the investigation of aircraft accidents. Events came to a head in 1927 when two accidents occurred before large crowds and, more importantly in the eyes of the daily paper, before the Duke and Duchess of York. Their Royal Highnesses were visiting Australia to open the new Parliament House in Canberra with due Imperial pomp and ceremony. On 21 April 1927, during their official visit to Melbourne and just as the royal procession was turning from St Kilda Road into the grounds of Government House, two DH.9 aircraft of the RAAF flypast collided. The crowds of many thousands watched as A6-5 and A6-26 disintegrated and plummeted to earth in the vicinity of Sturt Street, South Melbourne. Fortunately, there were no casualties among the crowd but all four RAAF aircrew were killed making it the worst aircraft accident in Australia to that time. Three weeks later, their Royal Highnesses had the misfortune to witness the crash of SE-5a A2-24 during the opening ceremony in Canberra on 9 May 1927. The pilot F/O F.C. Ewen was killed. The following day, while returning from Canberra to Melbourne with photographs of the opening ceremony, SE-5a A2-11 suffered an engine failure and crashed in remote bushland near Whitfield, Vic. The pilot, Sgt Orm Denny, walked 25 miles to secure assistance. This was too much for the newspapers. Bowing to pressure, Sir William Glasgow, Minister of Defence, signed a Statutory Rule on 25 May 1927 under the Air Navigation Act of 1920 appointing an Air Accidents Investigation Committee (AAIC). The committee was empowered to make an independent inquiry into aircraft accidents, to study probable cause and to suggest preventative measures. The committee made a flying start by holding its first meeting at Victoria Barracks Melbourne on the 25 May" [2].

The Aeronautical Research Laboratory (ARL) was established at a site on Fishermans Bend Victoria Australia [2] as a division of Council for Scientific and Industrial Research (CSIR) in 1939 following the recommendation of Mr. Wimperis, formerly Director of Scientific Research for the Air Ministry in Britain. Mr. Wimperis was commissioned to advise the Australian Government on the inauguration of aeronautical research in Australia. From its inception ARL provided a system of technology, science, facilities and tools to support the AAIC. The first part of the Laboratories to take shape was a structures and materials section and one of the first buildings on the ARL site was a Structural Test Laboratory, later to be referred to locally as the "Wing Bay", with a reinforced concrete floor for reacting the test loads applied to full-scale structures, largely to support investigations into in-flight structural failures. Subsequently came the wind-tunnel facilities, engine test cells, aircraft systems laboratories and human factor experts. In short a system was established in-part to support aircraft accident investigations.

The ARL[3] then provided the foundation to the conduct of independent and scientific aircraft accident investigations in support of Defence Aviation (in particular today the Directorate of Defence Aviation and Air Force Safety (DDAAFS)), and to the wider community, which is a staple to the present day. This paper presents a brief history of 75 years of systematic scientific support to aircraft accident investigation at the (now) Defence Science and Technology Organisation at the Bend.

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[2] From [1].

[3] ARL has experienced several changes of name (Aeronautical Research Laboratory, Aeronautical and Maritime Research Laboratory (AMRL) and currently the Defence Science and Technology Organisation (DSTO) Melbourne).

2. Some Technical Break-throughs[4]

DSTO has pioneered several significant technologies related to the investigation or prevention of aircraft accidents. These include the development of:

1. The “Black Box” flight data recorder.
2. The Tee – Visual Approach Slope Indicator System (T-VASIS) landing system that was adopted as the international standard in 1971.
3. Global Positioning Satellite (GPS) based wreckage mapping.
4. Human factors and visual optics.

2.1 Flight data recorders

The idea of a crash and fire protected device that records both the voices and sounds in the cockpit and some instrument readings before an accident was conceived by Dr David Warren at ARL circa 1954 [3].

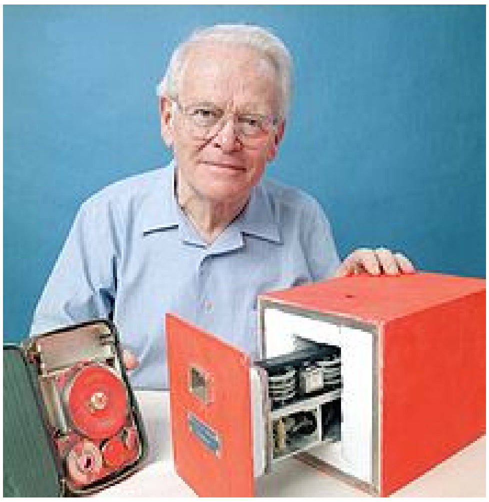

Figure 1: David Warren with the prototype “black box” circa 2000 (Source DSTO)

A demonstrator unit was produced in 1957, and successfully tested in an Australian F27. The device was compact and light, weighing about one half of a kilogram, and its recording tape was a fine stainless steel wire, as fine as a human hair. The wire tape could survive being heated to red-hot. As well as cockpit noise, it recorded eight channels of flight data such as aircraft speed, height, pitch and roll and had sufficient capacity to record these for four hours. The box was orange in colour. Despite what now appears to be undeniable virtues of such a device, it was not favourably received by the Australian Aviation Authorities at the time. The then Department of Civil Aviation (DCA) stated “Dr Warren’s instrument has little immediate use in civil aircraft”. The RAAF stated that “Such a device is not required. Opinion is that in fact the recorder would yield more expletives than explanations. To the RAAF, the loss of aircraft is an acceptable risk”. How things change!

[4] Throughout the years DSTO has received a number of commendations for its work in this area. Some include: a. Diplome d’Honneur of the Federation Aeronautique Internationale (FAI) for the invention and development of T-VASIS. b. 2008 Chief of the Defence Force Commendation: Accident Investigation of the Sea King Helicopter accident in Nias, Indonesia. c. 2009 Chief of Air Force Commendation, into the disappearance of Royal Australian Air Force Canberra aircraft A84-231.

