75 Years of Scientific Air Accident Investigation Support at the Bend

L. Molent and N. Athiniotis
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Aerospace Division

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The need for aeronautical science and technology 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, a forerunner to the current Defence Science and Technology Group (DST Group). 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 of DST Group to the present day.

This manuscript updates the paper presented at the International Society of Air Safety Investigators Seminar in 2014 which gave a brief history of 75 years of systematic scientific support to aircraft accident investigation at DST primarily at Fishermans Bend. The paper has been updated and more recent contributions to the field by DST have been included.

During these 75 years DST not only made significant contributions to the investigation into the causal factors behind many significant air accidents but also made significant innovative contributions to improvements in aviation safety, including the in-flight data recorder and the Tee Visual Approach Slope Indicator System (T-VASIS) international landing system. DST has a proud history in the support and enhancement of aviation safety and is now even better enabled to continue in this important role.

Dr Alex Zelinsky
Chief Defence Scientist
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” 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 intervening years has seen the establishment of internationally agreed delegations for the conduct of air accident and incident investigation (see ICAO Annex 13), the establishment of professional investigation bodies (e.g. the Australian Transport Safety Board) and the science and technology base to assist in what is still a complex and demanding endeavour. The Defence Science and Technology (DST) Group has contributed to innovations in flight safety and support to both Defence and civilian air safety investigations since its establishment in 1939 at the Bend in Port Melbourne Victoria.

The evolution of aircraft design has resulted in safer aviation; however the technical complexity of aircraft (particularly military) and performance continue to increase under pinning the constant need for science and technology to assist in the unlikely advent of an accident.

This book presents a brief history of 75 years of systematic scientific support to aircraft accident and incident investigation at DST.

Authors

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 250 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 DST’s Head of Emerging Aircraft Structural Integrity. In 2010 he was awarded with the Minister’s Award for Achievements in Defence Science. Mr Molent was recognised with an AM in the 2016 Queen’s Birthday honours.

Mr Athiniotis is Head of Aircraft Forensic Engineering and Accident Investigation. He commenced at DST 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.
INTRODUCTION

“In the 1920s, there was growing public disquiet at what was seen, likely, 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 Royal Australian Air Force (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 aircrrew 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 E.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, Victoria. The pilot, Sgt Orm Denny, walked 25 miles to secure assistance. This was too much for the newspapers. Bowing to pressure, the Royal Highnesses chose to use scratch foil recorders for flight data recording. The committee made a flying start by holding its first meeting at Victoria Barracks Melbourne on the 25 May”. 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 (CSIIR) in 1929 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 ARL1 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 (then) Defence Science and Technology Organisation at the Bend, now Defence Science and Technology (DST) Group.

DST 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.
4. Human factors and visual optics.

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]. 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 Royal Australian Air Force (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!

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 (BoI) 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 Warne 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.

1 From [1].
2 ARL has experienced several changes of name (Aeronautical Research Laboratory, Aeronautical and Maritime Research Laboratory (AMRL), the Defence Science and Technology Organisation (DSTO Melbourne) and currently Defence Science and Technology Group (DST Melbourne).
3 Throughout the years DST has received a number of commendations for its work in this area. Some include: a. Diploma 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 A84-25L.

Figure 1: David Warren with the prototype “black box” circa 2000 (Source DST)
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 International Civil Aviation Organization (ICAO) member nations.

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).

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 DST’s involvement in the accident investigation of two Australian Army Black hawk 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, DST 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) databases. 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]. An example of such a map is shown in Figure 3.

Visual Optics

The visual environment and achieved visual performance of aircrew can determine mission success or failure, particular so for military aviation. DST pioneered much applied research into visual displays, optical radiation hazards, visibility, transparency scatter, vision enhancement, helicopter separation judgement and visual landing aids [4].
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 [6].

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 [7].

Early Australian and DST-specific investigations up to 1992 (i.e. the first 50 years) were well described in [1]. In Table 1 a summary of significant DST accident/incident investigation activities up to July 2014 (i.e. 75 years since the inception of DST) 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.

### Black Hawk Mid-air

A mid-air accident between two Australian Army Black Hawk (see Figure 5) S70-A-9 helicopters occurred near Townsville, Queensland, in northern Australia, on 12 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) and considering their measured spread on the ground (e.g. Figure 6), the overlapping common areas was considered the most probable area of aircraft contact (see Figure 7). These two technical aspects were critical in postulating a credible scenario to explain the collision.

