DFSB
DEFENCE FLIGHT SAFETY BUREAU

SPECIAL EDITION: THE HOW AND WHY

SUMMARISING OUR RECENT INVESTIGATIONS

02 2021 EDITION

Spotlight

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FOREWORD

WELCOME TO *Spotlight* 02/2021. In this edition we take an in-depth look at some of the key investigations that DFSB has conducted in the previous two years.

In creating this *Spotlight* we've made every attempt to 'decode' some of the specialised aviation language and acronyms that are often very specific to a particular aircraft or operation so that a reader with limited knowledge can benefit and learn from these case studies. The key point behind our efforts is my view that every one of these events can occur in the range of scenarios and operations in which we operate within a complex system of systems.

Many of them have common themes:

- supervision
- human factors
- decision-making
- communication
- stress and
- the use and maintenance of complex systems within complex environments.

It is these common themes that the reader should seek to identify as they read on.

It is absolutely also worth pointing out that in all these cases, we have been most fortunate that we have not lost human lives. Aircraft have sometimes been damaged but economically repairable. Because we're in this privileged circumstance, we're able to openly and objectively discuss these events and learn from them. The question you might ponder is to whether we were just lucky or are we doing something within our Aviation Safety Management System that is worth fighting hard to retain? In your contemplation of the answer have a think about our commitment to safety, culture, hazard identification, risk management and the reporting culture that we have within ADF aviation.

Please enjoy reading this edition of *Spotlight*.

Regards,

GPCAPT Dennis Tan
Director DFSB

ROYAL AERONAUTICAL SOCIETY
AUSTRALIAN DIVISION

Dr Rob Lee Defence Flight Safety Award

This award recognises individual or collective efforts that have enhanced Defence flight safety. Nominations for the RAeS Flight Safety Award are open to all members of Defence aviation, including foreign exchange and loan personnel, Defence civilians and contractors.

The award covers a broad range of flight-safety initiatives, from a single act that prevented or could conceivably have prevented an aircraft accident or incident to implementation of long-term aviation safety initiatives and programs.

For details on the nomination process for the 2021 award please visit the DFSB Intranet site.

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A B300 Kingair aircraft conducting a routine task pitched nose-down, dropping 1700 ft within a four-second increment. The Aviation Safety Investigation Team (ASIT) determined rate of descent to be between 5100 and 25,000 ft per minute. **PAGE 50**

Hawk physiological episodes

A DEFENCE FLIGHT SAFETY Bureau (DFSB) Aviation Safety Investigation Team (ASIT) was formed on 25 January 2019 to investigate two separate oxygen flow events that occurred in a Hawk. Both events were experienced by the same pilot, while conducting similar missions (two-ship transit), in the same airframe, on consecutive days. The flights were terminated by the event pilot declaring an emergency (PAN for the first flight and MAYDAY for the second flight) before diverting into Kalgoorlie airport, the nearest suitable aviation facility.

Background

As part of the Hawk LIF fleet maintenance management plan, Hawk aircraft are frequently flown between RAAF Pearce and RAAF Williamtown. This movement of aircraft is conducted when required (operational/engineering considerations) to manage the distribution of the Hawk fleet.

The navigational routes taken by these transit flights are generally dictated by weather and the ability of airports en-route to facilitate Hawk operations. Hawk transit flights regularly utilise graduated Introductory Fighter Course (IFC) students, who are holding-over.[1] For the event flights, the occurrence aircraft was scheduled to be flown by a solo QFI with two hold-over pilots flying in the second aircraft of the formation.[2]

First event

On 23 January 2019, the occurrence aircraft was lead in a two-Hawk formation – call signs[3] Hawk 1 and Hawk 2 – conducting a transit flight from RAAF Pearce to RAAF Williamtown, via Ayers Rock Airport.

About 45 minutes into the flight, to the north-east of Kalgoorlie at Flight Level 330 (FL330), Hawk 1 experienced a restriction in the aircraft's oxygen flow, which the pilot described as "a feeling of the oxygen hose tightening". Concurrently, a Central Warning Panel (CWP) amber caption Back-up Oxygen (BUOXY) illuminated. Immediate Actions (IAs) from the Hawk's checklist (FCC) were initiated by the pilot, followed by a short period of fault finding. During this period, the onboard oxygen generation system (OBOGS) system reset automatically.[4]

After successfully dealing with the OBOGS malfunction, Hawk 1, as the formation leader, aborted the planned leg to Ayers Rock Airport and instigated a diversion to Kalgoorlie.

Hawk 1 informed Hawk 2 of an intermittent OBOGS failure and of the intent to divert into Kalgoorlie. Hawk 1 also informed Melbourne Centre ATC of the change of flight plan and requested a turn and descent into Kalgoorlie. During the turn, Hawk 2 fell to appoimately six miles astern, leaving Hawk 1 to manage the malfunction, the diversion, ATC and Hawk 2.[5]

As a consequence of the increased workload, Hawk 1 declared a PAN to expedite the recovery into Kalgoorlie.[6]

During the diversion into Kalgoorlie, Hawk 2 remained long-line astern, providing no assistance to Hawk 1. The formation landed safely at Kalgoorlie-Boulder Airport without any additional issues. [7]

After shutdown at Kalgoorlie, the crew debriefed the transit leg, inflight emergency and subsequent diversion. The pilot-in-command

(PIC) of Hawk 2 was debriefed as to what was expected of a wingman including basic formation keeping, support to an aircraft with inflight failures, and assistance during a diversion. The formation lead then telephoned the squadron to inform the duty supervisor[8] of the events that led to the diversion into Kalgoorlie.

Due to the nature of the malfunction, the potential for a physiological episode was discussed during the telephone call but was dismissed as the event pilot said they had not suffered any hypoxia-like symptoms.

A telephone authorisation brief was conducted for the formation to return to RAAF Pearce. During the brief, normal sortie considerations were covered, but specifically the flight was not to transit above a cabin altitude of 10,000 ft Pressure Altitude (PA). This plan was to mitigate for a re-occurrence of any oxygen malfunction in Hawk 1.

The squadron commanding officer was also advised of the diversion events into Kalgoorlie and the plan to return the formation to RAAF Pearce, and concurred with the plan.

The return flight from Kalgoorlie was uneventful, with the formation landing at RAAF Pearce at about 1300 on 23 January 2019.[9] The aircraft was released to maintenance on Computer Aided Maintenance Management 2 (CAMM2), including a verbal debrief by the event pilot to the maintenance staff.

It was agreed that the flight lead would be informed of the aircraft's serviceability by mobile phone – specifically whether it would be serviceable for a planned repeat of the sortie the following day . Maintenance staff found a fault with the front-seat oxygen regulator. This was replaced and recorded in CAMM2. The flight lead was informed of the fault and the rectification actions. Thereafter, the aircraft was made serviceable for the planned departure on 24 January.

Second-event flight

The pre-flight brief for the second-event flight was conducted on the morning of 24 January and covered weather, the departure, transit and emergencies. Hawk 2's crew constitution changed for the second flight, with the first flight's second pilot now authorised as the PIC. When accepting the aircraft at the flightline, Hawk 1 was briefed on the maintenance conducted to return the aircraft to a serviceable condition.[10]

Start-up, taxi, take-off and departure for the formation were uneventful. Mindful of the previous day's flight, the Fuel, Area, Cabin alt and Oxygen (FACO)[11] checks were carefully applied. Passing through FL280, Hawk 1's oxygen flow (OXFLW)[12] warning caption momentarily illuminated, coinciding with the oxygen flow indicator not registering the breathing rate of the pilot.[13]

This prompted the pilot of Hawk 1 to draw deeper breaths, which activated the flow indicator and rectified the situation. The pilot also elected to carry out a physical check of the mask seal and oxygen hose connection; both appeared normal.

The restricted flow and associated OXFLW caption were similar to those encountered during the previous flight. Content that the fault was transient in nature, the formation continued its climb. Before achieving FL330, the OXFLW caption illuminated briefly several more times.

To rectify the indication, BUOXY was selected manually to try and increase flow through the regulator; FCCs were consulted. The event pilot elected to not descend below 10,000 ft cabin altitude (as directed by the FCCs) as the captions were only transient in nature. The Oxygen System Test/Reset switch was also utilised to try and reset the system.[14]

Looking out from the cockpit, after a period of heads-in[15] fault finding, the pilot thought the horizon appeared blurred. This sensation was also accompanied by the pilot feeling slightly light-headed. In order to check their situation awareness (SA)[16] and cognitive capacity, fuel/distance calculations to Kalgoorlie were carried out satisfactorily, despite the pilot feeling unwell.

Hawk 1 then consulted Hawk 2 about the time of useful-consciousness[17] at FL330. Having responded, Hawk 2 thought no more about the line of questioning, particularly as Hawk 1 sounded normal over the radio.[18] At this time,

... after a period of heads-in fault finding, the pilot thought that the horizon appeared blurred. This sensation was also accompanied by the pilot feeling slightly light-headed. In order to check their situation awareness and cognitive capacity, fuel/distance calculations to Kalgoorlie were carried out satisfactorily, despite the pilot feeling unwell.

the formation was about 60 nm west of Kalgoorlie, the next waypoint.[19]

What seemed like a minute later (pilot's recollection), the formation was overhead Kalgoorlie conducting a left turn to track to the next waypoint. The event pilot was subsequently unable to account for the lapsed time. It was at this juncture that the pilot's symptoms worsened rapidly, reporting a sensation of dizziness, an accelerated heart rate (approximately 120 beats per minute[20] (BPM)) and a hunger for air.[21]

After an additional set of OXFLW and BUOXY captions (plus aural warning), Hawk 1 manually selected BUOXY and elected to depart the formation, declare a PAN and initiate a turn and rapid descent towards Kalgoorlie Airfield.[22]

During the descent, there was an over-speed of the aircraft (due to the aircraft's baggage pod configuration).

As the formation tracked towards Kalgoorlie, the event pilot decided to upgrade the PAN call to a MAYDAY in response to their decreasing ability to manage the situation. Thereafter, once the aircraft was below 10,000 ft cabin altitude, Hawk 1 removed their oxygen mask to breath-in normal cockpit air.

During the second flight, from the point of diversion into Kalgoorlie, it was noted that:[23]

- Hawk 1's flight performance appeared unimpaired
- The OBOGS performed normally with no further warnings or cautions
- Hawk 2 provided satisfactory support to Hawk 1.

The event pilot reported experiencing some shakiness in the latter stages of the diversion but the majority of the other symptoms dissipated with time at lower altitude. As the formation positioned for a straight-in approach to Kalgoorlie, Hawk 1 briefed the approach and landing, including the possible need for streaming the brake chute. The formation landed individually without the need for the brake chute, and taxied to the parking apron.

Post second-event flight

Upon vacating and securing their respective aircraft, the aircrew members were met by the airport manager who drove them to the terminal. The requested ambulance arrived about 40 minutes later.

While in the terminal, the event pilot drank some water but remained feeling generally unwell and complaining of exhaustion. Also, the pilot's hands had a blue tinge.

The squadron executive officer (flight authorising officer) was eventually called by the event pilot and advised of the emergency and the diversion into Kalgoorlie.

This prompted the wing executive officer and RAAF Pearce maintenance staff to contact the event pilot to ascertain their wellbeing and the state of the aircraft.

Medical treatment. On arrival at the local hospital, the pilot spoke with the duty doctor, who contacted Institute of Aviation Medicine (IAM). The duty medical officer

(MO) gave the doctor advice on treating a patient with suspected hypoxia.

The event pilot was placed on 100 per cent oxygen for 20 minutes and hydrated with water. They provided blood samples which were dispatched for analysis[24] and remained in hospital until the results of the blood tests returned.

The pilot was cleared to fly as a passenger on 25 January and returned via commercial air to Perth that day. Before departing the pilot recorded two unserviceabilities in the aircraft's EE500[25] – the oxygen system and the over-speed of the aircraft.

Qualification, currency and recency

The event pilot had the required qualifications, currency and recency for the sorties flown on 23 and 24 January. Squadron aircrew currencies are tracked via ULTRA-FP (software) using information from PMKeyS, training files, logbooks and other training/squadron records. According to ULTRA-FP, the event pilot was qualified and current, and had no restrictions against them at the time of the event flights.

The Aviation Safety Investigation Team (ASIT) assessed that the event pilot was medically fit to fly (including well rested), professionally qualified, and current to conduct the authorised flights.

Meteorological information

For both event days, the reported weather[26] in the vicinity of Kalgoorlie-Boulder Airport was light easterly winds, good visibility with no significant cloud.

Data collection

Data relevant to analysing aircraft performance was obtained from the aircraft's Head-Up-Display (HUD) and Health Usage Monitoring System (HUMS). These data sources provided audio/visual/coded information to the ASIT which were used to compile a history of the sorties.

Aviation Life Support Equipment (ALSE)

An authorised BAE ALSE technician completed a full service check (after the second-event flight) on the life-support ensemble used by the event pilot. The technician checked the oxygen mask for fitment, as well as checking the mask and the associated hose for leaks; no abnormalities were detected.

Engineering action (second flight)

On being informed of a second diversion, a BAE Hawk technician was dispatched to Kalgoorlie to provide engineering support and a HUMS download. The technician received a verbal debrief from the event pilot confirming repeated low-pressure warnings, accompanied by OXFLW captions, in the system.

Subsequently, a BAE recovery team was sent to Kalgoorlie to carry out preliminary fault-finding. The aircraft was secured for environmental protection but remained available for a probable return flight to RAAF Pearce. The aircraft remained at Kalgoorlie until 06 February 2019.

Maintenance actions

The squadron recovered the aircraft to RAAF Pearce under a Military Permit to Fly so that an investigation and rectification period could commence.

A detailed staged fault-finding plan was then developed between BAES and DFSB as follows:

- desktop review of the maintenance history of the OBOGS and related ECS components
- detailed examination and testing of aircraft wiring, searching for an intermittent fault in the wiring to or from Pressure Reducing Shutoff Valve (PRSOV), Molecular Sieve Oxygen Concentrator (MSOC) or Solid State Oxygen Monitor (SSOM)
- complete OBOGS functional testing and
- engine ground run including OBOGS PRSOV test.

The details of all maintenance actions conducted in support of this investigation are summarised below.

- The fault-finding analysis for the initial unserviceability of 'restricted oxygen flow at 33,000 ft AMSL' did not identify any specific causal factor. However, during the extensive engineering works after the second-event flight, the following three items were identified that could have contributed to an OBOGS unserviceability:
  - partial blockage of cooling fins of the Primary Heat Exchanger restricted the air flow resulting in a reduced flow of air supply to the OBOGS.
  - the main landing gear up-lock micro-switch was slightly misadjusted which, about as likely as not, could have caused engine bleed air to be intermittently diverted through the inducers, reducing the OBOGS air supply.
  - a faulty diode (VV193) was identified which could have possibly prevented BUOXY activation if cabin altitude was above about 25,000 ft PA.
- There was no evidence of contamination of the breathing system or the Environmental Control System.