The British however received the concept with more enthusiasm and further developed the device. On 10 June 1960, an accident occurred in which 29 people died in a Fokker F27 aircraft landing at Mackay in Queensland. The subsequent board of inquiry was unable to come to any definite conclusions as to the factors underlying the accident and recommended that all airliners be fitted with flight recorders. The Federal Government implemented this recommendation the following year. The decision was made that the Warren device was unsuitable and the US firm United Delta Corporation was approached to develop a device. They chose to use scratch foil recorders for flight data and plastic tape for speech. Accordingly, they struck problems of protecting the tape from the heat and damage of the crash. In 1967, the DCA were forced to admit: "The future prospect of recorders based on the use of magnetic wire is brighter now than they have ever been".

Australia was one of the first countries to introduce this requirement and today, all aircraft on the Australian register with a maximum take-off weight greater than 5,700 kg are required to carry both a cockpit voice recorder (CVR) and a flight data recorder (FDR). This is now also required for aircraft operating in or between ICAO member nations.

2.2 T-VASIS

Another notable aircraft safety system developed by ARL also took a considerable time to be accepted. The Human Engineering Division invented the "Tee" aircraft visual approach slope indicator system (VASIS), a method by which the pilots can judge whether they are on the correct glide path for landing (Figure 2) [4]. The "T" shaped pattern of lights on the runway approach became the international standard after some resistance from competing UK systems in 1972. The possibility of developing glide path guidance by visual means arose from a study of landing accidents initiated by ARL in 1956 supported by the Department of Civil Aviation (DCA). The concept was quite simple; a series of lights was positioned to each side of the approach to the runway. When the aircraft was on the incorrect guide slope a figure T was visible to each side of the runway. ARL set up a T-VASIS along with its UK competitor the red and white VASIS at Avalon Airfield near Melbourne for evaluation trials. ARL staff would be bussed to the top of You Yangs hills after work to partake in the evaluation, from which the T-VASIS was clearly visible. In 1973, the DCA and ARL shared receipt of the Diplome d'Honneur of the Federation Aeronautique Internationale (FAI) for the invention and development of T-VASIS. The patent for an "Improved glide path guidance means for aircraft" credited the inventors as John Baxter and Ronald Cumming (from ARL), and Bruce Fraser and Dr John Lane (DCA).

2.3 GPS Wreckage Mapping

During the investigation of aircraft mishaps, identification and mapping of wreckage is usually required prior to its collection (and, if necessary, detailed examination). This recording phase can be time-consuming and very expensive in resources, particularly when the wreckage is spread widely. Traditionally apart from the required surveyors, a team conversant with the aircraft's structure, a photographer, and one of the investigators may be necessary to produce useful data. This could take considerable time depending on the accuracy required and the number of parts to be mapped. Accurate mapping by conventional methods may restrict mapping to 50 or less points a day, followed by data plotting and map generation away from the accident site. The time consumed, and expense, were well illustrated during DSTO's involvement in the accident investigation of two Australian Army Blackhawk aircraft at High Range near Townsville during June 1996. In this case, a group of four surveyors was used along with two personnel familiar with the aircraft structure, a photographer and one of the investigation team. The process in the field was very slow and considerable time elapsed between the initiation of the wreckage survey, and the production of useable maps and the collection of the parts of interest. Indeed parts were collected and analysed, and reports were written well before wreckage maps were generated and made available to the investigators. As a direct result of the difficulties encountered with the Black Hawk investigation, DSTO began the development of a rapid wreckage mapping system. This had become possible as a result of the GPS being assembled by the US Department of Defense, and the development of mapping equipment using GPS signals, by commercial surveying instrument manufacturers. Other developments include the introduction of reasonably priced medium-resolution digital cameras, and the rapid rise in portable computing power and Geographic Information Systems (GIS) software, which are geographic coded (spatial) data bases. Although the use of GPS at accident scenes was not new, when fully developed and refined, the system developed provided considerably greater, almost instantaneous readouts of wreckage maps in any format desired. The accuracy is sub-metre and may be considerably better than this in a relative sense (relative position of points at a site) [5,6]. An example of such a map is shown in Figure 3.

2.4 Visual Optics

The visual environment and achieved visual performance of aircrew can determine mission success or failure, particular so for military aviation. DSTO pioneered much applied research into visual displays, optical radiation hazards, visibility, transparency scatter, vision enhancement, helicopter separation judgement and visual landing aids [7].

Significantly this research culminated in the development of the Head Up Display (HUD) which has undoubtedly led to increases in safety as well as operational effectiveness [7][5].

The Pulfrich Effect is a visual localisation error arising from unequally illuminated eyes viewing objects moving across the field of view. Researching (see Figure 4) the practical consequences of this led to the realisation that helicopter aircrew views of their own and adjacent main rotors were devoid of most of the usual cues to distance. This research was pivotal in understanding accidents related to rotor-craft main rotor strikes [8].

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[5] ARL's J. Baxter was seconded to transfer the DSTO technology, free, to the USA. The US Federal Aviation Agency provided a technical assistant but was adamant that Baxter be listed as second author of the resulting report (Workman and Baxter, 1962) [7].