### Macchi Trainer

On 22 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 [8,9]. The cracking was found to have initiated from a machining detail in the base of a flange fastener hole, Figure 8. 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...
Figure 6: Debris trajectory analysis of cargo door parts from B1 and B2, indicating most likely location of impact.

Figure 7: 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).

Figure 8: 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) 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 [10]). 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.

Royal Australian Navy Sea King Accident, 2005 Nias Indonesia

On 2 April 2005, RAN Sea King (see Figure 9) 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. DST 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 DST specialist team, and presentation of evidence at the BoI [11,12,13].

The rotating machinery on a helicopter makes sounds at various frequencies. DST 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 (see Figure 10). 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 DST 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 recovering 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 task to act as a prompt for the necessary associated maintenance and inspections. It was 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.

**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.

DST 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, DST 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 DST Air Operations Simulation Centre (see Figure 11), 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.

DST forensically examined the aircraft wreckage following its recovery, however did not identify anything that may have contributed to the accident. DST 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 DST 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.

**Locating Missing RAAF Canberra Aircraft from Vietnam, 1970**

On the night of 3 November 1970, a RAAF Canberra aircraft (see Figure 12), 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.

DST presented its evidence alongside DDAAFS at the subsequent BoI. The BoI determined that “The principal and overarching finding of the BoI 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 10: Sea King Accident Site, and disconnected fore/aft bellcrank (below)**

**Figure 11: Black Hawk impact on HMAS Kanimbla, and DST Simulator with ‘roll-in’ Black Hawk cockpit**

**Figure 12: Canberra bomber**
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”. DST’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.

DST 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 DST since this date; as well a few foreign military aircraft incidents and accidents. This includes both fixed wing aircraft and rotary wing aircraft. The DST 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 DST reconstruction provided a refined area of interest for the Principal Investigator (see Figure 13), which assisted in discovery of an aircraft. DST forensic examination of items recovered from the wreckage site confirmed that this aircraft was the missing RAAF Canberra and its crew.

**Chinook**

On May 30 2011 an Australian CH-47D Chinook (see Figure 14) was involved in an accident, which occurred in Afghanistan while assisting with the recovery of a downed US Army Blackhawk. The accident resulted in the loss of the aircraft and the death of one passenger (see Figure 15 and 16). Immediately prior to the accident the aircraft crossed a sharp ridgeline at around 1500ft above ground level (AGL). A sharp nose up pitch excursion was experienced followed by a series of pitch oscillations. Pitch attitudes were reported to have reached 60-80° nose up and 120° nose down (inverted) in the fourth oscillation. During the fourth oscillation the pilot applied large longitudinal cyclic inputs and the aircraft was returned to a level attitude at around soft AGL but with insufficient rotor energy to maintain a hover. Subsequently, the aircraft contacted the ground, rolled over and caught fire. The aircraft was later destroyed for tactical reasons before the FDR could be recovered. Three further incidents of pitch oscillations were encountered by Australian CH-47D aircraft during operations in Afghanistan over a three month period following the accident, and flight and operational data was recovered for each of these.

DST examined the FDR data from each of the incidents, and developed a flight control simulation model to estimate the performance of the Advanced Flight Control System (AFCS) during the oscillations. This indicated that saturation of the longitudinal AFCS was likely to have been the primary cause for the oscillations experienced during the incidents as well as the accident [18]. Subsequently, verification work was undertaken by a combined DST, DDAAFS and Aircraft Research and Development Unit (ARDU) team at the Boeing Helicopters Simulator (BHSIM) in Philadelphia, in which the conditions of the accident were able to be reproduced. This allowed a comprehensive set of recovery procedures to be developed, which were subsequently incorporated into the ADF CH-47D Flight Manual. Following the simulation work undertaken in the Boeing simulator, Boeing released a service note to all CH-47D operators worldwide informing them of the issue.

DST presented its evidence at the subsequent Commission of Inquiry (Col), covering CH-47D flight characteristics/flight control system analysis identifying the cause of the oscillations experienced in the accident, forensic analysis of life support equipment worn by the deceased passenger, and details of meteorological hindcasts of weather conditions in Afghanistan at the time of the accident. The Col determined that the method utilised by aircrew “for controlling pitch oscillations on CH-47D aircraft was incorrect and a causal factor in the CH-47D aircraft A15-102 call sign “Brahman 12” crashing in Afghanistan on 30 May 2011. As a consequence of following such method the Aircraft Captain did not take control of the aircraft prior to the aircraft exceeding its flight limits”. DST subsequently collaborated with the Australian Army to provide aircrew with detailed explanations of the flight characteristics associated with AFCS saturation, and produced a comprehensive training document to improve pilots’ awareness of the more advanced concepts associated with tandem rotorcraft operation.