The testing confirmed the serviceability of various aspects of systems, and that the risks to airworthiness had been reduced so far as reasonably practicable (SFARP).

As a result of the BAE maintenance actions, the aircraft was released back to the squadron for a check test flight, prior to being flown in dual configuration (with qualified flying instructor-qualified aircrew) before being utilised for normal operations.

Damage to aircraft

During corrective maintenance, certain items were replaced or adjusted but overall, there was no damage to the aircraft and it was returned to service on 08 May 2019.[27]

Perception

In the opinion of the Institute of Aviation Medicine Senior Aviation Medical Officer (IAM SAVMO), physiological events are a subjective experience, and the response to a trigger is shaped by both the strength of the stimulus and the aggregate priming effects of perception, bias, anxiety and previous occurrences.

The symptoms feel very real regardless of the underlying cause. Furthermore, the response to this type of episode may be more prevalent than initially thought, mainly because it has not previously been fully understood.

Awareness training

Hypoxia Recognition and Recovery Training and Hypoxia Awareness Training (HRRT/HAT), adopted by the wing, aims to provide aircrew with confidence in the breathing system, the ability to recognise a physiological event and the ability to respond effectively in a timely manner. Under a similar training scheme, the RAF reports significant success in reducing the level of exposure to hyper-arousal among Typhoon pilots.

Flight-crew checklist (FCC)

The event pilot told the ASIT they found the Hawk oxygen-related FCCs confusing during the physiological events. The ASIT notes that the initial actions (bold face) from the aircraft's emergency drills for pressurisation failure, oxygen failure, oxygen flow, restricted oxygen flow, hypoxia and oxygen contamination are fundamentally similar but they are nevertheless explicit.

However, for the FCC subsequent actions for oxygen-related emergencies, there are several actions that have the potential to be confusing during in-flight use. It was found that the Hawk emergency procedures pertaining to hypoxia, oxygen contamination and cockpit smoke and fumes do not drive aircrew to resolution when actioned in isolation.

Engineering assessment

The occurence aircraft continually passed oxygen-system testing on the ground with no replication of the airborne faults. In an effort to reproduce the airborne faults, BAES recorded the behaviour of the system at additional test points.

During fault-finding, they replaced the primary heat exchanger (not replaced in previous maintenance) which improved the performance of the OBOGS in low-flow conditions and reduced the likelihood of low supply pressure. BAES identified a misadjusted main landing gear up-lock micro-switch which could have led to intermittent opening of the inducer PRSOV inflight and induced a small drop in air supply to the OBOGS.

This intermittent fault could have combined with the potentially blocked heat exchanger to cause a small, intermittent decrease in OBOGS output.

...physiological events are a subjective experience, and the response to a trigger is shaped by both the strength of the stimulus and the aggregate priming effects of perception, bias, anxiety and previous occurrences.

Conclusion

The occurrence aircraft continually passed oxygen-system testing while on the ground with no replication of the airborne faults. Through rigorous testing, BAES put forward a plausible explanation that the aircraft could (more or less likely) have suffered a small, intermittent decrease in OBOGS output about the time of the second-event flight.

Evidentially, this physiological event can be related to a resistance to flow in the breathing system, at a location that imposes a restriction from OBOGS-supplied gas, and is independent to the BOS. The event is also relatable to the BUOXY incident the pilot experienced the previous day.

The investigation revealed that there was no evidence that the pilot suffered hypoxic hypoxia during this physiological event, nor was there any evidence of any correlating contamination of the breathing system.

Medical SME opinion is that this physiological event was a psychophysiological response to a breathing system exhibiting repeated OXFLW warnings, in a pilot with low-confidence in the breathing system generally.

The resistance to breathing and repeated low-flow conditions contributed to the event pilot reacting as they did, but may not have resulted in the same symptomology in another person who was not already hyper-aroused.

A psychophysiological reaction to a real or perceived critical event is not a remarkable response when viewed through an individual's state of arousal, priming, and experience.

Although not a predictable outcome, it is not abnormal. Evidence exists that aircrew confidence in the breathing system can be restored/maintained through targeted briefings, training, and education.

Director DFSB comment:

This type of issue is not exclusive to the Hawk and within the ADF we have a number of aircraft that utilise OnBoard Oxygen Generation Systems (OBOGS): Super Hornet, PC-21, F-35 and Hawk.

Outside of the OBOGS almost every aircraft in the ADF has some kind of pressurisation or supplemental oxygen system. However, the report found that although there were some components of the system that may have contributed to the event, the system otherwise appeared to be serviceable and had passed all ground maintenance checks. So, perhaps it wasn't a system fault.

There are a range of things that can occur to the human body other than 'hypoxic hypoxia' that may bring about an airborne Physiological Episode (PE), such as stress, illness, fatigue, dehydration or food poisoning for example.

The key point is that the lessons we learn from Aviation Medicine, including our Hypoxia Awareness Training, is vital in our ability to detect and manage our individual reactions and symptoms. A solid knowledge of bold face emergency actions is also vital, especially when thinking is impaired. And, of utmost importance is the open and honest reporting of any incident in which a PE has occurred. So that the cause may be investigated.

ENDNOTES

1 IFC students holding-over are awaiting the next phase of the fast-jet training continuum.

2 The second aircraft is for mutual support and is employed to mitigate the navigation limitations of the Hawk aircraft.

3 Call signs Hawk 1 and Hawk 2 are used to de-identify pilots for this publication

4 If OBOGS is reset after a malfunction, the valve operates to supply oxygen-enriched breathing gas to the regulator when the BOS pressure reduces.

5 It is expected that the non-emergency aircraft would assist the emergency aircraft.

6 Declaring a 'PAN' afforded the formation the priority initially sought from Melbourne Centre ATC.

7 The performance of Hawk 2 is relevant during the second-event flight.

8 Duty Supervisor (Duty Sup), is the supervisor on a squadron who authorises flights and runs the flying program. They are usually a flight commander or senior/experienced aircrew member.

9 Approximately four hours after initially departing RAAF Pearce.

10 The oxygen regulator had been changed and ground testing conducted, which proved the serviceability of the system.

11 FACO checks are carried out in the climb or every 10 minutes.

12 OXFLW warning indicates no oxygen flow, or continuous flow, for more than 15 seconds.

13 This can happen if the aircrew members are taking shallow breaths or the airflow is not strong enough to trigger the indicator.

14 Resetting the system only provided a temporary cessation of the CWP captions re-illuminating.

15 Heads-in' – terminology describing that the pilot activity was focused on equipment within the cockpit.'

16 Situation awareness means literally 'awareness of the situation' whereas situational awareness means 'a type of awareness relating to the situation'.

17 Time of useful-consciousness – the amount of time an individual is able to perform flying duties efficiently in an environment of inadequate oxygen supply.

18 Pilot-in-command of CR12 thought the quizzical line of questioning was in-line with normal QFI mentoring.

19 Approximately 60 nm in a Hawk at cruising speed would take about 8 minutes to be overhead Kalgoorlie.

20 Heart rate gleaned from the pilot's smart watch.

21 Air Hunger – a sensation of not being able to draw in enough air or of needing to breathe in more air, which typically results in deep, rapid, laboured breathing

22 The initial PAN call was to divert to RAAF Pearce, which was then amended by the event pilot to divert to Kalgoorlie airfield.

23 Noted by squadron/wing executives that reviewed the HUD recording. Also from witness testimony and HUMS data

24 The ASIT requested that a copy of the blood results be sent to IAM.

25 EE500 – the aircraft's maintenance log

26 The route forecast for the second flight was provided to the event pilot (by e-mail) by the RAAF Williamtown meteorological office

27 Solo students were restricted from flying the event aircraft for the first five hours post its return to the flying program.

It's way too close to Sydney Harbour

ON THE AFTERNOON of Australia Day 2019 a C-130J crew was preparing to conduct a flying display over Sydney Harbour. The display was to consist of two elements – a handling display in the early evening, followed by a flare dispense after sundown. In between, the crew had two flypasts in the vicinity of the Hawkesbury River. The weather had been sunny and clear for most of the day, but began to deteriorate in the late afternoon.

By the time the crew departed, weather reports indicated a visibility of 8 km and a cloud base of 600 ft. The crew was also receiving live weather updates from personnel in Sydney Harbour, and the aircraft captain elected to take-off and assess the weather once airborne. The crew conducted a flying display overheard RAAF Richmond before transiting to Sydney Harbour.

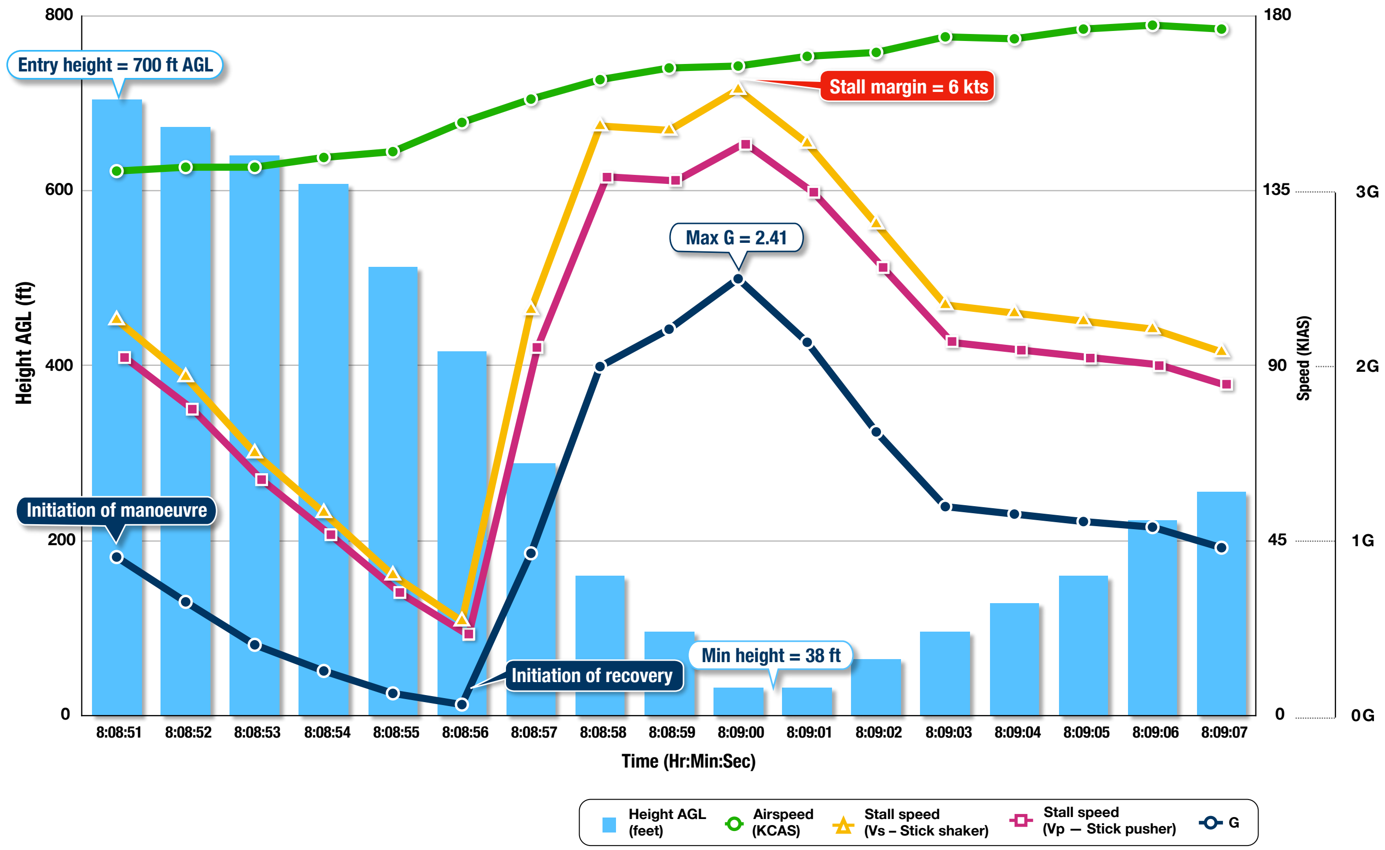
The flying display was planned to commence overhead Sydney Harbour Bridge but the low cloud precluded this. Instead, the crew requested a localiser approach to Sydney in order to descend safely below the cloud base. This was unsuccessful, so the crew conducted the missed approach and held to the east of the Harbour. Crew members were still in contact with personnel in the Harbour regarding weather conditions, and when a gap was identified in the cloud, they elected to descend to 500 ft and became visual. The crew entered the Harbour and began the display. The majority of the display was conducted with only minor amendments to the planned vertical manoeuvres. Following a ramp down pass overhead Circular Quay; the crew reconfigured the aircraft for the final manoeuvre, a zero-G bunt.

The manoeuvre was planned to commence at 1500 ft, push to zero G 30 degrees pitch nose down, and recover not below 250 ft minimum safe distance (MSD). Due to the low cloud; however, the aircraft captain decided to modify the manoeuvre by pitching only 15 degrees nose down, and recovering immediately and not below 250 ft MSD. Instead, the aircraft captain inadvertently pitched 28 degrees nose down.

The aircraft captain identified the entry error almost immediately and commenced a recovery manoeuvre. They intended to balance the available airspeed above the stall with G and available height above the water. The aircraft descended to 38 ft above Sydney Harbour.