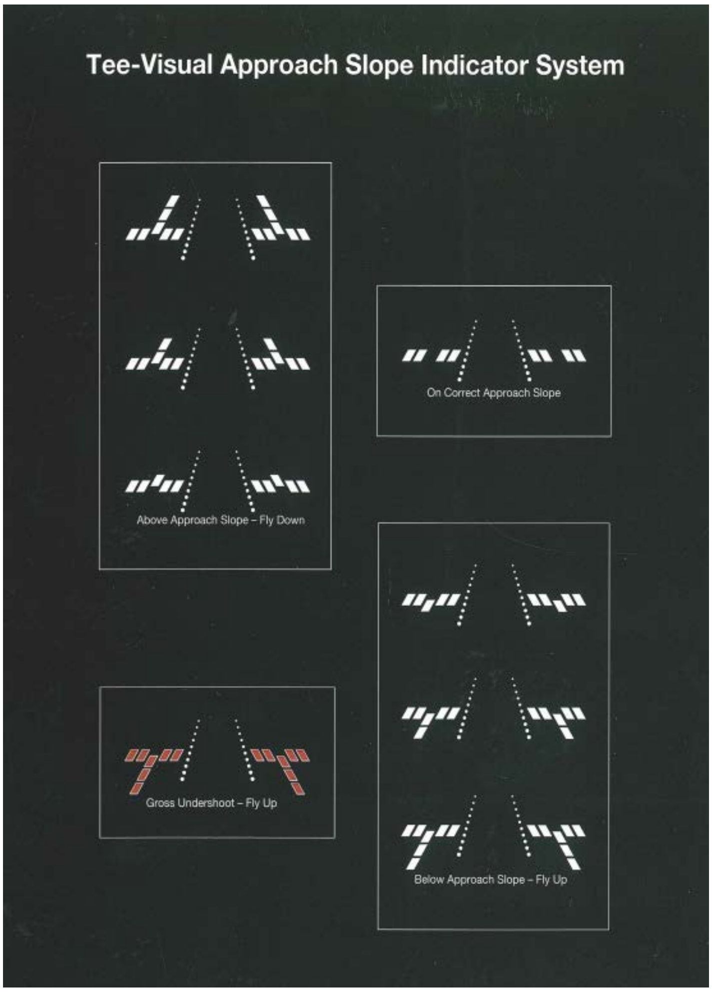

Figure 2: The Tee-Visual Approach Slope Indicator System runway light scheme

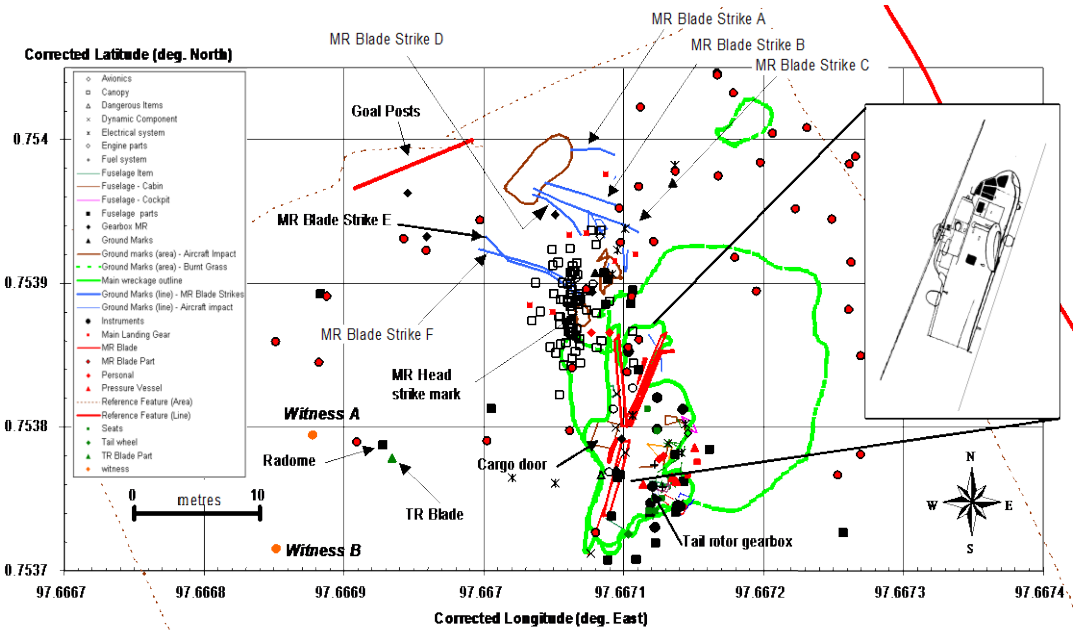

Figure 3: An example of a DSTO GPS/GIS generated wreckage map [5].

Figure 4: Barry Clark and his Rotor Rig in the Vision Laboratory

3. Some (further) Investigations of Note

Early Australian and DSTO-specific investigations up to 1992 (i.e. the first 50 years) were well described in [1]. In Table 1 a summary of significant DSTO accident/incident investigation activities up to July 2014 (i.e. 75 years since the inception of DSTO) is presented. Below are a few examples where significant advances in technology were applied to the accident investigation, or the accident itself was the result of unusual circumstances.

3.1 Black Hawk Mid-air

A mid-air accident between two Australian Army Black Hawk S70-A-9 helicopters occurred near Townsville, Queensland, in northern Australia, on the 12th of June 1996. The Army was conducting operational training and the mission was flown at night using night vision goggles and a formation of six aircraft. Aircraft B1 was the flight lead and in close formation (one rotor spacing) with aircraft B2. These aircraft collided and impacted the ground.

In addition to wreckage mapping, considerable efforts were devoted to aircraft reconstruction. By matching blade impact marks with the orientation of the aircraft an estimate of the impact projection of the two aircraft was made. By conducting individual trajectory analyses of each of the various component groups identified (e.g. rotor blades, light materials, major components etc) and considering their measured spread on the ground (e.g. Figure 5), the overlapping common areas was considered the most probable area of aircraft contact, see Figure 6. These two technical aspects were critical in postulating a credible scenario to explain the collision.