DST Group support to the MH370 search

On 7 March 2014, flight MH370 (a Boeing 777 registration 9M-MRO) lost contact with Air Traffic Control during a transition between Malaysian and Vietnamese airspace. Subsequent analysis of radar data and satellite communication system signalling messages placed the aircraft in the Australian search and rescue zone on an arc in the southern part of the Indian Ocean. On 17 March 2014, the Australian Transport Safety Bureau (ATSB) took charge of the search and rescue operation and over the following six weeks an intensive aerial and surface search was conducted by an international team. The DST contribution was led by Neil Gordon of National Security and ISR Division.

At the start of the search there was a time critical requirement to search for floating debris and acoustic transmissions from the battery-powered...
underwater locator beacon (ULB) attached to the aircraft’s “black box” flight recorder before the battery expired. The Australian Geospatial Intelligence Organisation (AGO) assisted with the debris search at this stage, scanning imagery of approximately 850,000 square kilometres of the ocean. The Australian Defence Vessel (ADV) Ocean Shield, with the aid of the United States Navy (USN), deployed a towed pinger locator (TPL) in an effort to detect acoustic transmissions from the ULB and quickly produced a number of possible underwater acoustic detections. However, overnight analysis by DST Group very quickly revealed these to be spurious detections. At the same time the RAAF dropped in excess of 1,400 sonobuoys in the TPL search area in an effort to detect the ULB before its battery expired. Subsequent analysis by DST quickly showed that, due to the depth of the ocean, there was minimal probability of any of the 1,400 sonobuoys being able to detect underwater locator beacon acoustic transmissions. DST were also asked by the Australian Transport Safety Bureau (ATSB) to independently analyse potential underwater acoustic detections of the 9M-MRO impact with the ocean by the Comprehensive Nuclear Test Ban Treaty Organization (CTBTO) undersea acoustic array located at Cape Leeuwin, south of Perth, and were again able to rapidly determine that the signals were extremely unlikely to have originated from 9M-MRO.

With the debris and ULB searches being unsuccessful, attention turned to information from Inmarsat related to the satellite communication system on-board 9M-MRO. Satellite communication systems rely on transmissions between a ground station (Inmarsat ground station located in Perth, WA), a satellite (Inmarsat Indian Ocean Region) and a mobile terminal (in this case 9M-MRO). It was noticed that for the last approximately 6 hours of flight, the satellite communication system on 9M-MRO had been automatically responding to hourly ground station initiated log-on confirmation messages (or handshakes). No explicit information relating to the aircraft location is contained in the messaging. The data available with each handshake message is limited to a measure of the range between the satellite and the aircraft and a frequency offset. The frequency offset gives a broad indication of allowable values of aircraft speed and heading at the time of the handshake. In addition to the hourly handshake measurements there are also frequency measurements associated with two unanswered satellite telephone calls initiated by Air Traffic Control to 9M-MRO. The first of these turned out to be critical in determining that 9M-MRO turned south after the final military radar detection.

ATSB convened a search strategy working group bringing together experts in satellite communication systems and statistical data processing from the following organisations: Air Accident Investigation Branch (UK), Boeing (US), Inmarsat (UK), National Transport Safety Board (US) and Thales (UK). DST was invited to join the working group and contribute expert analysis and advice in satellite communication systems, target tracking and sensor data fusion for trajectory prediction. The task for predicting the 9M-MRO flight path was to re-process and calibrate the communication system transmissions in such a way as to infer plausible aircraft locations at the time of the final satellite handshake. DST and CSIRO analysis is that this one piece of debris could not significantly refine the search zone derived from the Inmarsat data. However it does increase our confidence that the flight path analysis underpinning the search zone area is not wrong.

At the time of writing, the search had covered an area of about 67,000 km² which contained approximately 50% of the probability content of the search probability distribution. The search is on-going.

The novel Bayesian numerical procedures developed by DST [18] to more accurately define the search zone are summarised below (see Figure 17). The Bayesian prediction method developed by DST has been validated against a number of earlier flights of the accident aircraft 9M-MRO. Inmarsat data logs and accurate measurements of the actual aircraft location are available for these validation flights from the aircraft’s logging system and give good agreement with the predicted probability distribution in each case.