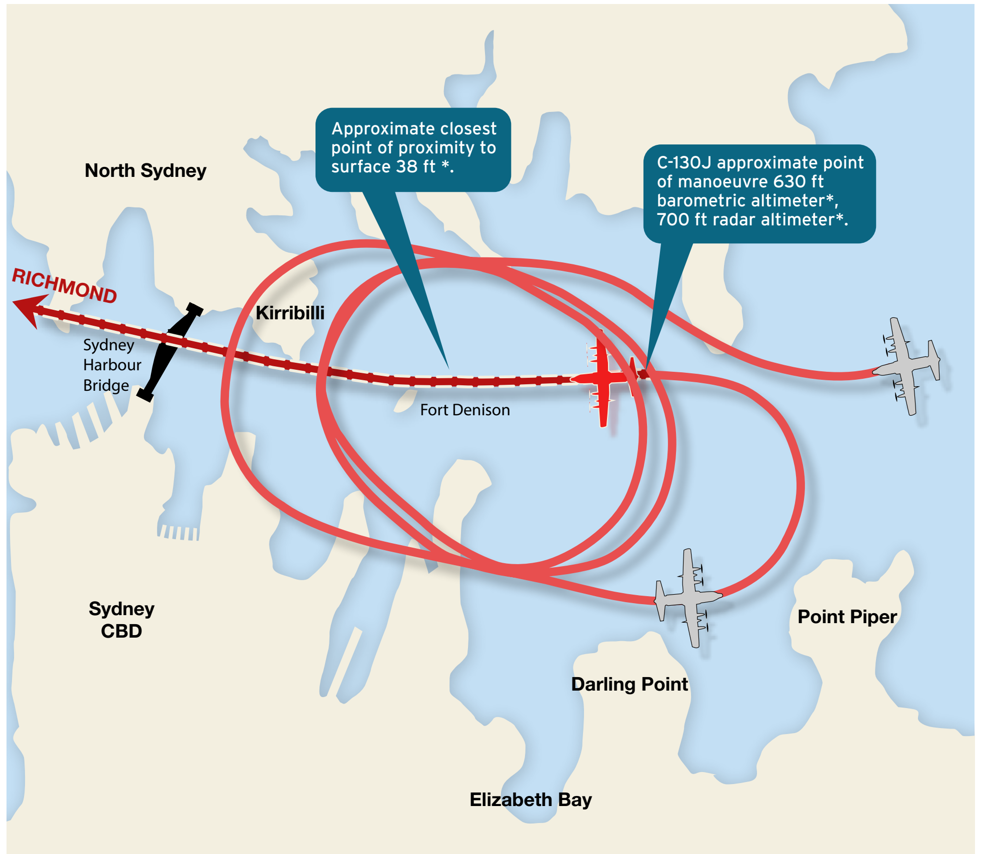
Once above 250 ft MSD the crew members confirmed that there was no overstress or overspeed of the aircraft, and after discussion with the authorising officer decided to continue with the remainder of the sortie.

As part of the investigation, the Aircraft Research and Development Unit (ARDU) was asked to analyse the data from the Flight Data Recorder and the Data Transfer and Diagnostic System to determine the flight profile and safety margins of the aircraft recovery. ARDU identified that the maximum G pulled was 2.41 G, the minimum stall margin was 6 kts above the stick-shaker speed (incipient stall) and 18 kts above the stick-pusher speed (fully developed stall).



Aircraft parameters during recovery

The analysis determined that had the aircraft captain pulled to 2.5 G, the stick shaker would have activated. As 0.1 G is barely perceptible to the pilot, the recovery flown was considered approximate to an optimal recovery. The Aviation Safety Investigation Team (ASIT) considers; however, that as the performance of the aircraft was 0.09 G below stick-shaker activation, with a surface clearance of 38 ft, the margin between a successful recovery and controlled flight into terrain is minimal.



Sydney Harbour with display track

Flying displays

Flying displays carry inherent risk. By their nature, they are high profile and require careful planning and skilled execution. Even in heavy aircraft such as the C-130J, the combination of sequenced manoeuvres, height and distance restrictions, workload and pressure to perform, create a unique and demanding environment for the crew.

The ASIT reviewed past flying-display-related accidents and incidents, and reviewed contemporary best practice for display planning, preparation and execution. Several key elements were identified and considered in the context of this event.

Crew selection. The ASIT identified that the squadron had no documented criteria for the selection of display crews. Furthermore, there was no documented policy or guidance at wing, group or command to support squadrons to make appropriate selections of display pilots, and display crews. While the squadron made a considered selection for the aircraft captain, the same was not true for the co-pilot. The ASIT found that the late addition of the co-pilot, their lack of experience in flying displays, and the lack of crew co-ordination negatively affected the crew's ability to act as a team, and did not allow the co-pilot to provide appropriate support to the aircraft captain during the display.

Display selection. The squadron did not have a documented display profile, or approved display manoeuvres. The display profile was selected by the aircraft captain based on previous C-130J flying-display experience, and modified to suit the constraints of Sydney Harbour. While the standard C-130J manoeuvres are trained for, practiced and used on a regular basis by C-130J crews, the combination and sequencing of them for display is not. Furthermore, the zero-G bunt manoeuvre was not standard, and had reportedly been introduced to the RAAF C-130J community through the

Due to the low cloud; however, the aircraft captain decided to modify the manoeuvre by pitching only 15 degrees nose down, and recovering immediately and not below 250 ft MSD. Instead, the aircraft captain inadvertently pitched 28 degrees nose down.

Royal Air Force exchange program. The ASIT also found there was no documented policy or guidance at wing, group, or command levels to support squadrons in the selection and standardisation of flying displays, or display manoeuvres. Standard display manoeuvres, either in isolation, or as a standard profile, provide a number of advantages, including:

- the risks associated with each manoeuvre, and the linking of them, are appropriately considered
- a consistent approach to training and preparing crews for display flying
- supports crew to have a common mental model and well understood procedures to fall back on
- reducing workload through standardised training and crew cohesion.

Work up. The squadron did not have a documented work-up process, nor was the ASIT able to find any higher level documented instructions or guidance for display work-up processes. The aircraft captain described designing the work up around their Air Academy experience, and previous flying display experience.

Unfortunately, due to the late addition of the co-pilot to the crew, they were not part of the simulator event, and instead flew only four practice events, all in fair weather, with no low cloud. The simulator event would have provided valuable exposure to the practice of, and discussion around, emergency and abnormal events.

The ASIT identified that the changes, made within a week of the display, including a new co-pilot, the addition of an extra manoeuvre (at the request of the event organisers) for better crowd visuals, and an unexpected aircraft configuration (extra wing tanks), all increased workload and complexity.

The ASIT found that a standardised work up would likely have provided additional risk controls, including the ability for individuals and supervisors to identify high workloads and deficiencies in the development and planning of the display.

Alternative show. The ASIT found that contemporary best practice for flying displays was to have a low or alternative show, or to cancel a show that could not be done within the practiced parameters. The squadron did not have a planned alternative, as they had determined minimum conditions for the display, and did not plan to continue outside those parameters. On the day; however, a number of factors led to the crew continuing the display, and amending the manoeuvres as they went.

The aircraft captain planned to amend the zero-G bunt; however, this was not communicated to the crew, and during the manoeuvre, the aircraft captain inadvertently reverted to the practised and known 30 degrees nose down. An alternative show would have provided a planned and practiced mental model for all of the crew, of how the display would be flown, reducing opportunity for error.

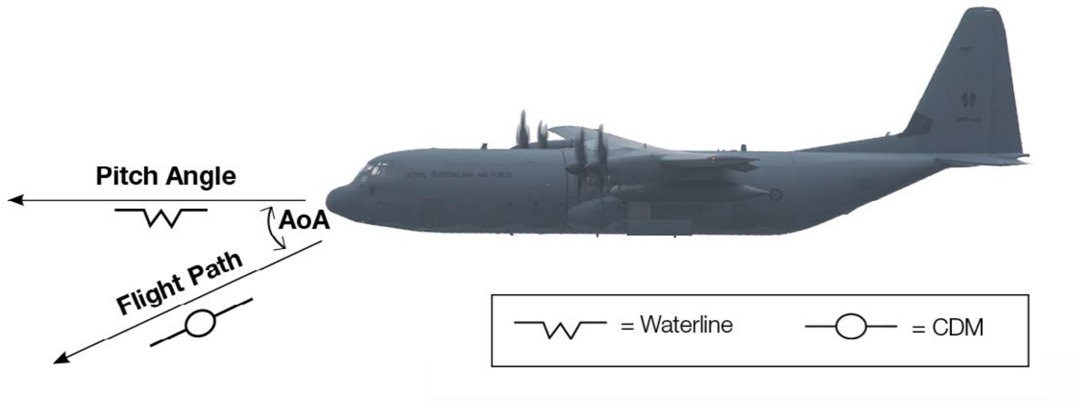
Risk management

Flying displays are an opportunity to demonstrate professionalism and capability but it is important to consider who the audience is and what will have the most impact.

The ASIT found that the risk-management documentation for the display was poorly prepared, and did not adequately cover elimination decisions, unique hazards associated with the display location, or how described risks were to be minimised. Fundamentally, the ASIT found no evidence that the squadron or wing had appropriately considered the risks associated with a non-standard manoeuvre, in a confined area against the benefit of what it added to the display.

It was also notable that the nominal conditions of the risk management plan listed "all display operations will be conducted in VMC. The minimum conditions for display flying are 1500 ft AGL cloud base and greater than 5 km visibility".

There was no further consideration of weather conditions below minimum listed. The risk-management-plan weather conditions were not discussed during the authorisation process, crew briefing, or during mission execution.



Angle of attack/flight path as the aircraft pitch passed the horizon

Flying supervision and authorisation

In the six months preceding the display there were a number of executive postings and deployments within the wing and squadron, resulting in key positions being gapped or filled by temporary commanders.

These included the squadron commanding officer. The incoming executive officer was promulgated as temporary commanding officer. The executive officer position remained empty for the first month of 2019, resulting in a significant workload for the temporary commanding officer.

Additionally, the ASIT identified that a number of key positions had limited or no flying-display experience. The increased workload for squadron and wing executives, and the lack of flying-display experience ultimately reduced opportunities to provide valuable oversight and support to the crew to ensure safe and effective preparation and execution of the flying display.

The authorising officer for the display was the squadron's temporary commanding officer. IAW Squadron Flying Orders, the unit CO is the only individual who can authorise flying displays. The ASIT found; however, that the extant flying order was not current, and no consideration had been given to the temporary commanding officer being the most appropriate person to authorise the display.

The ASIT found no higher level instructions to support decision-making for flight authorisation responsibilities where there is temporary command or where a specific mission would benefit from subject matter expertise. The temporary commanding officer had taken a non-traditional pathway to squadron executive, had only one tour as a pilot on C-130J and no flying-display experience. There is no specific requirement for an authorising officer to have experience in all profiles that they authorise; however, DASR and OIP do articulate the requirement for experience and technical mastery.

The flying display was scheduled for the Saturday afternoon, and as the temporary commanding officer had public relations duties in Sydney Harbour, the flight authorisation brief was scheduled for the afternoon prior. The temporary commanding officer had authorised the practice flights, and had been part of the planning process so felt comfortable with the display profile and requirements. As a result, when an additional practice was added on Friday afternoon, and the temporary commanding officer was no longer available for a face-to-face brief, the authorisation was done by phone. Overall, the ASIT found that there was no full authorisation brief, that what did occur was not commensurate with the higher risk profile of display flying, and did not fully address the high workload, late changes or deteriorating weather.

Mission execution

The ASIT found that the crew was unprepared for the poor weather conditions, there was no low show or alternative weather plan, and the crew and authorising officer did not discuss or adhere to the minimum weather conditions prescribed by the risk management plan. During the conduct of the display, a number of additional conditions were identified that negatively affected the crew decision-making and performance.

Workload. The aircraft captain described their workload in the lead up to the display as high, with the bulk of the display administration and preparation solely their responsibility. Additionally, the aircraft captain was involved in changes to unit structure, holding an executive position, and undertaking normal duties in the lead up. The co-pilot, who was added to the crew six days before the event, was undertaking an upgrade course at the same time. During the event, the normal high workload expected in a flying display was exacerbated by the weather, the requirement to amend manoeuvres on-the-go, poor communications with ATC and display co-ordination communications.

Distraction. Co-ordination for the flying display was via *WhatsApp*. The *WhatsApp* group was established on 23 January 2019, and included the C-130J crew, the temporary commanding officer, the Air Command Liaison Officer, the ATC Liaison Officer, and crews from other platforms also displaying in Sydney Harbour on Australia Day. The group was used to co-ordinate planning, confirm timings and provide weather updates. The message thread on Saturday started in the morning, and continued throughout the day with commentary on the lunchtime display and banter.

As the day progressed and it became clear that the weather might be an issue, the message thread became increasingly busy. A number of participants provided weather updates, opinions on the ability of the crew to conduct the display, and advice on how to achieve the display. These continued after the aircraft launched. In the approximately 45 minutes between take-off and the commencement of the display, there were 34 message exchanges on the one *WhatsApp* thread.

The increased availability of alternative methods of communication has increased flexibility and information exchange but it also introduces (or re-introduces) new hazards. The ASIT found in this event, the *WhatsApp* message thread introduced a lack of clarity in communications, additional pressure through the banter and the push to continue the display despite the weather, and unnecessary distraction through the non-essential messages that were part of the thread.

Stress. Stress is defined in the DFSB *Non-Technical Skills Guidebook* as "a state of emotional arousal, characterised by an individual's perception of what they are required to achieve against the resources available to support them". The ASIT found a number of indications that the aircraft captain was exposed to higher-than-normal workplace stressors, including a complex task with a high level of scrutiny, perception of the cost of failure to conduct the display and the late and continued changes to the display profile.

The aircraft captain was an experienced pilot, with previous exposure to planning and executing flying displays, periods of high op tempo and operations in areas of higher risk. There was no reported history of significant or out of the ordinary stress reactions; however, stress affects individuals differently at different times, and stressors can be cumulative.

The aircraft captain informed the ASIT that they felt under "immense pressure", and the ASIT identified a number of behavioural and cognitive symptoms that can be symptomatic of increased stress, including; reduced communications, regression to previous behaviour, filtering of information, and sub-optimal decision-making. The ASIT therefore found that the aircraft captain's performance was likely adversely affected by stress.

Lack of team performance. The crew had carried out a pre-flight briefing, and had conducted the practice displays together; however, these events were all predicated on fine weather. During the display, the aircraft captain determined the modifications as they needed to happen, and did not remember briefing the crew at any stage. The co-pilot recalled assuming that the final manoeuvre would be modified but not what the modification would be. This meant the co-pilot and the loadmasters were not part of any immediate risk management for the amended manoeuvre, and could not provide back up to the aircraft captain before or during the manoeuvre.

The ASIT found that the lack of planned low show, or additional planning and briefing when it was apparent that the weather was below optimum, reduced the crew's ability to work effectively as a team.

Learned behaviours. On entry to the manoeuvre, the aircraft captain inadvertently pushed through the planned 15 degrees nose down to approximately 28 degrees nose down. The aircraft captain had conducted this manoeuvre a number of times in practices for, and during displays, and had deliberately built habit patterns to reduce workload during the display. It is not unusual, and often encouraged, for Defence aircrew to form habit patterns. By building instinctive reactions to certain situations, we reduce the likelihood of error, speed up reaction times and free up attention for other tasks. Unfortunately, in this instance, the aircraft captain was under significant workload and pressure, and that led to a reversion of a previously learned action.

This significant safety event has highlighted the exacting nature of flying displays, and the requirement, even for simple display profiles, for careful planning and preparation. The ASIT identified a number of deficiencies in the lead up to the event, including substandard risk management, high workload and late changes to the profile, the crew and the aircraft configuration. Additionally, the ASIT found that the number of executives within both squadron and wing either absent, newly posted in or in temporary roles increased individual workloads and reduced the organisation's overall ability to provide appropriate oversight of, and guidance to, the authorisation officer and the display crew.