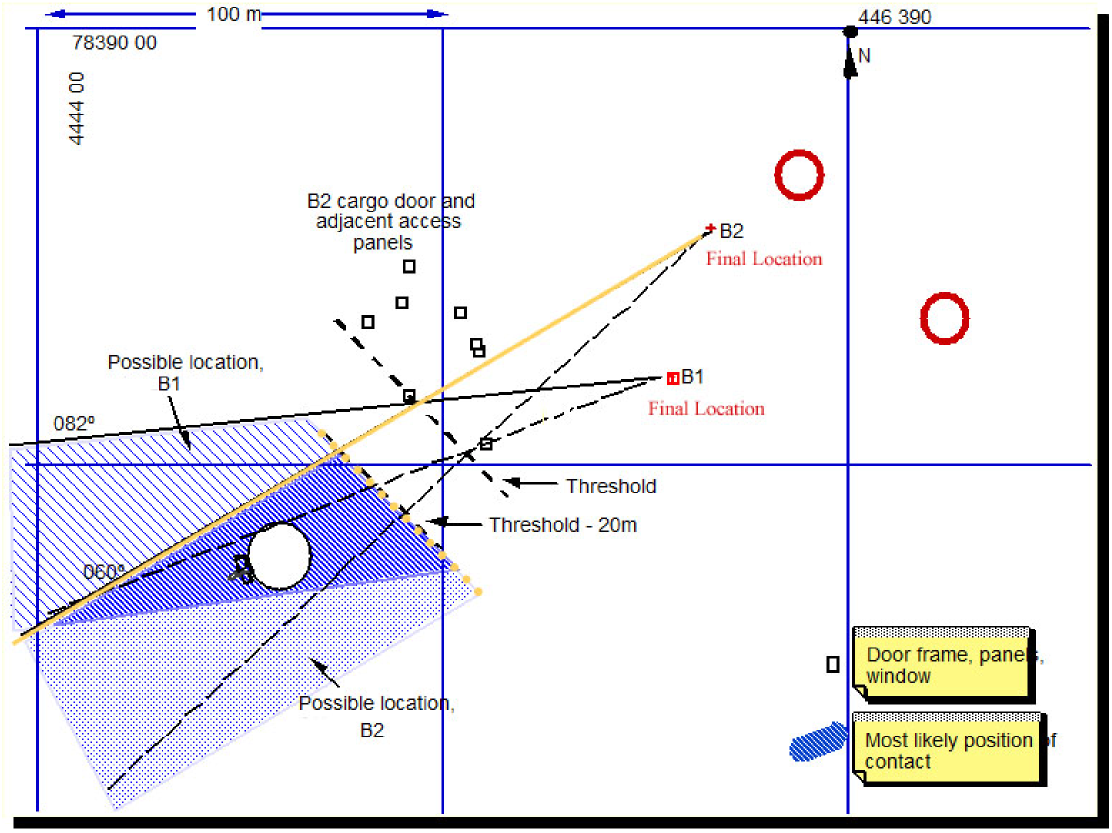

Figure 5: Debris trajectory analysis of cargo door parts from B1 and B2, indicating most likely location of impact.

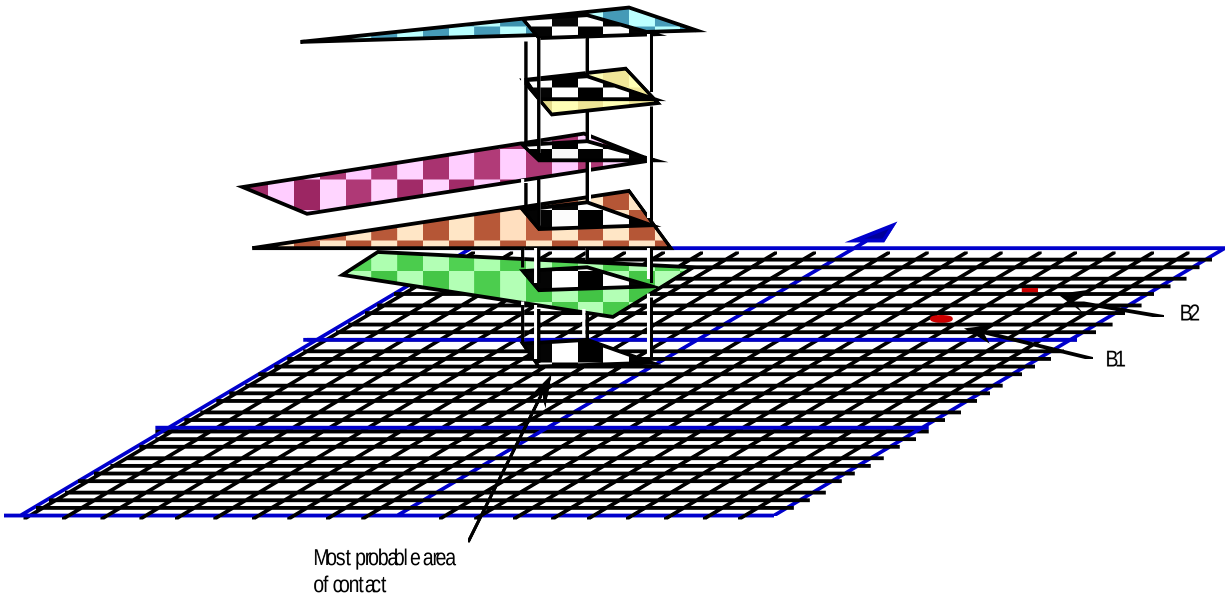

Figure 6: Most likely location of impact (grey shaded area). Each other colour represents the estimated projection of a component group (separated in height dimension for illustration purposes).

3.2 Macchi Trainer

On the 22nd of November 1990 RAAF Macchi aircraft A7-076 was observed by other pilots in the vicinity to suffer a wing failure during an air combat manoeuvre. Examination of the wreckage recovered from the sea disclosed that the port wing had failed when the aluminium alloy 7075-T6 lower spar boom broke as the result of a large fatigue crack [9,10]. The cracking was found to have initiated from a machining detail in the base of a flange fastener hole, Figure 7. This defect had the effect of introducing a severe notch into the fastener hole. Examination of the recovered starboard wing revealed further fastener hole cracking. All spars in the RAAF fleet had been replaced in a life extension program however a fatigue test of the new configuration had not been conducted. Examination of the Deutsch™ fastener hole from which the fatigue crack initiated revealed that the hole had been drilled though the flange to a depth where the drill tip had just penetrated the rear surface of the flange. This penetration had occurred in the central region of the hole and corresponded to the centre of the tapered end of the drill used to machine the hole. The cracking had initiated at the resultant tapered base of the hole between where the hole penetrated the back face of the flange, and the main bore of the hole. Cracking had occurred on either side of the penetration, roughly in the plane perpendicular to the length of the spar boom with the cracking on either side being slightly offset. Providence dictated that the step produced by the fastener hole drilling was aligned at the worse possible orientation, namely approximately perpendicular to the principal loading direction. The depth of the notch-step produced was estimated to be approximately 0.22 mm (i.e. a large flaw, see [11]). It was postulated that the stress concentration effect of this notch, coupled with that of the hole and low interference of the fastener, contributed to the rapid crack growth rate. Further, teardown inspection of the recovered starboard wing revealed the presence of other fatigue cracks, including at the mirror location to the port wing failure site, generally these cracks could also be attributed to poor hole machining quality. With the aid of the load history from the aircraft's Nz meter, the growth pattern on the fatigue fracture surfaces of two holes was determined via quantitative fractography. The largest of the cracks were investigated to establish their growth rates which, coupled with assistance of the non-destructive inspectors, enabled the RAAF to conduct a safety-by-inspection program which helped to recover their training capability.