On 29 July 2015 a wing control surface known as a flaperon was recovered from Reunion Island which was later confirmed as being debris from 9M-MRO. The debris and ULB searches being unsuccessful, attention turned to information from Inmarsat related to the satellite communication system on-board 9M-MRO. Satellite communication systems rely on transmissions between a ground station (Inmarsat ground station located in Perth, WA), a satellite (Inmarsat Indian Ocean Region) and a mobile terminal (in this case 9M-MRO). It was noticed that for the last approximately 6 hours of flight, the satellite communication system on 9M-MRO had been automatically responding to hourly ground station initiated log-on confirmation messages (or handshakes). No explicit information relating to the aircraft location is contained in the messaging. The data available with each handshake message is limited to a measure of the range between the satellite and the aircraft and a frequency offset. The frequency offset gives a broad indication of allowable values of aircraft speed and heading at the time of the handshake. In addition to the hourly handshake measurements there are also frequency measurements associated with two unanswered satellite telephone calls initiated by Air Traffic Control to 9M-MRO. The first of these turned out to be critical in determining that 9M-MRO turned south after the final military radar detection.

ATSB convened a search strategy working group bringing together experts in satellite communication systems and statistical data processing from the following organisations: Air Accident Investigation Branch (UK), Boeing (US), Inmarsat (UK), National Transport Safety Board (US) and Thales (UK). DST was invited to join the working group and contribute expert analysis and advice in satellite communication systems, target tracking and sensor data fusion for trajectory prediction. The task for predicting the 9M-MRO flight path was to re-process and calibrate the communication system transmissions in such a way as to infer plausible aircraft locations at the time of the final satellite handshake. DST and CSIRO analysis is that this one piece of debris could not significantly refine the search zone derived from the Inmarsat data. However it does increase our confidence that the flight path analysis underpinning the search zone area is not wrong.

At the time of writing, the search had covered an area of about 67,000 km² which contained approximately 50% of the probability content of the search probability distribution. The search is on-going. The novel Bayesian numerical procedures developed by DST [18] to more accurately define the search zone are summarised below (see Figure 17). The Bayesian prediction method developed by DST has been validated against a number of earlier flights of the accident aircraft 9M-MRO. Inmarsat data logs and accurate measurements of the actual aircraft location are available for these validation flights from the aircraft’s logging system and give good agreement with the predicted probability distribution in each case.

On 29 July 2015 a wing control surface known as a flaperon was recovered from Reunion Island which was later confirmed as being debris from 9M-MRO. CSIRO used data from un-drogued Global Drifter Program [19] drifting buoys (drifters) to generate a probability distribution of the crash site based on the debris find, which was incorporated into the search distribution by DST. The result of the DST and CSIRO analysis is that this one piece of debris could not significantly refine the search zone derived from the Inmarsat data. However it does increase our confidence that the flight path analysis underpinning the search zone area is not wrong. At the time of writing, the search had covered an area of about 67,000 km² which contained approximately 50% of the probability content of the search probability distribution. The search is on-going.
Assisting the Australian Federal Police in investigating the MH17 disaster

DST contributed to a whole-of-government response supporting the investigation and recovery operations following the destruction of Malaysian Airlines aircraft flight MH17 in a conflict zone over Ukraine on 17 July 2014.

The passenger list released by Malaysian Airlines on 20 July identified 38 Australian citizens and residents on board the plane. It is suspected that the plane was brought down by a surface-to-air missile.

The Australian Government dispatched a team of Australian Federal Police (AFP) investigators and forensics experts to help identify and repatriate the remains of the passengers and to conduct an investigation into what was responsible for bringing down the aircraft. DST scientists were included in the team that remained in Australia to assist the AFP in its accident investigation.

In support of the resulting international investigation, led by the Netherlands authorities, the AFP sought further input from DST [19].

The DST 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.

Over many years, the DST has developed a deep level of expertise and experience across a broad range of unique and world class sovereign capabilities, delivering science excellence and outcomes for Australia’s defence and national security. It is these multi-disciplinary capabilities that are drawn upon to provide the high level scientific contribution necessary in order to fully understanding the causes of air accidents, and to preventing similar accidents in the future. Further details of some of the investigations highlighted in this book and the people involved can be obtained from the references cited.

The authors wish to acknowledge the outstanding contributions of the many staff within the DST and other Defence Groups (past and present) who have demonstrated expertise, leadership and commitment in support and advice towards air investigations. Their contributions have been instrumental towards a safer air defence community.