At an organisational level, the ASIT identified a lack of OIP to support commanders in the selection of flying-display crews, display profiles, and work-up processes. For comparison, the ASIT found comprehensive guidance in some wing- and unit-level organisations that would be invaluable in the development and preparation of all flying displays conducted by Defence aviation.

Conclusion

No single contributory factor was considered primary in this event rather, the ASIT identified a number of local conditions, absent or failed risk controls, and organisational deficiencies. Together they reduced the safety buffers normally present, and resulted in an unintentional manoeuvre that led to the descent of a C-130J to 38 ft over Sydney Harbour.

Director DFSB comment:

Some essential lessons have been learnt by the C-130 and Air Mobility Group community through this event. However, there are key lessons here for any aviator undertaking display-flying activities. Whether it's a flypast or handling display, the pressure is always on when the crowds are watching and that pressure can affect the decision-making process. This dynamic is centrally important for flying supervisors to understand as well and although a good display is always a great aspiration, it's impertive that we create ample opportunities to be able to say 'no' if that's what's required on the day.

Wide of the mark

On 30 September 2019, a pair of F/A-18A aircraft were providing close air support to Exercise Phoenix Black, a Joint Terminal Attack Controller (JTAC) training-and-currency exercise in the Townsville Field Training Area. On the third target engagement, a BDU-33 (practice bomb) was released and impacted 2.8 km north-west of the intended target. The JTAC observation post was 1000 m to the south-east of the impact point and in-line with the aircraft track.

A detachment of 10 JTACs was positioned at the predesignated observation posts and was the controlling authority for the serial. Callsigns[1] Hornet 1 (lead) and Hornet 2 (incident pilot) were the second pair of aircraft on that day. Before commencing close air support (CAS) the formation checked in with the Range Safety Officer.Hornet 1 gave a standard check-in brief on behalf of the formation and was subsequently given a situation update and game plan.

Incident engagement. The formation was informed this would be a type-2 sequential attack; Hornet 1 was to carry out a medium level roll-in from the overhead, and Hornet 2 was to conduct a low-level attack from the northwest.

The JTAC conducted a laser spot hand-off[2] to the formation, and subsequently provided a target talk-on to a curved burnt patch on the ground. When the formation was satisfied they had the correct target, Hornet 1 called "Tally Target"[3] for the formation.

During this final attack run, Hornet 2 released a single BDU-33HD onto a target, which landed outside the weapon trace. Due to fire restrictions in the area, there were no spot charges in use[4] and the JTACs did not see the weapon impact. Post-flight review of the cockpit HUD video, identified the weapon impacted 2.8 km to the north-west of the intended target position and outside weapon trace. The JTAC OP was situated in a direct line between weapon impact point and the intended target, 1000 m to the south-east of the impact.

ACG support to CAS

Proficiency in highly complex tasks is a function of training, experience and recency. Even highly proficient individuals, after a period away from a specific task, will need time and practice to regain elements of the skill set.

Both the F/A-18A and the F/A-18F platforms primarily use smart weapons and associated profiles in their core roles. During three years of operations in the Middle East Region, ACG was primarily engaged in air-to-ground operations using precision weapons from medium level. Following this period of deployment, ACG largely focused on air-to-air skills through 2018 and 2019.

During the preeding two years, the squadron had been programed for six weeks of CAS, of which three weeks was in support of exercises in September 2018. Wing identified in the planning for the 2019 JTAC exercises that an effective work up was needed to ensure strong performance in CAS. The risk management plan (RMP) stated that "operations have had a heavy focus on air-to-air and as such, the pilots will not be considered fully worked-up for missions".

The investigation noted that the type of weapons and the delivery profiles utilised for CAS in this exercise are infrequently employed by the wing. It also noted the squadron had limited exposure to smart weapons and their associated delivery techniques during almost all recent engagements.

Risk management

For the first three days of the exercise, squadron pilots were restricted to operations that fell within their category. They were cleared to fly out-of-category under supervision for development purposes from day four of the exercise. By the start of week three, pilots had flown between four and seven sorties and were considered current and proficient.

Stress and fatigue

Stress is a state of unpleasant emotional arousal characterised by an individual's perception of what they are required to achieve against the resources available to support them. When this is out of balance, individuals can perceive this as a threat and react accordingly. While a level of stress (arousal) is considered necessary to motivate individual performance, too much negative stress can have the opposite effect.

Workplace stress can be either chronic – that is negative conditions in the workplace over a protracted period – or acute – short-term events such as increased workload, high cost of failure, fear of failure, uncertainty or changing expectations or outcomes. While the effects of stress are dependent on the individual, there are a number of common effects on behaviour, emotion and cognition.

CAS is a high-workload mission. During this event, workload was further increased by lack of currency with CAS tasks, issues with equipment (helmet functionality), and poor target definition. During the run-in to the target, the incident pilot displayed some cognitive symptoms associated with acute stress, including errors, filtering and bias.

On the weekend prior to the event the squadron had two rest days. Most of the aircrew used these days for rest and relaxation. The incident pilot used this designated rest period to study and prepare for the following week.

While preparation and planning are crucial to successful performance, so too is rest and recuperation. The decision to work through the weekend may have had a negative effect on the incident pilot's fatigue level and chronic stress. Fatigue can make an individual more susceptible to the effects of stress.

9-line. The controlling JTAC gave a 9-line[5] to the formation to complete the targeting contract and requested Hornet 1 remain in the overhead while Hornet 2 conducted the low-level attack. Hornet 2 departed formation and tracked to the north-west to set up for the low-level attack. The final attack run needed to be within final attack heading restrictions (142–168º). At 15 nm the formation began a right-hand descending turn to begin the target run-in.

Hornet 2 had scene-track mode selected for target identification. This slewed the Forward Looking Infra-Red (FLIR) to the EP, and allowed Hornet 2 to visually identify the target area as passed by the JTAC. The formation was given a more precise talk-on to a specific area from the JTAC, and Hornet 2 entered a target point into the system from this talk-on, but did not designate this point.

The designation of a point determines the aircraft steering to that point. By leaving the system in scene track, steering was based on the FLIR tracking of the target point, which is reliant on line-of-sight (LOS). As the aircraft tracked away from the target and descended, LOS to the target was interrupted. The system has a memory mode that attempts to remain on target point, using Inertial Navigation System and picture matching; however, it is known to drift with periods of lost LOS, and particularly when the targets are not easily discernible from the surrounds.

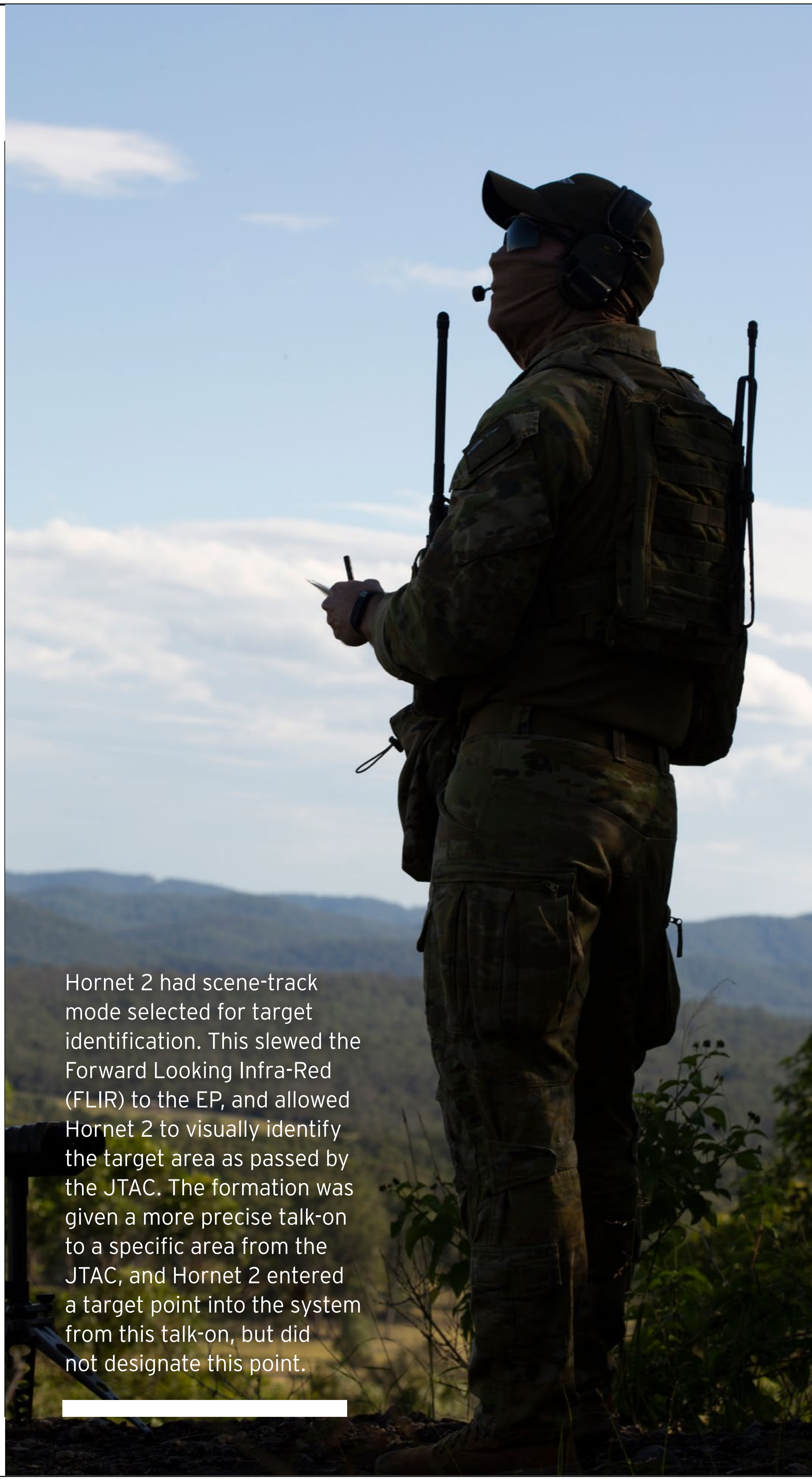
The system drift is a known issue, and the squadron pilots were briefed on the potential for this following its occurrence during a sortie the previous week.

The incident pilot was present at this brief and was aware of the issue. Prior to the target run-in, Hornet 2 should have completed the air-to-ground checks, which includes a waypoint designation step. Hornet 2 recalls conducting the air-to-ground checks. The Aviation Safety Investigation Team (ASIT) confirmed the verbalisation of these checks on the HUD tape.

The air-to-ground checks are supposed to be positively marked off as each item is completed. Positively checking should have prompted Hornet 2 to confirm a target point was correctly designated. Hornet 2 believed they had designated the target point and that the system was steering towards the correct target prior to the turn away[6]. As the target was not designated, it is likely Hornet 2 did not properly conduct this step of the air-to-ground checks.

Action errors occur when actions deviate from an individual's plan and usually during routine tasks or when attention is diverted. The incident pilot entered the target co-ordinates and saved the target point in accordance with normal procedures and intended to designate the target but did not complete the process. This allowed the system to drift. The incident pilot did intend for the task to be completed, but their attention was diverted.

Thornton Gap VFR corridor transects the two primary operating areas above the training area. Military aircraft that pass through this corridor during missions



During this final attack run, Hornet 2 released a single BDU-33HD onto a target, which landed outside the weapon trace. Due to fire restrictions in the area, there were no spot charges in use[8] and the JTACs did not see the weapon impact. Post-flight review of the cockpit HUD video identified the weapon impacted 2.8 km to the north-west of the intended target position and outside weapon trace. The JTAC OP was situated in a direct line between weapon impact point and the intended target, 1000m to the south-east of the impact.

are responsible for identification of, and separation from, civilian VFR aircraft.

During CAS engagements in the F/A-18A, aircrew members are required to select a different system (radar), with a corresponding different screen displayed on the Multi-function Display (MFD). While conducting an air-to-ground pass, this has the potential to be a distraction in a high-workload situation.

The incident pilot recalls selecting air-to-air on the radar in order to clear Thornton Gap, and displaying this on the right-hand MFD. While this is a normal process and considered good airmanship, in this event the radar picture was left on much longer than is considered normal. This selection further exacerbated the target designation error, as it likely prevented the incident pilot from identifying that the system was still in scene track.[7]

It is a requirement of BOT engagement that the target is positively identified[8] before weapon release. Hornet 2 did not visually confirm the target before weapon release. The pilot does recall a moment of unease just prior to weapon release, based on a dirt road feature that was not expected; however, they did not act on that unease and abort the weapon release.

The incident pilot recalled feeling under high workload in the run-in to the target, and was distracted by helmet failures (and the required bit checks[9] to correct those), radio issues and the Thornton Gap VFR lane. Filtering describes how an individual can unconsciously filter out cues or information due to overload. Confirmation bias describes the favouring of information that confirms previously held or existing beliefs.

The incident pilot believed they had correctly designated the target point, and the weapon release was going to be on the correct target. It is possible that the incident pilot disregarded the conflicting information (the momentary unease associated with seeing the dirt road) due to filtering or confirmation bias.

At 3.6 nm (25 seconds to weapon release) to the target, Hornet 2 transmitted "In heading 145" on COMM 1[10]. This call was repeated at 2.2 nm (12 seconds to release). Hornet 1 advised Hornet 2 that they were transmitting on the formation frequency, and Hornet 2 re-transmitted on COMM 2. J1 cleared Hornet 2 hot[11] at 1.0 nm (five seconds to release) from the target.

Type-2 control does not require the JTAC to be visual with either the target or the aircraft. Hornet 2 armed the Master Arm Safety Switch at 0.6 nm (two seconds to release) to the target. Weapon release was at 0.4 nm to run. The JTACs did not see the weapon impact[12]; however, they did recall seeing the aircraft overfly the OP after the weapon release, and considered that unusual.

Hornet 2 re-joined Hornet 1 in the overhead. There were no indications that the weapon had impacted outside the weapon trace.

The target selected by the JTAC was a burnt area on an expanse of dry scrubland with a number of rocks. When the incident pilot called 'Tally Target' at the completion of the talk-on, the aircraft was at FL160 looking down at the target. From that altitude, the burnt area was easily distinguishable from the surrounding landscape; however, the attack run-in was at low level and the burnt patch was not as distinct.

The selection of targets available to the JTAC in Impact Sector East is limited and not all are optimised for air-to-ground training. Those that are available lack important features such as shape, colour, contrast and size.

These features of target identification make targets distinguishable from their surroundings. Additionally, from low level there was no discernible silhouette to assist in positive visual identification. The lack of suitable targets in the training area has been highlighted by several ADF organisations that regularly use the ranges for air-to-ground exercises.

While the incident pilot did not follow procedure and visually positively identify the target prior to weapon release, a more distinct target would likely have provided a stronger cue that the system was not depicting the actual target, aiding in preventing erroneous weapon release.