Figure 7: Fracture surface of A7-076 lower spar cap after recovery from the ocean. Note the fatigue progression marks propagating from the upper (nominally) blind fastener hole (upper left hand side).

3.3 Royal Australian Navy Sea King Accident, 2005 Nias Indonesia

On 2 April 2005, RAN helicopter N16-100 (call sign “Shark 02”), deployed to Indonesia as part of the Australian humanitarian support operation “Sumatra Assist II”, crashed on approach to the village of Tuindrao, on the Indonesian island of Nias. DSTO support for the investigation of the crash of RAN N16-100 began with the on-site investigation support with specialist materials and structural assessments of the wreckage and its mapping, followed by laboratory analysis by a larger DSTO specialist team, and presentation of evidence at the Board of Inquiry [5].

The rotating machinery on a helicopter makes sounds at various frequencies. DSTO has developed techniques to analyse the frequency of the ambient noise which can identify and isolate the noise generated by rotating machinery such as engines, gearboxes, and pumps. The Sea King Crash Data Recorder signal analysis of the microphone channels confirmed that the main rotor gearbox and engines were working correctly, and did not show any evidence to indicate a failure in the rest of the aircraft rotating propulsion system components. This supported the accident site and laboratory assessment and analysis.

The most significant evidence found suggested that a flight control system failure occurred due to disconnection of the fore/aft bellcrank from the flight control’s Mixing Unit, Figure 8. The physical evidence indicated that an unsecured castellated nut detached from the end of a bolt holding the fore/aft bellcrank onto the Mixing Unit lugs. The bolt then slid out of the lugs, permitting the bellcrank to separate from the Mixing Unit. The Sea King flight modelling developed at DSTO indicated that the forward motion of the bellcrank and its detachment from the fore/aft lugs of the Mixing Unit would, in less than a second, cause the aircraft to pitch forward rapidly, leading to a nose-dive towards the ground. Any fore/aft inputs made by the pilot with the cyclic stick would have been ineffective because the disconnection of the fore/aft bellcrank from the Mixing Unit prevented fore/aft cyclic stick motions from being transmitted to the swashplate. There was no possibility of recover the aircraft.

The last known maintenance activity on the fore/aft bellcrank occurred on HMAS KANIMBLA, 40 flight hours before the accident, by Sea King detachment personnel on 4 February 2005. The fore/aft bellcrank was removed due to suspected lateral play in the pivot point of the Mixing Unit.

Due to the difficulty in re-installing the item, the maintenance activity carried out by the early watch handed over the task to the late watch with the fore/aft bellcrank loosely secured at the pivot point, with the castellated nut not torqued and with no split-pin fitted. Whilst those undertaking the maintenance were aware of the activity, no Aircraft Maintenance Documentation existed that recorded the removal, serviceability assessment, reinstallation or final inspections of the fore/aft bellcrank. This meant that there was no documented record of a Critical Maintenance Operation maintenance task to act as a prompt for the necessary associated maintenance and inspections. It is considered that this lack of documentation and therefore prompt to inspect the critical item which may have noticed the missing split pin, that ultimately led to the unwinding of the castellated nut, extraction of the bolt and separation of the fore/aft bellcrank from the Mixing Unit pivot point.

The Board of Inquiry (BoI) commenced on 5 September, 2005 and concluded, one year later, on 6 September, 2006. The BoI sat for 111 days, heard 161 witnesses, and tendered 566 exhibits. The BoI Report was released to the Public on 21 June 2007. It contained 1,700 pages and consisted of 759 findings and 256 recommendations for improving aviation safety.

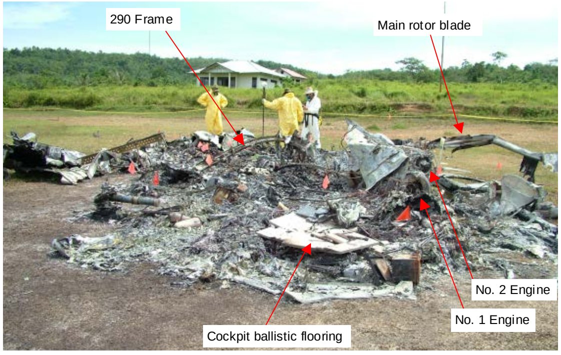

Figure 8. Sea King Accident Site, and disconnected fore/aft bellcrank (right)

3.4 Australian Army S-70A-9 Black Hawk Accident, 2006

On 29 November 2006, an Australian Army S-70A-9 Black Hawk helicopter carrying four crew and six soldiers crashed into the deck of HMAS *Kanimbla* and sank into 3000 m water while conducting routine training operations in international waters southwest of Suva, Fiji. Two persons died as a result of the accident.

DSTO investigations commenced in parallel to the deep sea operation to recover the aircraft, deceased and the Flight Data Recorder (FDR). Using the recovered (and water damaged) video from an on-board hand-held camera along with the ship's video of the flight deck impact, DSTO photogrammetry was used to reconstruct the flight path and estimate the approach speed of the aircraft. This information was then used to develop a flight model and reconstruction of the accident, which was used in the DSTO Air Operations Simulation Centre, Figure 9, to assist pilot instructors to fly a series of manoeuvres that started with defined initial conditions and ended in a manner similar to that recorded by the video imagery of the actual accident. This allowed an understanding of the phases of the approach that led to impact with the flight deck.

DSTO forensically examined the aircraft wreckage following its recovery, however did not identify anything that may have contributed to the accident. DSTO also examined Life Support Equipment to determine the sequence of events leading to the death of the pilot. The reconstruction of the recovered FDR data matched closely to the initial DSTO flight reconstruction, and confirmed that the combination of low speed, large aircraft attitudes and high yaw rate caused a large angle of side slip and placed the aircraft in an unrecoverable state leading to the impact on the ship's flight deck and subsequent ditching.