The authors would also wish to acknowledge the aircrew and passengers who have lost their lives serving their country and the international community.
REFERENCES


Table 1: Summary of DST Accident and Incident Support 1981-2014

<table>
<thead>
<tr>
<th>AIRCRAFT TYPE, SNO.</th>
<th>PLACE AND DATE</th>
<th>DST INVESTIGATION</th>
<th>CAUSE</th>
</tr>
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<tbody>
<tr>
<td><strong>1981</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bell UH-1B A2-380</td>
<td>30/10/1981</td>
<td>Tail rotor drive shaft coupling bolts</td>
<td>Tail rotor drive shaft coupling bolts appear to have failed in flight due to incorrect heat treatment</td>
</tr>
<tr>
<td>Bell UH-1B A2-380</td>
<td>Williamtown NSW 19/08/1981</td>
<td>Tail rotor drive shaft, 45 degree gearbox, pitch control cables, mast, warning lights, tail rotor pitch quadrant, fin</td>
<td>Pitch control cable pick up and tail rotor loss. Terminal mast bump</td>
</tr>
<tr>
<td><strong>1983</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wessex N7-215 [1]</td>
<td>Into sea Ninety Beach Vic 04/12/1983</td>
<td>Main gearbox components</td>
<td>Fatigue failure of input pinion</td>
</tr>
<tr>
<td>Pilatus Porter A14-702</td>
<td>Point Cook RAAF Base Vic 07/12/1983</td>
<td>Pilots seat, warning lights</td>
<td>Controlled flight into terrain</td>
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<tr>
<td><strong>1984</strong></td>
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<tr>
<td>Lockheed Orion P3B AP-300</td>
<td>Edinburgh SA 29/03/1984</td>
<td>Oxygen system components</td>
<td>Oxygen assisted fire</td>
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<tr>
<td><strong>1985</strong></td>
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</tr>
<tr>
<td>Macchi MB326H A7-085</td>
<td>Williamtown 19/08/1985</td>
<td>Control system components</td>
<td>Inflight fire</td>
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<tr>
<td><strong>1986</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Macchi MB326H A7-085</td>
<td>Williamtown 19/08/1985</td>
<td>Control system components</td>
<td>Inflight fire</td>
</tr>
<tr>
<td>Bell 206</td>
<td>Into sea NT 14/04/1986</td>
<td>Main and auxiliary gearbox components, engine exhaust</td>
<td>Fuel Problem</td>
</tr>
<tr>
<td>Cessna 202 Air Ambulance</td>
<td>Essendon Airport 3/9/1986</td>
<td>Left propeller fine pitch lock, right fuel pump and connection to Air Thrust body</td>
<td>Power loss</td>
</tr>
<tr>
<td><strong>1987</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>General Dynamics F111 A8-128</td>
<td>Armadale NSW 2/04/1987</td>
<td>Instruments and warning lights</td>
<td>Controlled flight into terrain</td>
</tr>
<tr>
<td>Wessex helicopter RAN</td>
<td>Botany Bay NSW 26/05/1987</td>
<td>Compressor blades</td>
<td>Engine failure</td>
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<tr>
<td>Boeing F/A-18B A21-104</td>
<td>Great Palm Island Northern Qld 18/11/1987</td>
<td>Stand by instruments and the chest mounted oxygen regulator</td>
<td>Controlled flight into terrain</td>
</tr>
<tr>
<td>AIRCRAFT TYPE, SNO.</td>
<td>PLACE AND DATE</td>
<td>DST INVESTIGATION</td>
<td>CAUSE</td>
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<tr>
<td>Macchi MB326H A7-033</td>
<td>Pearce WA 01/02/1988</td>
<td>STBD brake housing</td>
<td>Ran off runway</td>
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<tr>
<td>Winjeel A85-458</td>
<td>Mt Seaview NSW 24/02/1988</td>
<td>Instruments</td>
<td>Controlled flight into terrain</td>
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<tr>
<td>Macchi MB326H A7-056</td>
<td>Sale Vic 10/03/1988</td>
<td>Speed brake actuator</td>
<td>Mid-air collision</td>
</tr>
<tr>
<td>Macchi MB326H A7-038</td>
<td>Sale Vic 10/03/1988</td>
<td>Control rods</td>
<td>Mid-air collision</td>
</tr>
<tr>
<td>Winjeel A85-409</td>
<td>Williamtown NSW 05/04/1988</td>
<td>Instruments</td>
<td>Stall</td>
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<tr>
<td>Macchi MB326H A7-030</td>
<td>Pearce WA 05/04/1988</td>
<td>Fuel shutoff valve, instruments, warning lights, fuel filters</td>
<td>Fuel Problem</td>
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</table>