JTAC observation post

The JTAC observation post was 1000 m from the assessed weapon impact point and in-line with the aircraft approach. Normally, the range or weapon drop restrictions (as per the 9-line) provide procedural controls to prevent the aircraft overflying the observation post. The system drift in this event caused the final attack run-in heading to align with the JTAC observation post position.

The weapon impact point was 1000 m to the north-west of the observation post, as the aircraft was tracking 145, it was between the weapon impact point and the intended target. JTAC OPs are not normally marked in a specific way and protection from friendly fire is based on attack procedures and communications between the aircraft and the JTACs. In this event, the JTAC OP was not within the weapon trace and the JTACs did not see the impact but the risk of system drift to the JTAC location did exist.

Had the OP been marked, or better distinguished from the surrounding area the visual cue to a pilot may have been the final defence against a friendly fire incident or accident. While the ASIT notes that this is not practical in operations, during training events marking friendly positions using available marker options will reduce the risk of friendly fire.

Conclusion

There are several elements, both system and human that came to play in the culmination of this event. High workload, pressure to perform, distraction and system reliance on the part of the pilot combined with low levels of currency in close air support within the unit led to a situation where a bomb was released outside the Townsville Training Area weapon trace.

Add to this a target that had no distinct features at low level and we can see how holes in the defences are beginning to align. The cap this, the last line of defence, a well-defined observation post was missing, completing the equation.

ENDNOTES

1 Call signs Hornet 1 and Hornet 2 are used to de-identify pilots for this publication

2 A laser spot hand off is when one platform matches the laser to a point that has been illuminated by another platform's laser.

3 Sighting of a target, non-friendly aircraft, or enemy position

4 A spot charge is a small explosive charge used to assist in the identification of the impact location for practice munitions.

5 9-line is the standard proforma by which target information is passed between a JTAC and an attacking aircraft.

6 Prior to departing the overhead of the target area and turning to the north-west to gain separation to set up for the attack run-in.

7 Having the right-hand MFD in FLIR mode would have provided two cues to the pilot; first the screen would depict a 'SCENE' notification on the bottom of the picture, and then the system would have been visually drifting. The pilot still may not have identified the error, as this screen is not primary for this stage of target run-in.

8 Positive identification requires visual confirmation of the target.

9 Bit checks are built-in checks that hardware devices have to control the accuracy of the systems.

10 Due to poor radio performance earlier in the sortie, the JTAC frequency was switched to COMM 2, and formation FREQ to COMM 1. The initial in-call was made on COMM 1 (inter flight).

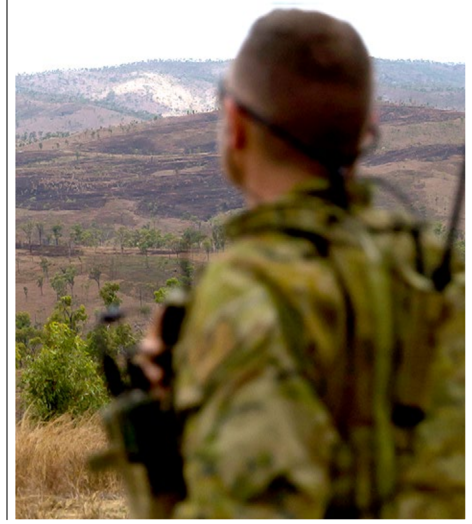
11 'Hot' is the clearance to release the weapon.

12 Weapon impacts are normally marked by spot charges; however, these were not in use due to a fire ban in the area.

Director DFSB comment:

The role of a fighter pilot will always be extremely demanding and learning and practising new skills will test even the very best. However, this event does not just present lessons for our fast-jet community because it demonstrates that under pressure, a simple error like selecting the incorrect system mode, could have major consequences. Humans will make mistakes – so this needs to be catered for in planning and risk management.

In this particular event, the weapon was a practice bomb with no explosive charges that was released over an unpopulated Defence range area. How different this outcome might have been if a high-explosive live weapon had been released in a populated area! It is very clear that the training scenario had actioned some prudent risk-elimination and minimisation strategies.



Canopy opens during flight

ON 14 APRIL 2019, an Australian Air Force Cadet (AAFC) solo pilot, flying a DG1000-S glider, aborted an aero-tow take-off after realising that the aircraft's rear canopy was unlocked and conducted a turn-back manoeuvre to Bathurst Regional Airport.

During the manoeuvre, the glider's rear canopy fully opened; however, the pilot successfully executed a safe turn back and landed on the reciprocal grass runway.

The glider suffered damage to the airframe associated with supporting the rear canopy structure.

Glider

The DG1000-S is a visual flight rules (VFR) two-seat, high-performance sailplane used for aerobatic training and cross-country flight. Air Force gliders are registered in the Utility Category with the Glider Federation of Australia (GFA) and deliver air experience and flying training flights to AAFC units.

Flight history

Pre-flight. Following the pre-solo check flight, the solo supervising instructor (SSI) vacated the rear cockpit of the glider, secured the rear-seat harness, closed and locked the rear canopy, closed the sliding vent (the vent provides access to the internal locking handle) and removed the tail ballast weights (to configure the glider for a solo flight configuration). The pre-solo flight brief was conducted in situ between the SSI and the event pilot-in-command (pilot) before the instructor returned the ballast weights to the assigned storage space and authorised the event flight.

The event pilot conducted the pre-boarding checks (ABCD)[1], boarded and carried out the pre-take-off checks (CHAOTIC)[2]. When the event pilot occupied the forward pilot's position, the glider was third in line on the duty runway awaiting an aero-tow by the tug aircraft.

On the two occasions that the glider was moved forward in the launch line, the pilot sought assurance from the ground crew/canopy holders[3,4] that the rear cockpit/rear canopy remained secured for launch. Each time, the pilot was told (from the attending ground crew) that the glider was ready in all respects for launch.[5]

Due to the high ambient temperature during the launch sequence, the event pilot kept the front-seat canopy open for ventilation. The canopy was closed only during the launch of those gliders ahead of him in the launch sequence to avoid prop wash. As the canopy was predominantly open before launch, the event pilot was in constant communication with the attending ground crew.[6]

Prior to the launch, the event pilot was satisfied that both the rear- and front-seat

> During the turn-back, the canopy fully opened (and remained so for the rest of the recovery), markedly increasing the wind rush noise within the cabin space. Despite the distractions, the PIC conducted a safe turn-back recovery to the airfield before the glider came to rest …

canopies were appropriately secured.[7] On reaching the launch position, the tug tow rope was checked for knots and the towing ring inserted into the tow-hook release mechanism.[8]

Take-off. During the towed take-off run prior to lift off, the pilot was content with the handling qualities of the aircraft but noted there was a discernible rumbling noise interspersed with occasional banging emanating from behind him. Believing that the noises were associated with wheel rumbling/bouncing, the pilot continued with the towed take-off. Once airborne from the grass runway strip, the noises continued.

Canopy open during flight. At approximately 50 feet above ground level (AGL), the pilot glanced over their left shoulder to identify where the unusual noises were emanating from and noticed that the rear canopy was unlocked.[9] The pilot quickly assessed the situation and decided to continue with the aero-tow until in a position to effect a safe turn-back manoeuvre – once outside the non-manoeuvring area[10] (NMA) – to the airfield.

Recovery. Having assessed the NMA options[11], the pilot aborted the aero-tow at approximately 200 ft AGL and conducted a constant speed (about 100 kmh/54 kts)[12] right-hand turn, in a shallow descent, towards the airfield.[13] During the turn-back, the canopy fully opened (and remained so for the remainder of the recovery), markedly increasing the wind rush noise within the cabin space. Despite the distractions, the pilot conducted a safe turn-back recovery to the airfield before the glider came to rest on Runway 35 Grass Left. [14]

Post event. The ATS unit immediately paused flying operations to assimilate the facts before electing to return to flying for the remainder of the day. Thereafter, the unit received a verbal instruction from CB-AF to cease flying operations on Monday 15 April 2019. This instruction was in accord with the Cessation of Flying Directive issued on 16 April 2019.

Damage to aircraft

Due to the inertia and aerodynamic forces involved when the canopy completely opened in flight, the canopy hinge attachment points sustained over-extension damage, which resulted in a canopy misalignment. This was most notable when the Perspex part of the canopy was in the closed position, as it could not be correctly seated and locked. There was also minor delamination to the hinge arm supporting structure of the canopy mount.

The perspex portion of the canopy utilises a retaining line and clip to prevent over-extension of the canopy mechanism during normal ground operations. This clip was over-extended, to the point of separation, which resulted in minor contact scratching to the adjacent wing structure.

Had the canopy detached from the airframe during flight and struck the empennage, it is expert opinion that the controllability of the glider would likely have been compromised.

Qualification, currency and recency

The event pilot was deemed by the ASIT to be qualified, competent and current on the DG1000-S for the event sortie and was correctly authorised for the sortie by the SSI. The pilot's total gliding experience consisted of 42 dual flights and 12 solo flights. In the 12 months prior to the event, the pilot had conducted seven solo flights.

Canopy

The DG1000-S glider has two Perspex canopies servicing a single cockpit area. The front- and rear-seat canopies are separated from one another by a single curved supporting spar. Each canopy is secured to the airframe by hinges rigged on the starboard lower side of the canopy. The corresponding locking mechanisms for both canopies are situated on the port side of each cockpit below where the canopy meets the airframe.

Design

The canopy hinges are attached to the fuselage mounts by a control rod connected to the emergency release handle lever. It also has a gas strut attached at the front of the canopy and a restraining cable at the rear to prevent the canopy from over-extending.

When the canopy is closed, it is locked into position by the canopy white-red locking handle lever which operates the canopy locking pins. The canopy locking handle (moves the locking pins to mate with the front and rear locking pin holes on the fuselage canopy structure.

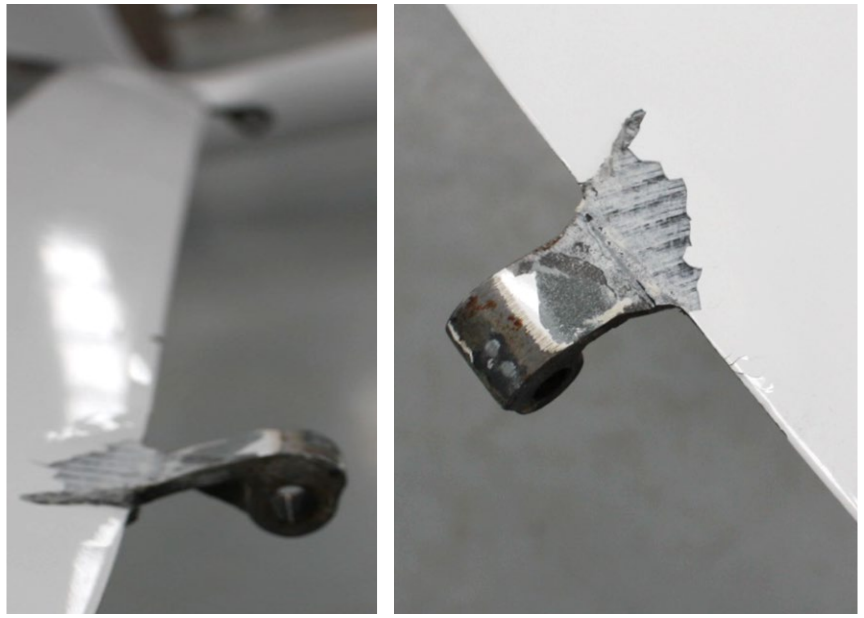
Operation

Cycling the canopy locking handle from open to closed moves the handle lock and pinning mechanism freely through the matching locations on the fuselage. When the locking handle is in the closed position the locking pins extend into/through the matching locations on the fuselage ensuring positive engagement of the locking pins to the fuselage.

Thereafter, the canopy is fully closed and locked flush with the fuselage.

Voice and flight data recorder

AAFC DG1000-S gliders are fitted with conventional FLARM[15] Flight Data Logger, which records metric flight data that can be used to determine aircraft usage and post-accident or incident analysis.



Hinge over-extension and supporting structure damage

Had the canopy detached from the airframe during flight and struck the empennage, it is expert opinion that the controllability of the glider would likely have been compromised.

Database search

A review of GFA safety operations and airworthiness reports for previous unlocked-canopy events revealed the AAFC ATS had experienced three similar events, which involved either gliders or tug aircraft. Since April 2016, there have been two other reported canopy events that occurred under the auspilotes of AAFC operations.[16]

Planning and risk management

Prior to the event pilot's solo flight, the SSI had ensured that the pilot was compliant with the qualification requirements to fly, as stipulated by the GFA. Before the event flight, the SSI conducted a 17-minute solo check flight with the event flight pilot. During the solo-check sortie, the pilot was assessed on flight manoeuvres relevant to the event flight, all of which were assessed as well flown. Notably, a simulated malfunction and turn-back procedure were discussed during the pre-solo check flight where airspeed calculations and emergency actions were rehearsed.[17]

The event pilot's logbook is annotated with an assessment as competent to conduct launch emergencies.

Operations

Launch line operations (training). The ground handling team is drawn from AAFC members. New cadets are initially introduced to glider operations as members of the attending ground-handling team and learn their duties through tuition and from working with more senior cadets.

Air Force cadets attending their first glider camp wear a dayglow coloured vest annotated with BASIC on the back so that all participants can recognise their inexperience and treat them accordingly. When a cadet is deemed suitably trained and competent to conduct ground-support operations, their flying log book is annotated by an authorised senior cadet.

The ASIT found no evidence of a ground-handling training syllabus on how to prepare and launch gliders nor what constituted a cadet to be suitably trained and competent to conduct ground-support operations.

Similarly, the ASIT did not find any evidence that a ground-crew-to-aircrew challenge/response checklist or procedure was used to ensure that the event DG1000-S glider was correctly configured prior to take-off. The pre-launch checklist issued in SOI 01-19 was already in use within the wider glider community, but had not been mandated for use by AAFC.

The ASIT acknowledges that the Resumption of Flying Directive specified that flying could only resume under two conditions. The second of those conditions was the introduction of glider pre-launch checks (SOI 01-19), designed to ensure that gliders are ready, in all respects, for launch. SOI 01-19 has been published; however, has not been incorporated into mainstream AAFC orders, instructions and publications (OIP).

Launch line ground handling. Before the event flight, the event aircraft was third-in-line awaiting aero-tow launch and the solo pilot completed the pre-boarding and pre-take-off checks (ABCD and CHAOTIC).

For solo operations, it is normal that the rear canopy is closed to maintain a sterile[18] rear cockpit. Conversely, it is usual to have the front canopy open, as it is easier to communicate

between the pilot and attending ground crew; and facilitates ground movement.