DSTO presented its evidence alongside DDAAFS at the subsequent BoI. The BoI determined that "The principal and overarching finding of the Board of Inquiry was that the cause of the crash was pilot error by the aircraft captain," and "this accident was the regrettable result of a number of factors coming together which culminated in this tragic incident. There was a gradual adoption of approach profiles which, on occasions, exceeded the limits of the aircraft. Other factors included a 'can do' culture in the Squadron, inadequate supervision, the pressures of preparing for operations, the relocation of the Squadron and a high operational tempo".


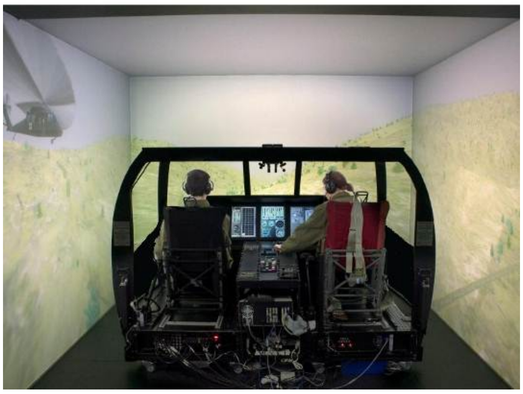

Figure 9. Black Hawk impact on HMAS *Kanimbla*, and DSTO Simulator with 'roll-in' Black Hawk cockpit

3.5 Locating Missing RAAF Canberra Aircraft from Vietnam, 1970

On the night of 3 November 1970, a RAAF Canberra aircraft, call sign Magpie 91, went missing following a routine bombing mission in Vietnam. The aircraft had flown from Phan Rang where it made contact with the ground controller and was directed to the target without incident. Shortly afterwards the aircraft disappeared from radar. A three-day intensive aerial search failed to locate the crew or aircraft. A Court-of-Inquiry held in late November 1970 in Phan Rang, Vietnam, considered all available evidence but was not able to determine the cause of the disappearance.

What happened to Canberra A84-231 and her crew remained a mystery for almost 39 years until renewed investigation in 2008 to locate the missing aircraft and recover the two missing pilots was launched, in what was called "Operation Magpies Return". DSTO's forensics and flight reconstruction capabilities were utilised to estimate the flight path of the Canberra aircraft with the purpose of providing possible locations of aircraft wreckage or debris.

DSTO have been developing methods, tools and software to reconstruct the flight-paths of aircraft involved in incidents and accidents since early 1990. All Australian Defence Force (ADF) aircraft incidents and accidents have been reconstructed by DSTO since this date; as well a few foreign military aircraft incidents and accidents. This includes both fixed wing aircraft and rotary wing aircraft. The DSTO reconstruction of the Canberra flight path utilised audio tape recordings of the pilot and the ground controller which provided airspeed, heading changes/corrections, and included weather at the time, aircraft weight, trajectory calculations, mission briefings and normal pilot actions.

The DSTO reconstruction provided a refined area of interest for the Principal Investigator, Figure 10, which assisted in discovery of an aircraft. DSTO forensic examination of items recovered from the wreckage site confirmed that this aircraft was the missing RAAF Canberra and its crew.

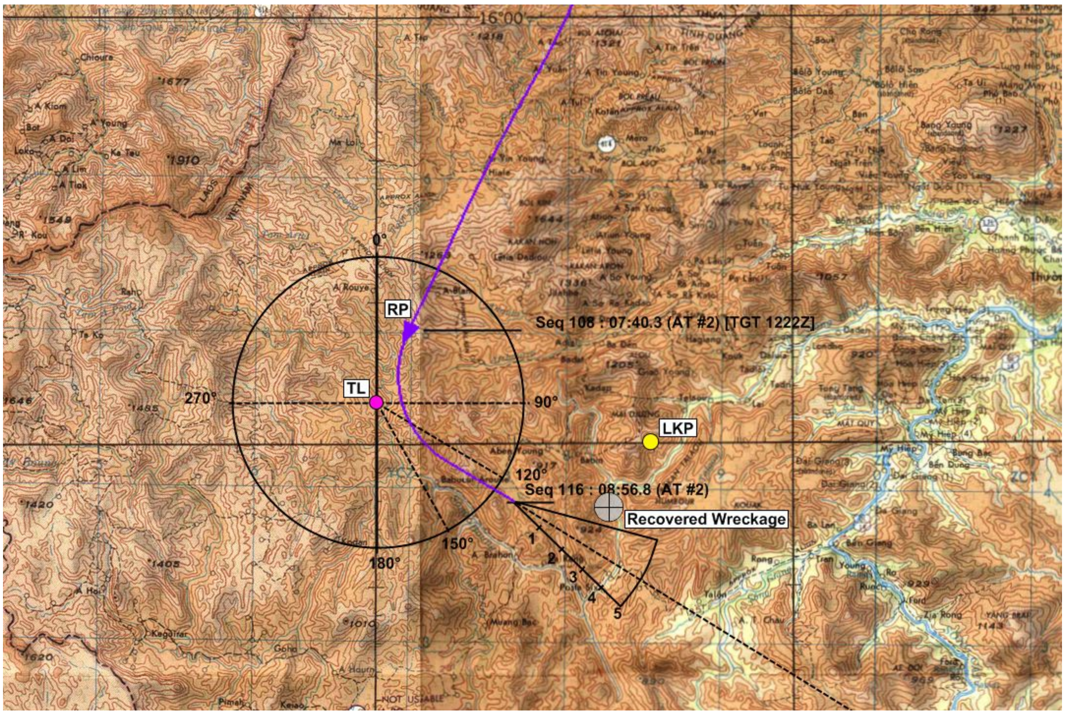

Figure 10: Reconstructed flight path showing approximate location of recovered aircraft. RP =Release Point, TL=Target Location, LKP= Last Known Position based on radar 1970. DSTO predicted quadrants including possible in-flight breakup (debris field based on fragmentation size).

4. Conclusions

The DSTO has a 75 year history of providing the system of technologies and know-how to support the investigations of air accidents. During this period significant technical advancements were made which have significantly contributed to safer aviation and more efficient investigations.

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6. Vale

In memory of the late John Kepert, and in the words of his favourite investigator:

Arrange your facts. Arrange your ideas. And if some little fact will not fit in – do not reject it, but consider it closely. Though its significance escapes you, be sure that it is significant.