<table>
<thead>
<tr>
<th>AIRCRAFT TYPE, SNO.</th>
<th>PLACE AND DATE</th>
<th>DST INVESTIGATION</th>
<th>CAUSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boeing F/A-18B A21-106</td>
<td>Cape Clinton Queensland 19/05/1992</td>
<td>Site, instruments, general wreckage analysis, controls, engines flight reconstruction</td>
<td>Controlled flight into terrain</td>
</tr>
<tr>
<td>Bell Kiowa (OH-55) A17-044</td>
<td>Oakley Qld 03/03/1993</td>
<td>Site: Structural and materials investigation of tail, tail boom and tail rotor drive shaft</td>
<td>Vertical stabilizer hit ground</td>
</tr>
<tr>
<td>Boing F/A-18B A21-009</td>
<td>Near Williamtown NSW 13/07/1993</td>
<td>Inspection of damage, trailing edge flap monoball bearing examination</td>
<td>Failure of outboard trailing edge flap hinge</td>
</tr>
<tr>
<td>GD F111C A8-127</td>
<td>Gujra NSW 13/09/1993</td>
<td>Reconstruction. Instruments, warning lights, fire damage, structural damage, windscreen and actuators</td>
<td>Controlled flight into terrain</td>
</tr>
<tr>
<td>Boeing F/A-18B A21-022</td>
<td>Tindal NT 22/11/1993</td>
<td>Rear PTs bearing of AMAD gearbox</td>
<td>Bearing failed resulting in AMAD fire</td>
</tr>
<tr>
<td>Bell Iroquois A2-085</td>
<td>Cape Crawford NT 09/06/1994</td>
<td>Skids, struts</td>
<td>Skid collapse, heavy landing</td>
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<tr>
<td>Aerospatiale Squirrel A335OB A22-02A</td>
<td>Canberra ACT</td>
<td>Tail damage structural and material investigation</td>
<td>Heavy landing (other aircraft with damage A22-020,010,008)</td>
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<tr>
<td>Ansett F50 (BASI)</td>
<td>Canberra ACT 01/03/1994</td>
<td>No. 3 bearing from P&amp;W 125B engine</td>
<td>Bearing failed due to undersize ball</td>
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<tr>
<td>Boeing F/A-18B A21-53</td>
<td>Butterworth 13/10/1994</td>
<td>Stabilator bolt, composite material</td>
<td>Midair impact with RMAF F5E</td>
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<tr>
<td>Macchi MB326H A7-038</td>
<td>Bulahdelah NSW 24/10/1994</td>
<td>Wings and centre section</td>
<td>Midair impact with A7-088</td>
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<tr>
<td>Macchi MB326H A7-088</td>
<td>Bulahdelah NSW 24/10/1994</td>
<td>Wings and centre section</td>
<td>Midair impact with A7-038</td>
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<tr>
<td>Hughes 296C VH-PKX (Schweizer AIRCRAFT)</td>
<td>Near Moorabbin Airport 16/02/1995</td>
<td>Parts of failed tailboom support structure and rotor head</td>
<td>Failure of left tailboom support strut cluster fitting attachment lugs</td>
</tr>
<tr>
<td>Aerocommander 690A</td>
<td>Near Sydney Airport 14/02/1995</td>
<td>Tail structure, instruments</td>
<td>Controlled flight into terrain (water)</td>
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<tr>
<td>Macchi MB326H A7-079</td>
<td>Barrington Tops GO Nm NW of Williamtown</td>
<td>Fuel system components, Instrument</td>
<td>Engine icing</td>
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<tr>
<td>AIRCRAFT TYPE, SNO.</td>
<td>PLACE AND DATE</td>
<td>DST INVESTIGATION</td>
<td>CAUSE</td>
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<td>1996</td>
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<tr>
<td>Black Hawk A25-209</td>
<td>Townsville High Range fire station Barbara Qld 12/06/1996</td>
<td>Site inspection, tail and main rotor blades, engines, helmets, instruments etc.</td>
<td>Midair impact with A25-113</td>
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<tr>
<td>Black Hawk A25-113</td>
<td>Townsville High Range fire station Barbara Qld 16/06/1996</td>
<td>Site inspection, parts of failed tailboom support structure and tail and main rotor blades, engines, helmets, instruments etc.</td>
<td>Midair impact with A25-209</td>
</tr>
<tr>
<td>Bell 206L-3 VH-CKP</td>
<td>Tartus Qld 02/5/1997</td>
<td>Fixed and portable oxygen systems</td>
<td>Oxygen fire in fixed system</td>
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<tr>
<td>Lockheed Ventura VH-VFF RAAF Richmond 11/05/1996</td>
<td>Ventura Engine Magneto Switch Vibration Test</td>
<td>Engines failed on takeoff</td>
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<tr>
<td>Re-investigations of Mirage A3-040</td>