During the ground-handling evolutions the solo pilot sought assurance from the ground crew/canopy holders[19] that the rear cockpit remained secure after each move forward. The canopy holders who attended the glider revealed that, during the ground moves, they "didn't pay any attention to the canopy handles, sliding vent or notice the rear canopy not being flush with fuselage".

They also recounted that the rear canopy was never opened as the glider progressed down the launch line, adding that they were unsure of the position of the canopy handle throughout the process.

Both the pilot and SSI said they had locked the rear canopy and closed its sliding vent[20] prior to the pilot boarding the aircraft. The security of the rear canopy was also confirmed by the attending ground crew.

Given the presented evidence, the aircraft's structural integrity, the robustness of the canopy locking mechanism[21] and the AAFC DG1000-S's record of service, the ASIT concluded that that the glider almost certainly commenced its aero-tow launch with the rear canopy unlocked. During the launch sequencing, the evidence supports that there were several instances where the support from the ground crew was not in accordance with established procedures. This approach to ground operations very likely contributed to the glider launching with its rear canopy unlocked.

The ASIT considers that this deviation from established ground-handling procedures is not confined solely to this event. The lack of checklists and formal training for ground crew supports this assertion. This arrangement is of particular concern for solo operations, as it is difficult for a front-seat pilot to check the physical status of the rear canopy's locking handle.

Remediation

To ensure that launch sequencing is better managed, the ASIT recommended that a dedicated, and suitably qualified, lead ground-handler[22] be assigned to all solo-piloted airframes during the launch sequence. The lead ground-handler is to provide a continuity of service to the pilot and ultimately, assurance that the glider is, in all respects, ready to launch. The lead ground-handler qualification (and the duties thereof) should be clearly articulated within AAFC OIP.

Safety controls

The ASIT was unable to definitively conclude the sequence of events that led to launching with an unlocked canopy. However, it is clear from the photographic evidence that the rear canopy was opened after the pilot conducted their pre-launch checks. It is also evident that a number of ground crew members had the opportunity to identify that the rear canopy was open and/or unlatched. Human information-processing errors were evident during this event.

Conclusion

From the evidence available, the ASIT found that the glider commenced a towed take-off with the rear canopy unlocked. The pilot believed that both the rear and front-seat canopies were appropriately secured for flight. The mistaken belief that the rear canopy was locked stemmed from advice from the attending ground crews'.

The ASIT concluded that sub-optimal training, a lack of checklist/procedures and poor visual cues probably contributed to the ground crew not identifying that the rear canopy was unlocked. Had a dedicated lead ground-handler been allocated to the launch process and tailored ground crew training and robust OIP been in place prior to launch, it is probable that this event would not have occurred.

Director DFSB comment:

Cadet experience flying with the AAFC plays a key role in developing future military aviators so it's an activity that the Air Force will want to continue. However, the workforce within the AAFC isn't a highly standardised, full-time workforce so we need to carefully manage the hazards and risks associated with the AAFC operation so it can be done safely.

There are many findings in this report that demonstrate a conscientious approach to supervision and training and excellent initiatives such as the introduction of pre-launch checks and training of ground handlers. However, procedures are only good when they are followed properly – all the time.

Once again, we have an event that could have been much more serious which gives us an opportunity to learn some important lessons on how things could have been done better. There are many small things that all contributed to one big thing. And again, we confirm that even the best humans are fallible.

ENDNOTES

1 ABCD is the pre-boarding checks pneumonic consisting of Airframe, Ballast, Controls and Dollies (ground-handling equipment).

2 CHAOTIC is the pre-take-off checks pneumonic consisting of Control Access, Harness, Airbrakes and Flaps, Outside (airspace and flight path)/Options (emergency plan and critical speeds), Trim (as required for launch), Instruments (including radio, transponder and battery voltage) and Canopy (closed and locked), Carriage (undercarriage) and controls (effects).

3 AAFC non-flying student aircrew commonly act as attending ground crew to those AAFC members who are programmed to fly. The ground crew assists in the movement and positioning of queuing gliders awaiting launch.

4 Ground crew can only ground move the gliders by using specific strong points on the airframe. Some of those strong points are only accessible if the rear canopy section is opened.

5 As attested by the event PIC during the ASIT interview. This viewpoint was not contested by attending ground crew members who were also interviewed by the ASIT.

6 From the ASIT interview, the event PIC stated that there was no continuity of service from any one particular ground crew member due to the ad-hoc nature of ground crew employment.

7 Attested by the event PIC. The front-seat canopy was physically locked by the solo PIC. The rear-seat canopy was visually adjudged to be secure by the PIC (by looking over his left shoulder). The PIC recollects (but is not certain) that the rear canopy had been confirmed locked by attending ground crew.

8 Ground crew duties for launch include checking the rope condition and ensuring the connecting ring is placed correctly into the aero-tow release mechanism.

9 While appearing to be in the closed position, the canopy was unlatched and the port side of the canopy was bouncing on the aircraft frame.

10 During any take-off, there may be a point where, if the winch, tug or self-launcher's engine loses power, the glider is not high enough to turn back to the strip but is too high to land straight ahead (within the airfield boundary). This is called the non-manoeuvring area (NMA)

11 The NMA's lower boundary is defined by the height at which a pilot can no longer safely land straight ahead within the airfield and its upper boundary by the height at which the pilot can easily turn and make a modified circuit to land back on the airfield.

12 Airspeed derived from the aircraft's Flight Data Logger a FLARM (an acronym based on 'flight alarm'). See paragraph 34 for more detail. The FLARM utilises metric units (kilometres/metres)

13 Utilising the FLARM, VH-NGH reached a zenith of 63 m (207 ft) AGL at 103 kmh (57 kts) and was on finals (reciprocal to departure heading) to land at ~ 36 m (118 ft) AGL at 104 kmh (56 kts).

14 SME opinion is that there would have been a slight increase in the aircraft's drag (with the canopy fully open). The PIC did not report any noticeable change to the glider's handling characteristics during the event.

15 FLARM is the proprietary name for an electronic device which is in use as a means of alerting pilots of small aircraft, particularly gliders, to potential collisions with other aircraft which are similarly equipped.

16 Winch launch, solo pilot, front-seat canopy unlatched during take-off. Pilot secured canopy during downwind leg; April 2016. 2) After release of glider, in a 95 kt descent, tow aircraft's starboard Perspex hatch unlocked. On landing, hatch was found shattered and had punctured fuselage fabric. Both events attributed to the canopy locking mechanism not correctly secured prior to take-off.

17 All the flight details were derived from the SSI (during an ASIT informal discussion).

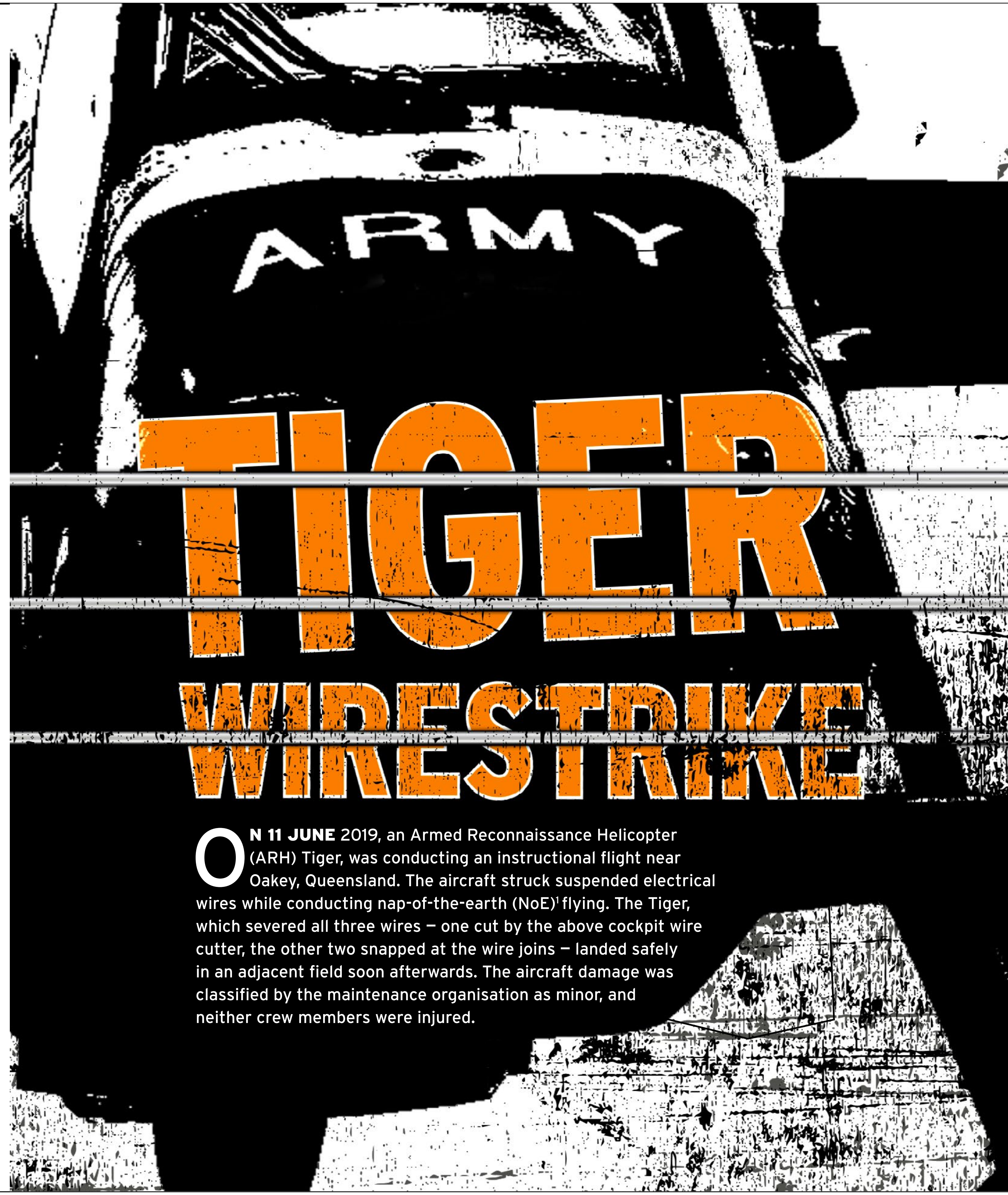
18 Sterile equals secure, clean and unused. No one has messed it up or done anything to it. Free of distractions.

19 During solo operations, canopy holders are instructed to concentrate on the rear-seat harness and ensure there are no obstructions to the flight control stick when giving the all clear to the PIC.

20 When the rear seat is not occupied, the canopy is placed in the closed position (down) and the sliding vent is used to access the locking handle (from outside the canopy). The sliding vent (if required) can then be slid forward to the closed position.

21 The ASIT was unable to definitively establish the position of the locking mechanism handle when the aircraft came to rest.

22 Lead ground-handler is a generic phrase, the operator may derive a term that better articulates the role in their context. Other services and nations use plane captain.



TIGER WIRESTRIKE

ON 11 JUNE 2019, an Armed Reconnaissance Helicopter (ARH) Tiger, was conducting an instructional flight near Oakey, Queensland. The aircraft struck suspended electrical wires while conducting nap-of-the-earth (NoE)[1] flying. The Tiger, which severed all three wires – one cut by the above cockpit wire cutter, the other two snapped at the wire joins – landed safely in an adjacent field soon afterwards. The aircraft damage was classified by the maintenance organisation as minor, and neither crew members were injured.

Seconds later, the nose of the aircraft impacted the powerlines. Two of the three wires slid up the fuselage. The first snagged on the front-seat pilot's windscreen wiper stop, the second wire continued to the upper wire cutter and snapped.

Pre-flight brief

The trainee pilot delivered the sortie brief to the qualified flying instructor (QFI) about 90 minutes before the sortie utilising the briefing format from the ARH Flight Crew Checklist. During the brief, the planned mission sequence was modified by the QFI, amending one of the navigation routes to maintain safe separation from a known set of wires.

The QFI reinforced the sortie aims, particularly those relating to the management and captaincy aspects. The QFI also emphasised the need for the crew to fly wire aware[2] and identified the geographical position (on an appropriate map) of conflicting wires.

The trainee had conducted syllabus rear-seat training sorties (simulated and actual flight) but not while conducting NoE flight. The shortcomings pertaining to the restricted visibility for the rear-seat pilot were not covered during the pre-flight brief.

Flight authorisation brief

The flight authorisation brief, between the QFI and the authorising officer (AO), was conducted after the crew pre-flight brief. The AO highlighted that the selected low-flying area (LFA) for the event sortie contained multiple wires with several wires strung across valleys.

As such, the AO instructed the sortie QFI "to identify the high wires" so the trainee pilot would be aware of them prior to the next sortie. The AO did not direct the QFI to conduct the sortie in another LFA that contained no wires. LFAs are designated as L1, L3, L4, L5, L6, L7, L8 and L10.

Flight

The occurrence aircraft launched from Oakey airfield at 1003 departing to the north. The trainee pilot conducted the departure administration and flew the pre-planned navigation route to L10C, Pad 8.[3] The QFI (pilot-in-command) occupied the aircraft's front seat; the rear seat was occupied by the trainee pilot.