Hercule Poirot – The Murder on the Links (Agatha Christie, 1923)

Table 1: Summary of DSTO Accident and Incident Support 1981 -2013

Aircraft type, SNo.	Place and date	DSTO investigation	Cause
1981			
Bell UH-1B A2-380	30/10/81	Tailrotor drive shaft coupling bolts	Tailrotor drive shaft coupling bolts appear to have failed in flight due to incorrect heat treatment.
Bell UH-1B A2-1023 [1]	Williamtown NSW 19/8/81	Tailrotor drive shaft, 45 degree gearbox, pitch control cables, mast, warning lights, tailrotor pitch quadrant, fin	Pitch control cable pick up and tail rotor loss. Terminal mast bump.
1983			
Wessex N7-215 [1]	Into sea Ninety Beach Vic 04/12/83	Main gearbox components.	Fatigue failure of input pinion.
Pilatus Porter A14-702	Point Cook RAAF Base, Vic 07 /12/83	Pilots seat, warning lights	Controlled flight into terrain.
1984			
Lockheed Orion P3B A9-300	Edinburgh SA 29/1/84	Oxygen system components.	Oxygen assisted fire.
1985			
Macchi MB326H A7-085	Williamtown 19/8/85	Control system components.	Inflight fire.
1986			
Bell 206	Into sea NT 14/4/86	Main and auxiliary gearbox components, engine exhaust.	Fuel Problem?
Cessna 202 Air Ambulance	Essendon Airport 3/9/86	Left propeller fine pitch lock, right fuel pump and connection to Air Throttle body.	Power loss.
Macchi MB326H A7-082	Pearce 12/11/86	Fuel system components, warning panel lights and fuel filter.	Fuel problem, in-flight flame-out.
1987			
General Dynamics F111 A8-128	Armadale NSW 2/4/87	Instruments and warning lights.	Controlled flight into terrain.
Wessex helicopter RAN	Botany Bay NSW 26/5/87	Compressor blades.	Engine failure.
Boeing F/A-18B A21-104	Great Palm Island Northern Qld 18/11/87	Stand by instruments and the chest mounted oxygen regulator.	Controlled flight into terrain.
1988			
Macchi MB326H A7-033	Pearce WA 1/2/88	STBD brake housing.	Ran off runway.
Winjeel A85-458	Mt Seaview NSW 24/2/88	Instruments.	Controlled flight into terrain.
Macchi MB326H A7-049	Sale Vic 10/3/88	Speed brake actuator.	Mid-air collision.
Macchi MB326H A7-054	Sale Vic 10/3/88	Control rods.	Mid-air collision.
Winjeel A85-409	Williamtown NSW 5/4/88	Instruments.	Stall?
Macchi MB326H	Pearce WA 5/4/88	Fuel shut-off valve,	Fuel Problem?

A7-018		instruments, warning lights, fuel filters.	
1989			
Macchi MB326H A7-021	Sale Vic 3/8/89	Instruments	Engine fire
1990			
Boeing F/A-18 A21-29 [1]	Near Tindal NT 2/8/90	Inspection of damage.	Mid-air collision with A21-042.
Boeing F/A-18 A21-42 [1]	Near Tindal NT 2/8/90	Inspection of wreckage.	Mid-air collision with A21-029.
Augusta A109C M38-02 of the Malaysian Air Force	Kuala Lumpur Malaysia 19/9/90	Flight controls, gear box mounts, wreckage examination.	Mechanical failure.
General Dynamics F111C A8-130	Amberley, Qld 31/10/90	P&W TF30-P3 Engine S/N P65-9064	Catastrophic in-flight engine failure caused by 4 1/2 bearing failure
Macchi MB326H A7-076 [1] [12]	Williamtown NSW 22/11/90	Wings and centre section.	Fatigue failure of lower port wing spar.
1991			
Lockheed Orion P3C A9-754 [1], [13]	Cocos Islands 26/4/91	Wreckage inspection, general wreckage analysis, elevators and leading edges. Failure analyses	Lost three leading edges.
Boeing F/A-18B A21-41	Weipa Old. 5/6/91	Instruments, actuators and oxygen diluter demand regulator.	Hypoxia?
Nomad N24A A18-403	Tindal NT, 17/9/91	Instruments, general wreckage reconstruction and analysis, controls, engines.	Lost control?
Pilatus PC9A A23-035	Sale Vic 5/8/91	Instruments, general wreckage analysis, canopy, ejection seats and actuators.	Controlled flight into terrain.
Boeing 707-388C A20-103	Into sea Sale Vic 29/10/91	Instruments, general wreckage reconstruction and analysis, controls, engines.	Lost control.
1992			
Pilatus PC9A A23-055	Albany airfield WA 21/3/92	Instruments for glass cockpit work	Engine shut down in circuit
Boeing F/A-18B A21-106	Cape Clinton Queensland 19/5/92	Site, Instruments, general wreckage analysis, controls, engines.	Controlled flight into terrain.
1993			
Bell Kiowa (OH-58) A17-044	Oakey Qld 3/3/93	Site. Structural and materials investigation of tail, tail boom and tail rotor drive shaft.	VStab hit ground.
Boeing F/A-18B A21-009	Near Williamtown NSW 13/7/93	Inspection of damage, trailing edge flap monoball baring examination.	Failure of outboard trailing edge flap hinge.
GD F111C A8-127	Guyra NSW 13/9/93	Reconstruction.	Controlled flight into terrain.