<td>East of Williamtown over the sea</td>
<td>Structural integrity of wings</td>
<td>Lost at sea</td>
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<td>Aerospatiale Squirrel AS350B A22-007</td>
<td>Canberra ACT</td>
<td>Main rotor star flex. Tail boom</td>
<td>Ground resonance</td>
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<tr>
<td>Aerospatiale Tiger</td>
<td>Townsville High Range</td>
<td>Site inspection and wreckage mapping</td>
<td>Controlled flight into terrain</td>
</tr>
<tr>
<td>Boeing FA-18 USMC Delamere range NT</td>
<td>Site inspection and wreckage mapping</td>
<td>Controlled flight into terrain</td>
<td></td>
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<tr>
<td>1998</td>
<td></td>
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<tr>
<td>F-111G A8-291</td>
<td>Palau Aur Malaysia 18/04/1999</td>
<td>Site inspection, wreckage mapping, detailed examination of wreckage</td>
<td>Controlled flight into terrain</td>
</tr>
<tr>
<td>1999</td>
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<tr>
<td>Aerospatiale Squirrel AS350B N22-021</td>
<td>Wagga Wagga 05/2001</td>
<td>Site inspection, tail failure investigation</td>
<td>Tail strike</td>
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<tr>
<td>RNZAF Skyhawk NZ 6211 Novara, NSW 17/02/2001</td>
<td>Laboratory examination of instruments, throttle quadrant, elevator booster package, fuel</td>
<td>Controlled flight into terrain, after attempting a plugged barrel roll</td>
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<td>2001</td>
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<td>Kiowa A17-023</td>
<td>Clermont QLD 06/05/2002</td>
<td>Site inspection, detailed examination of wreckage, laboratory examination</td>
<td>Dynamic rollover</td>
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<tr>
<td>F-111C A08-112</td>
<td>Darwin 26/06/2002</td>
<td>Aircraft inspection, laboratory investigation</td>
<td>Arcing of the No. 3 fuel pump line led to ignition of the fuel rich air mixture in the F2 fuel tank</td>
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<tr>
<td>Army Kiowa A17-003</td>
<td>AAAC Oakey Qld 10/2002</td>
<td>Site inspection</td>
<td>Heavy landing</td>
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<tr>
<td>RAN Sea King N16-125</td>
<td>HMAS Manoora</td>
<td>Part Engine examination</td>
<td>Engine failure, due to salt build-up</td>
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<tr>
<td>2002</td>
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<td></td>
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<tr>
<td>Chinoos A15-102</td>
<td>High Range Townsville 06/2008</td>
<td>Flight reconstruction, wreckage examination</td>
<td>Heavy landing</td>
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<tr>
<td>C300H A97-008</td>
<td>East of Williamtown</td>
<td>Flight reconstruction, wreckage examination</td>
<td>Fatigue failure from pre-existing flaw</td>
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<tr>
<td>Caribou A4-285</td>
<td>Melbourne</td>
<td>Site, Wreckage examination</td>
<td>Heavy landing</td>
</tr>
<tr>
<td>Canberra A8-231</td>
<td>Operation MAGPIES 03/11/1970</td>
<td>Flight reconstruction to confirm aircraft</td>
<td>Possible engine failure</td>
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<td>2003</td>
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<tr>
<td>Caribou A4-204</td>
<td>Yalumet PNG 08/02/2003</td>
<td>Laboratory examination</td>
<td>Failure of nose wheel steering components due to severe overload</td>
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<td>Bell 206L-3 VH-CKP</td>
<td>Tartus Qld 02/5/1997</td>
<td>Fixed and portable oxygen systems</td>
<td>Oxygen fire in fixed system</td>
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<td>RAN Kalkara</td>
<td>Jervis Bay NSW</td>
<td>Laboratory testing of parachute lanyards</td>
<td>Failure of &quot;chinese fingers&quot;</td>
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<td>Black Hawk A25-216</td>
<td>Mt Walker Qld 23/02/2004</td>
<td>Site inspection and wreckage mapping</td>
<td>Controlled flight into terrain</td>
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<tr>
<td>USN F/A-18 VFMA-212</td>
<td>Tindal NT 14/09/2004</td>
<td>Site inspection and wreckage mapping</td>