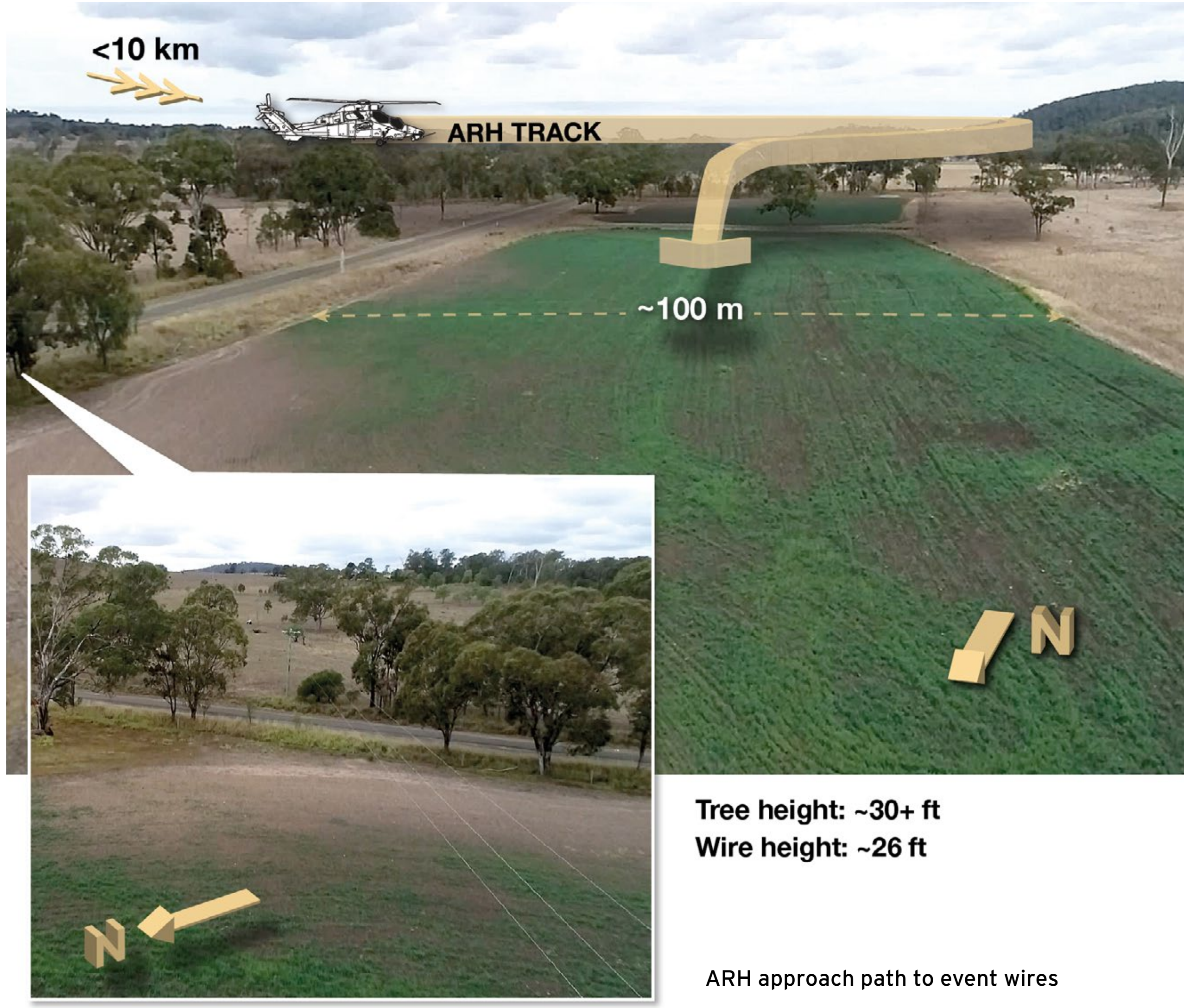
On entering LFA L10C, the Tiger operated at a height not below 50 ft above the highest obstacle.[4] Three of the L10C powerlines briefed by the AO were identified by the crew prior to the first non-navigational sequence of the sortie. This first sequence included a confined area[5] approach into Pad 8.

Following the departure from Pad 8, the Tiger contour navigated[6] to Pad 5, at a height not below 50 ft above the highest obstacles. The route generally followed the pre-selected base heading chosen to minimise encountering wires. The next approach into Pad 5 was deemed too steep and fast for the confined area, so a go-around was conducted. The subsequent approach into Pad 5 was flown to the satisfaction of the QFI.

A Reduced Visibility Operations (RVO) take-off[7], into NoE flight, was then conducted from Pad 5. For this flight leg, it was planned that the aircraft would not descend below 10 ft above the highest obstacle; with a decision height of 10 ft set internally. The QFI, as the non-flying pilot (NFP), provided navigation direction (including notification of wires/pylons) while the trainee pilot flew the designated route. At this point, the aircraft's mean line of advance was westerly (approximately 7 km clear of any surveyed wires) before turning to the north, with the intent to then navigate the aircraft back towards the east of the LFA.

Shortly before the event the aircraft approached wires (identified from the in-flight map)[8] from the south. The QFI briefed that these wires were associated with a road and once the aircraft was to the north of that road, and clear of the briefed wires, the trainee pilot could descend the aircraft to the briefed NoE operating height.

As the aircraft progressed and cleared a set of trees, the briefed powerlines were seen about 500 m ahead. This coincided with the intended flight path (to the north-west of the now observed wires) also coming into view. Due to the elevated terrain and trees on the north-western side of the planned route, the QFI assessed that the terrain to the south-east of the seen powerlines better suited NoE flight.



ARH approach path to event wires

Based on this assumption, the QFI directed the trainee to fly south-east of the observed wires and to track north, north-easterly

The in-flight maps depicted the event wires crossed from right to left of the new flight path (which spurred from the observed wires). The QFI recalled prioritising lookout into the intended flightpath over checking the map for wires, and therefore did not see the wire obstacle. Unbeknown to the aircrew, the right-hand support pole for the unidentified wires that lay across the revised navigation track was obscured by roadside trees, making un-alerted visual detection of the wires difficult.

The trainee pilot, now flying the revised navigation track, descended back down to NoE height. During the descent, both crew reported that they were looking out along the new flight path for wires. Descending into the clearing, the ARH Voice and Flight Data Recorder (VFDR) recorded the aircraft's speed as 58 KIAS.[9]

Seconds later, the nose of the aircraft impacted the powerlines. Two of the three wires slid up the fuselage. The first snagged on the front-seat pilot's windscreen wiper stop, the second wire continued to the upper wire cutter and snapped. The third wire went below the nose and snapped when it came into contact with the gun turret. Immediately thereafter, the

QFI took control of the aircraft and conducted an expedited but safe landing in the paddock that lay ahead of the aircraft about 100 m down track from the point of wirestrike.

During the landing sequence, the VFDR data shows that the aircraft pitched to approximately 20° nose up during the deceleration to land, with a minimum of roll to the left. The rate of descent did not exceed 600 ft/min. The aircraft ran onto the paddock at a fast walking pace, leaving light, tell-tale marks on the surface. The landing area was a dry, flat, grassed area with no undulations or detrimental outcrops.

Post flight

After confirming that neither crew member had sustained any injuries during the wirestrike event, the crew unsuccessfully attempted to make radio contact with air traffic control (ATC), school of army aviation (SAA) Flight Operations and any other aircraft in the area.

The aircraft was shut down normally. Both aircrew members checked that the airframe was clear of fallen wires before exiting and conducting a cursory inspection of the aircraft and local surrounds.

Soon after, the crew contacted the operations officer (OPSO) by mobile phone and notified them of the wirestrike event, the perceived extent of the damage and that there were fallen wires across the adjacent road.

Hazards. To make the aircraft safe, the QFI disconnected the aircraft batteries and installed the safety pins.[10]

A passer-by identified the electrical hazard posed by the downed wires and called the local electricity provider and blocked off the affected road. ERGON Energy and the Critical Incident Response (CIR) helicopter arrived about 50 minutes after the wirestrike.

Medical. Both crew members were extracted from the event site by the CIR helicopter and transferred to the Oakey Health Centre. They were assessed by the Senior Aviation Medical Officer (SAvMO) and cleared fit to fly. Their 72-hour histories were reported by the SAvMO as unremarkable. At the time of the event, both crew members held current aircrew medical categories. No injuries were sustained by the crew during the wirestrike event, the landing or subsequent disembarkation from the aircraft.

Aircraft

Damage. Shortly after the wirestrike event the crew conducted a cursory damage assessment of the ARH before making the aircraft safe and fitting the appropriate blanks and covers.

The following day, a comprehensive inspection of the aircraft was carried out by an authorised maintenance crew under the supervision of the Aviation Safety Investigation Team (ASIT) and senior maintenance staff.

The inspection included a tap test[11] of the forward nose area to search for any potential delamination under the skin of the fuselage.

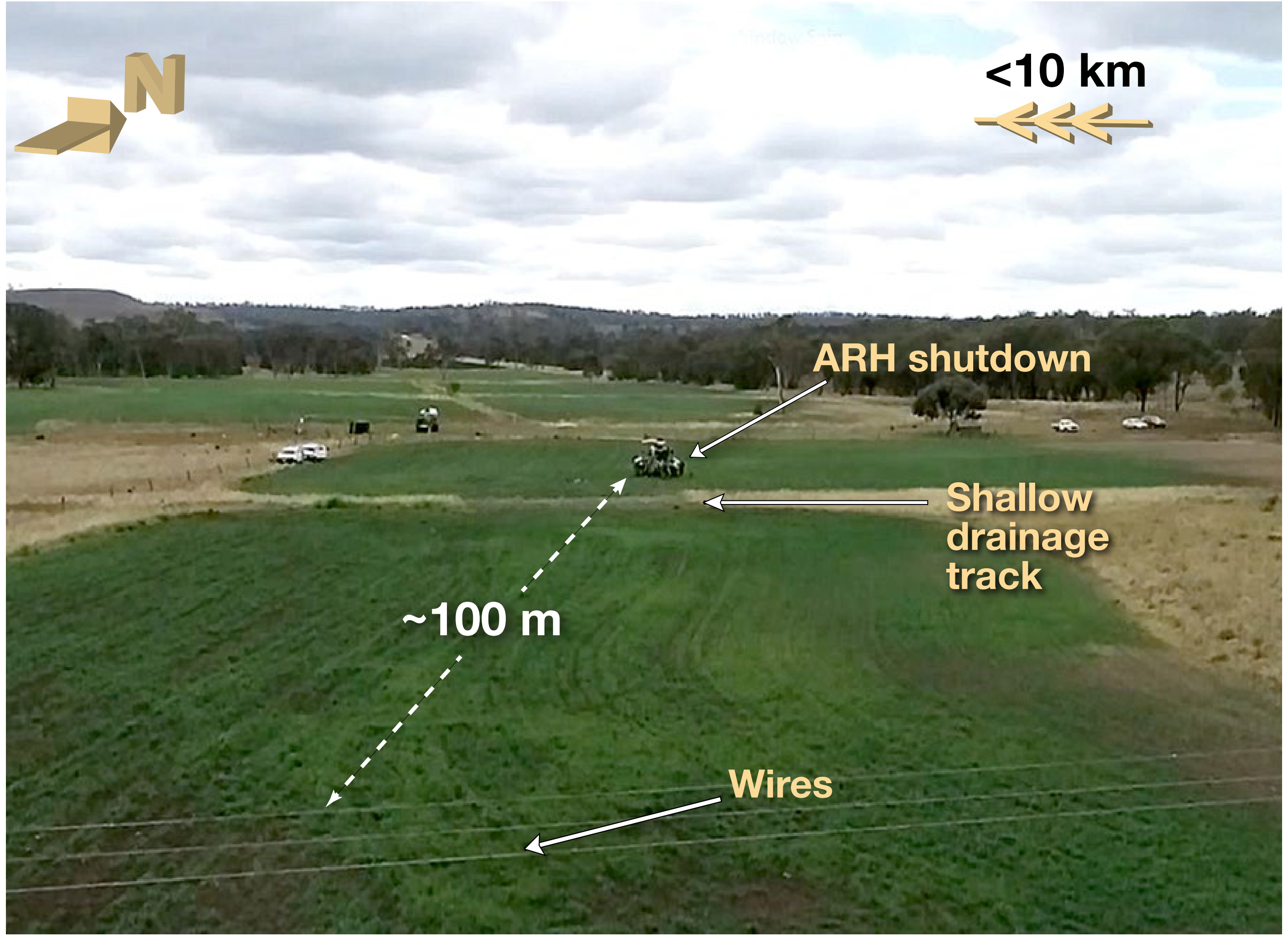
The in-situ inspection revealed evidence of airframe electrical arcing through the wirestrike points all the way to the upper Wire-Strike Protection System (WSPS). There were also several superficial damage/scoring instances to the fuselage, pylons and main rotor disc.

Other damage to the aircraft included the shearing of the breather stem of the starboard stub-wing ferry tank, damage to the exterior sheath of the wiring loom, damage to the starboard-side windscreen cabin metal strip and the attached wiper stop.

There was also a deep gouge on the bottom side of the 30 mm gun cradle mount. As there was evidence of electrical arcing on the aircraft, the maintenance staff established the serviceability of the avionics system by carrying out functional testing[12], and no defects were found.

Qualifications, currency and recency

The QFI and the trainee were appropriately qualified and current to conduct the assigned sortie. Their sortie was authorised and correctly (electronically) recorded.



Wirestrike event – landing area

Environmental

Terrain. The event site is situated on an area of flat, level, agricultural land, surrounded by low, hilly terrain. The paddock where the Tiger struck the wires and then landed, is oblique in shape, less than 1 km^2 in area, with its longest length orientated in the direction of aircraft travel. Though sparsely vegetated, there are several tree lines in the immediate vicinity of the struck wires. Parallel, and to the right of the direction of travel, there is an irregular scattering of trees, approximately 10 m tall, associated with a minor metalled road. These trees mask the easterly stanchion for the event wires, making the cues to wire detection difficult. About 100 m to the south of the wirestrike site, another tree line lies perpendicular to the trees associated with the road, marginally hindering the aircrew's forward visibility.

Wires. The three event wires (strung closely together) were 12 mm in diameter and strung at approximtely 8 m (26 ft) above ground level. The ASIT was informed by ERGON Energy that the restrung wires were the same colour

Tap test to nose section

The ASIT checked the replacement wires after the event[13] and determined that they were, regardless of the ambient light, dull in appearance and difficult to distinguish from the background features.

as the wirestrike wires. The ASIT checked the replacement wires after the event[13] and determined that they were, regardless of the ambient light, dull in appearance and difficult to distinguish from the background features.

Flight recorders

The ARH VFDR system consists of a Data Acquisition Unit, a crash-tolerant solid-state memory module (Crash Survival Memory Unit), and an Area Microphone installed between the front and rear cockpit positions.

Following the strike event, the VFDR unit was removed from the aircraft and both voice and data, for the entirety of the event flight, was quarantined for analysis.

Survival aspects (WSPS)

The ARH is fitted with a WSPS to mitigate the effects of in-flight helicopter wirestrikes. The WSPS system is designed to allow the aircraft structure to assist by guiding cables around the forward part of the airframe to the upper and lower cable-cutting fixtures. These fixtures consist of an upper cable-cutter that is secured to the rear cockpit roof and two lower cable-cutters, located on the main landing gear trailing arms.

When the 30 mm gun is locked in the ferry position, as in this case, the gun also forms part of the WSPS, directing cables into the lower cable cutters. During this wirestrike event, the three wires broke at the point of impact, or very soon after. Two wires progressed above the nose of the aircraft, and one went below. All three cables appear to have separated as a result of the aircraft's forward motion through the wires. The upper WSPS successfully broke one wire as designed, which prevented any further upward travel of the wire into the rotor disc.

The second upper wire appeared to break under the increasing strain while snagged on the pilot's windscreen wiper stop and impacted the side of the aircraft causing superficial damage. The gun successfully deflected the third wire from impacting the underneath section of the aircraft, but resulted in the scoring marks on the lower gun mount.

Aircraft emergency response services

The crew alerted OPS to the event after effecting a safe landing. The commanding officer activated the Oakey Base Emergency Plan. These actions included activation of the CIR Helicopter and Oakey Medical Centre.

The unit also activated the media response plan, including Facebook messaging. The crew was retrieved by the CIR helicopter and taken to the Oakey Medical Centre for the appropriate post-incident screening.