		Instruments, warning lights, fire damage, structural damage, windscreen and actuators.	
Boeing F/A-18B A21-022	Tindal NT. 22/11/93	Rear PTS bearing of AMAD gearbox	Bearing failed resulting in AMAD fire.
1994			
Bell Iroquois A2-085	Cape Crawford NT 9/6/94	Skids, struts.	Skid collapse, heavy landing.
Aerospatiale Squirrel AS350B A22-024	Canberra ACT	Tail damage structural and material investigation.	Heavy landing? (other aircraft with damage A22-020,010,008)
Ansett F50 (BASI)	Canberra ACT 1?/3/94	No. 3 bearing from P&W 125B engine	Bearing failed due to undersize ball
Boeing F/A-18B A21-53	Butterworth 13/10/94	Stabilator bolt, composite material.	Midair impact with RMAF F5E.
Macchi MB326H A7-038	Bulahdelah NSW 24/10/94	Wings and centre section.	Midair impact with A7-088
Macchi MB326H A7-088	Bulahdelah NSW 24/10/94	Wings and centre section.	Midair impact with A7-038
1995			
Hughes 296C VH-PKK (Schweizer AIRCRAFT)	Near Moorabbin Airport 14/2/95	Parts of failed tailboom support structure and rotor head.	Fatigue failure of left tailboom support strut cluster fitting attachment lugs.
Aerocommander 690A	Near Sydney Airport 14/1/94	Tail structure, instruments.	Controlled flight into terrain (water)
Macchi MB326H A7-079	Barrington tops 60NmNW of Williamtown	Fuel system components, Instrument.	Engine icing (99%)
1996			
Black Hawk A25-209	Townsville High Range fire station Barbera. QLD 12/6/96	Site inspection, tail and main rotor blades, engines, helmets, instruments etc.	Midair impact with A25-113
Black Hawk A25-113	Townsville High Range fire station Barbera. QLD 12/6/96	Site inspection, parts of failed tailboom support structure and tail and main rotor blades, engines, helmets, instruments etc.	Midair impact with A25-209
1997			
Bell 206L-3 VH-CKP	Tartus QLD 2/5/1997	Fixed and portable oxygen systems	Oxygen fire in fixed system
Ventura		Ventura Engine Magneto Switch Vibration Test	Engines failed on takeoff
Re-investigation of Mirage A3-040	East of Williamtown over the sea	Structural integrity of wings	Flew into sea
Aerospatiale Squirrel AS350B A22-007	Canberra ACT	Main rotor star flex. Tail boom	Ground resonance?
1998			
Aerospatiale Squirrel Tiger	Townsville High Range	Site inspection and wreckage mapping	Controlled flight into terrain
Boeing F/A-18 USMC	Delamere range NT 2010/98	Site inspection and wreckage mapping	Controlled flight into terrain

1999			
F-111G A8-291	Palau Aur, Malaysia, 18/04/99	Site inspection, wreckage mapping, detailed examination of wreckage	Controlled flight into terrain
2001			
Aerospatiale Squirrel AS350B N22-011	Wagga Wagga May 2001	Site inspection, tail failure investigation	Tail strike
RNZAF Skyhawk NZ 6211	Nowra, NSW	Laboratory examination of instruments, throttle quadrant, elevator booster package, fuel	Controlled flight into terrain, after attempting a plugged barrel roll
2002			
Kiowa A17-023	Clermont QLD, 06/06/2002	Site inspection, detailed examination of wreckage. Laboratory examination	Dynamic rollover
F-111C A08-112	Darwin, 26/06/2002	Aircraft inspection, laboratory investigation	Arcing of the No. 3 fuel pump loom led to ignition of the fuel-rich air mixture in the F2 fuel tank.
Army Kiowa A17-003	AAAC, Oakey, QLD, Oct 2002	Site inspection	heavy landing
RAN Sea King N16-125	HMAS Manoora	Part Engine examination	Engine failure, due to salt build-up
2003			
Ilyushin 76TD Euro Asia Aviation RDPL-34141 [14]	Baucau, East Timor, 31/01/03	Site inspection, wreckage mapping, detailed examination of wreckage	Controlled flight into terrain
Caribou A4-204	Yalumet PNG, 08/02/2003	Laboratory examination	
2004			
RAN Kalkara	Jervis Bay, NSW	Laboratory testing of parachute lanyards	Failure of “chinese fingers”
Black Hawk A25-216	Mt Walker QLD. 21/02/04	Site inspection and wreckage mapping	Controlled flight into terrain
USN F/A-18 VFMA-212	Tindal NT, 14/09/04	Site inspection and wreckage mapping	Hydraulic failure followed by double engine failure
2005			
PC9 A23-029	Sale, Vic	Site inspection and wreckage mapping. Wreckage reconstruction	Mid-air (with A23-039)
Sea King N16-100	Nias Indonesia	Site inspection, wreckage mapping, detailed examination of wreckage	Mechanical failure
RAN Kalkara	Jervis Bay	Examination of telemetry tapes	Unknown
USN bomb release	Delamere range NT, 10/08/05	Site inspection and wreckage mapping	Release of 500lb live bomb on Delamere control complex
2006			
Black Hawk A25-221	HMAS KANIMBLA Fiji	Wreckage, FDR, Simulation	Blade droop
2008			
Chinook A15-102	High Range Townsville June 2008	Flight reconstruction, wreckage examination	Heavy landing

C130H A97-008	Dirt strip near RAAF Richmond	Failure investigation of NLG Oleo	Fatigue failure from pre-existing flaw
Caribou A4-285	PNG	Site Inspection, Wreckage examination	Heavy landing
Canberra A84-231 'Magpie 91'	Operation MAGPIES Return. Vietnam 3/11/1970	Flight reconstruction to predict debris field, wreckage examination to confirm aircraft	Possible engine failure
2009			
Black Hawk A25-204	E. Timor 9 Feb 2009	Flight Reconstruction	Heavy landing
MRH-90 A40-011	Edinburgh	-	-
Caribou A04-199	High Range training Area Townsville, 25 Sept 2009	Site investigation	Missing HStab hinge bolts
2011			
PC-9 A23-039	E. Sale 18 May 2011	Engine, Pump, Flap Actuator, Props etc	Failed Engine High Pressure Fuel Pump
CH-47D A15-102	MEAO	Modelling, Animation, Weather, Clothing, Forensic investigation to determine sequence of events. Z51 lanyard testing	Pitch Oscillation leading to loss of control
CH47D A15-103	MEAO	Forensic investigation of failed aft LCTA, and FDR simulation	Fatigue
2012			
Black Hawk A25-106	Kakoda, PNG	Engine Output Shaft	Failure of Engine Output Shaft flexible coupling
2013			
Hawk A27-023	Pearce WA	Low Pressure Turbine Blades	Fatigue failure of LPT Blade
Kiowa A17-051	Brymaroo, QLD	Skids	Heavy landing leading to failure of skids