<td>Hydraulic failure followed by double engine failure</td>
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<tr>
<td>Sea King N16-100</td>
<td>Nias Indonesia</td>
<td>Site inspection, wreckage mapping, detailed examination of wreckage</td>
<td>Control system failure</td>
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<tr>
<td>RAN Kalkara</td>
<td>Jervis Bay</td>
<td>Examination of telemetry tapes</td>
<td>Unknown</td>
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<td>USN F/A-18 bomb release</td>
<td>Delamere range NT 10/08/2005</td>
<td>Site inspection and wreckage mapping</td>
<td>Release of 500lb live bomb near Delamere control complex</td>
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<td>2005</td>
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<td>Black Hawk A25-221</td>
<td>HMAS KANIIMBLA Fiji</td>
<td>Wreckage, FDR, Simulation</td>
<td>Blade droop</td>
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<td>2006</td>
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<td>2007</td>
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<td>Caribou A4-285</td>
<td>East of Williamtown</td>
<td>Site, Wreckage examination</td>
<td>Heavy landing</td>
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<td>Caribou A4-231</td>
<td>Operation MAGPIES 03/11/1970</td>
<td>Flight reconstruction to confirm aircraft</td>
<td>Possible engine failure</td>
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<td>2009</td>
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<tr>
<td>Black Hawk A25-204</td>
<td>E. Timor 09/02/2009</td>
<td>Flight Reconstruction</td>
<td>Heavy landing</td>
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<tr>
<td>Caribou A4-199</td>
<td>High Range training Area Townsville 25/09/2009</td>
<td>Site investigation</td>
<td>Missing HStab hinge bolts</td>
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<td>AIRCRAFT TYPE, SNO.</td>
<td>PLACE AND DATE</td>
<td>DST INVESTIGATION</td>
<td>CAUSE</td>
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<tr>
<td><strong>2010</strong></td>
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<td>MRH-90 A40-011</td>
<td>Edinburgh</td>
<td>Forensic investigation of failed No. 1 Engine</td>
<td>Fatigue cracking of engine compressor blades</td>
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<tr>
<td><strong>2011</strong></td>
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<tr>
<td>PC-9 A23-039</td>
<td>E. Sale 18/05/2011</td>
<td>Wreckage examination including engine, fuel system, flap actuator, propeller system and cockpit instruments</td>
<td>Failed Engine High Pressure Fuel Pump</td>
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<tr>
<td>CH-47D A15-102</td>
<td>MEAO</td>
<td>Modelling, Animation, Weather, Clothing, Forensic investigation to determine sequence of events. Air Warrior Aircrew Ensemble lanyard testing</td>
<td>Pitch Oscillation leading to loss of control</td>
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<tr>
<td>CH47D A15-103</td>
<td>MEAO</td>
<td>Forensic investigation of failed aft Longitudinal Cyclic Trim Actuator, and FDR simulation</td>
<td>Fatigue</td>
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<td><strong>2012</strong></td>
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<td>Black Hawk A25-106</td>
<td>Kakoda, PNG</td>
<td>Engine Output Shaft</td>
<td>Failure of Engine Output Shaft flexible coupling</td>
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<tr>
<td><strong>2013</strong></td>
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<tr>
<td>Hawk A27-023</td>
<td>Pearce WA</td>
<td>Low Pressure Turbine (LPT) Blades</td>
<td>Fatigue failure of LPT Blade</td>
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<td>Kiowa A17-051</td>
<td>Brymaroo, QLD</td>
<td>Skids</td>
<td>Heavy landing leading to failure of skids</td>
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<td><strong>2014</strong></td>
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<tr>
<td>MH370</td>
<td>Indian Ocean</td>
<td>Defined search area</td>
<td>Ongoing</td>
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<tr>
<td>MH17</td>
<td>Ukraine</td>
<td>Support to government investigation</td>
<td>Likely surface to air missile</td>
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