A security detail ensured that the aircraft remained secure and quarantined in-situ. Detailed pictures and drone footage of the event site were also taken. All recording devices in the aircraft were quarantined in accordance with (IAW) the extant requirements for a DFSB investigation.

Previous similar occurrences

On 08 March 2012, another ARH struck the same wires as this wirestrike event. The ASIT identified the following similarities between the two ARH wirestrike events:

- a D-Category QFI was conducting non-flying pilot (NFP) duties in both instances
- a recent change in input to the ARH Pilot Course continuum
- both were NoE flights in L1OC
- wirestrike of the same powerlines within metres of one another
- the aircraft suffered similar damage.

Conclusion

The ASIT identified that, although a single crew was involved in the flight, deficiencies in organisational compliance and risk control exposed the crew to a significant safety event that Army had previously experienced. The ASIT found:

- the event was almost identical to the 2012 ARH wirestrike
- Army had not implemented actions specified by the 2012 Implementation Directive which likely would have prevented reccurrence
- Army has no documented hazard analysis for wirestrike
- the ARH training syllabus was in conflict with Army OIP designed to reduce risk
- AAvnTC has not adequately conducted junior QFI mentoring and supervision
- Had these organisational issues been rectified after the 2012 wirestrike event, it is highly likely that this wirestrike would not have occurred.

Director DFSB comment:

It's easy to be critical of an accident or serious incident, particularly from a 'one-G armchair' and with the benefit of hindsight. However, I am of the view that this event should have not occurred, perhaps most prominently because the same thing happened some seven years ago – also with an ARH and on the same wire. So, it might be worth reflecting on why the period of seven years is so significant to this case study.

When you examine the ADF's posting cycles, where we move people out of their jobs every two or three years, you might conclude that after about three posting cycles there is potential for the lessons previously identified to be forgotten or diluted.

Army aviation is addressing this and has introduced several initiatives in support of knowlege retention.

How can we learn from the lessons we identify in a manner that is enduring?

ENDNOTES

1 Nap-of-the-earth (NoE) is a type of very low-altitude flight used by military aircraft to avoid enemy detection and attack while operating in a high-threat environment. During NoE flight, geographical features are used as cover rather than flying over them.

2 'Wire aware' – the concept of maintaining good wire/pylon awareness.

3 The LFAs have designated landing pads which can be utilised by military helicopters day or night (specific to the type of aircraft). The registry for controlling the landing pads is held with AAvnTC Operations.

4 The crew briefed to use the aircraft's Decision Height (electronic warning) as a crew alert height above the minimum authorised height to enable a crew decision on terrain avoidance. It assists terrain separation and provides the ability to acknowledge the warning tone without the need to climb.

5 A confirmed area is an area where the flight of the helicopter is limited in some direction by terrain or the presence of obstructions, natural or manmade.

6 Contour navigation is the following of a terrain contour, keeping approximately the same height as one goes

7 An RVO take-off is where the visibility of flight is reduced temporarily below visual conditions due to the interaction of the helicopter airflow and the terrain (for example; dust, snow).

8 Both hard and soft copies (maps) are available to the aircrew.

9 Given the south-easterly wind (see meteorological information) at the time of the event, it is very likely that airspeed and ground speed correlate.

10 Safety pins are installed on the ground to make the canopy jettison system safe. The canopy jettison system includes pyrotechnic shear cords, which separate and disintegrate the acrylic glass of the door and canopy windows to allow for emergency escape from the ARH.

11 A tap test is an initial testing protocol. It can only find the presence of delamination and disbanding in relatively thin materials and even then it is not sufficiently reliable to determine the extent of any damage.

12 Testing demonstrated that the aircraft had not suffered any detrimental effects to the electrical system or the avionics suite.

13 The replacement wires were viewed by ASIT staff from both ground level (naked eye) and via computer screen from images taken from drone footage. The drone was hovered/flown at the same height and marginally above the height of the replacement wires, following the direction of flight taken by the wirestrike ARH.

Hawk engine-failure

ACCELERATING THE HAWK to the point of rotation during a touch-and-go manoeuvre, the pilot heard a loud bang followed by excessive vibration, which was felt through the aircraft. This was followed by a whirring sound and continued vibration.

The aircraft initially touched down approximately 600 ft beyond the threshold. About three seconds later, the pilot applied full power in preparation for the planned touch-and-go take-off. At rotation speed (about 125 KCAS)[1], the pilot heard a loud bang, followed by the onset of noticeable airframe vibration.[2]The pilot immediately placed the nose wheel on the ground and conducted a high-speed abort based on the assumption that the aircraft had blown a main undercarriage tyre.

Having determined that the safest course of action was to abort the take-off, the pilot reduced the throttle to idle, streamed the brake chute, applied the aircraft's brakes and informed air traffic control (ATC) of the intention to abort the take-off.[3] ATC acknowledged these intentions and offered the pilot the use of the barrier.[4] As the aircraft was safely under control and decelerating normally and within the confines of the runway, the pilot instructed ATC that there was no requirement for the use of the barrier.

During aircraft deceleration the pilot noted that the T6NL caption[5] illuminated on the aircraft's central warning panel. Responding to this additional information, the pilot elected to shut the engine down in accordance with the engine surge or over-temperature emergency procedure.

Neither the aircraft's central warning system (aural warning for T6NL), nor the associated attention getters functioned in association with the T6NL caption.[6,7]

During aircraft deceleration on the upwind portion of of the runway, the pilot informed ATC that the aircraft was suffering from vibrations following a large bang, and asked if they had seen anything during the aborted take-off. ATC reported that flames had been briefly seen emanating from the rear of the aircraft. The pilot, reasoning that the aircraft may have experienced an engine surge/fire, decided to egress the aircraft when it came to a full-stop. The pilot informed ATC of that intention, rolled the aircraft to a full-stop on the upwind end of the runway and egressed the aircraft as per the flight-crew checklist.

BAES maintenance staff attended the aircraft and noticed several perforations in the port side of the fuselage adjacent to the low-pressure turbine section of the engine. A visual inspection by maintenance staff confirmed that there was discernible damage to the low-pressure turbine/airframe where several blades appeared to have been sheared/released. After taking all the necessary precautions to render the aircraft safe, it was towed back to the BAES maintenance facility and quarantined.

Flight authorisation

A comprehensive flight-authorisation brief addressed all aspects of the sortie.[8] Navigation routes and the choice of suitable airspace specific to the conduct of the planned airborne sequences were also specified. The flight was to commence with a heavy weight circuit prior to departing to the local training area for a series of Hawk turns, followed by a period of aerobatics, before returning to Pearce.

Post abort recollection.[9]The following points contributed to the pilot's decision-making process after applying the abort immediate actions:

- the aircraft was not overly heavy, three-quarter fuel load
- no other aircraft were in the circuit; good understanding of the air picture
- no bird activity or foreign object ingestion seen
- Noise and vibration was described as:
  - a loud bang
  - classic 'engine shutting down' sound or that of a tyre out of balance
  - abnormal spooling down sound, as if under load similar to a tyre explosion followed by remainder of tyre spinning
- vibration was moderate, uncomfortable, but the pilot could still read aircraft instruments
- had not experienced engine surge before.

The pilot remembered that on seeing the T6NL caption they realised the tyre had not blown but instead, the aircraft had an engine issue, which resulted in the pilot shutting the engine down.

The pilot conceded that their decision to abort was influenced by the knowledge that the maximum speed for the abort was 155 kts, and this speed was based on runway 36R from a stationary start. Given the aircraft was at approximately 125 kts at touchdown, the pilot calculated that they had used less runway than from a normal take-off-and-abort scenario.

Additionally, the pilot knew they had the option of the barrier. Having seen the 5000 ft to-go marker pass the aircraft about the time of the engine-failure, the pilot assessed that there was sufficient runway to abort the take-off. The pilot acknowledged that their immediate response was to stay on the ground and deal with the perceived malfunction.[10]

Abort decision. The pilot accepted that the abort decision was not based on any visual indication or flight crew checklist (FCC), but entirely on the loud bang and subsequent airframe vibration. They also accepted it was not a normal execution of emergency drills. The pilot considered that "the loud bang and the resultant airframe vibration was a good reason not to get airborne with this problem".

Relevant information. The pilot commented that they were surprised how well muscle memory from simulator emergencies filtered through to their actions during the malfunction. Aborts are not taught in the aircraft during the IFC course'.[11] The pilot remembered a recent event when the squadron commanding officer conducted an abort during a touch-and-go due to a bird strike and felt adequately prepared for the event.

Research has demonstrated that in 80–90 per cent of decisions made during safety-critical scenarios, pilots utilise incremental actions to adaptively react to dynamic and challenging situations. In these situations, comprehensive analysis is rarely used.

DFSB evaluation. The pilot's decision to abort the take-off proved to be timely but strictly speaking, was not IAW with the example emergency brief. Given the relative inexperience of the pilot and the lack of cockpit feedback the aircraft provided, the ASIT is of the opinion that the pilot acted creditably during this event sequence.

Nevertheless, had the pilot comprehended the aircraft's loss of thrust at the point of engine-failure, it is certain that the abort decision would have been IAW the emergency brief.

Decision-making. This event serves to highlight the hazards associated with making split-second decisions when dealing with significant aircraft malfunctions. Research has demonstrated that in 80-90 per cent of decisions made during safety-critical scenarios, pilots utilise incremental actions to adaptively react to dynamic and challenging situations. In these situations, comprehensive analysis is rarely used.

Recognition-primed decision-making (RPD) is often used by aircrew who have only a matter of seconds to address an aircraft malfunction. RPD generates fast reactive courses of action which may be difficult to justify as decisions are more instinctive than planned.

Defence aviation exploits this trait by enforcing the rehearsal of boldface actions, which can be intuitively used during high-stress situations (priming RPD from rule-based decision-making). Rule-based decision making caters for all levels of experience and results in expedient and justifiable actions based on expert instructions; however, if the rule is applied without consideration, a person may apply a wrong or sub-optimal rule.

Alternatively, choice-based decision making allows for the comparison of viable options, which leads to optimal and justifiable decision-making. For this uncontained engine event, the pilot initially applied an RPD as they did not have an appropriate rule-based decision-making model that suited the perceived malfunction.

As the seconds passed, and the pilot was in a position to better assimilate the presented information for the malfunction, the pilot adjusted their initial RPD to that of rule-based decision-making. While individuals primarily rely on rule-based or choice-based decision-making during their aviation career, they may be faced with unique challenges where they have to design a temporary fix using non-standard procedures.

This is known as creative decision-making and produces an untested solution for an unfamiliar problem. This type of decision making may be difficult to justify without precedent. It is important for aircrew to be mindful of their limited experience when making decisions and where possible, should ideally rely on rule-based decision-making (orders, instructions and procedures) in instances such as the event engine failure.

Damage to the aircraft

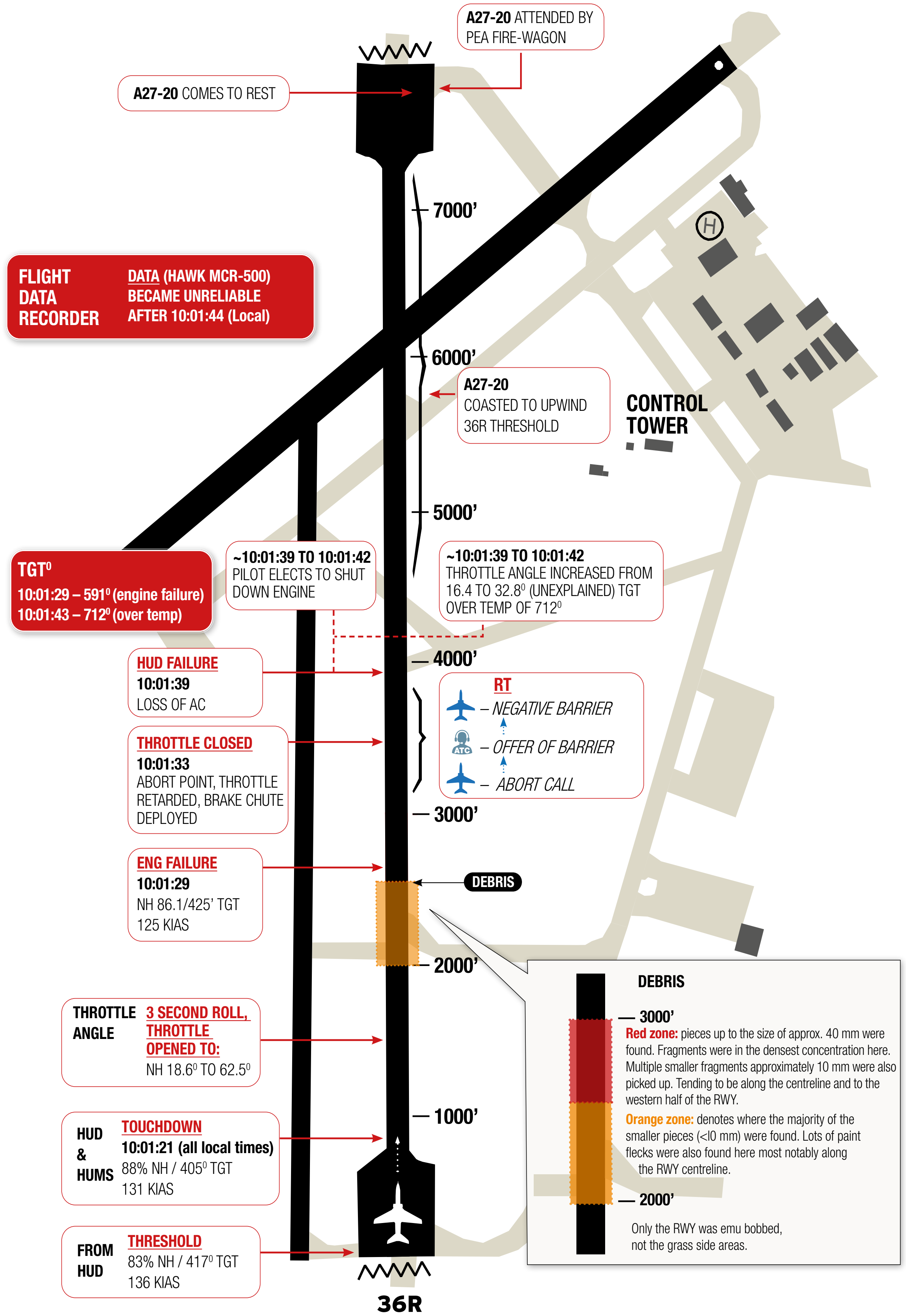
As a result of the uncontained engine failure[12], the aircraft damage level was categorised as substantial,[13] requiring significant time and resources to rectify, including an engine change, multiple component changes, wiring rectification and repairs to the aircraft's structure. After removal of the engine, damage was also evident in the engine bay.

Wiring. During the event, several components/wire looms suffered damage causing associated electrical, data sub-systems and components to not function correctly.

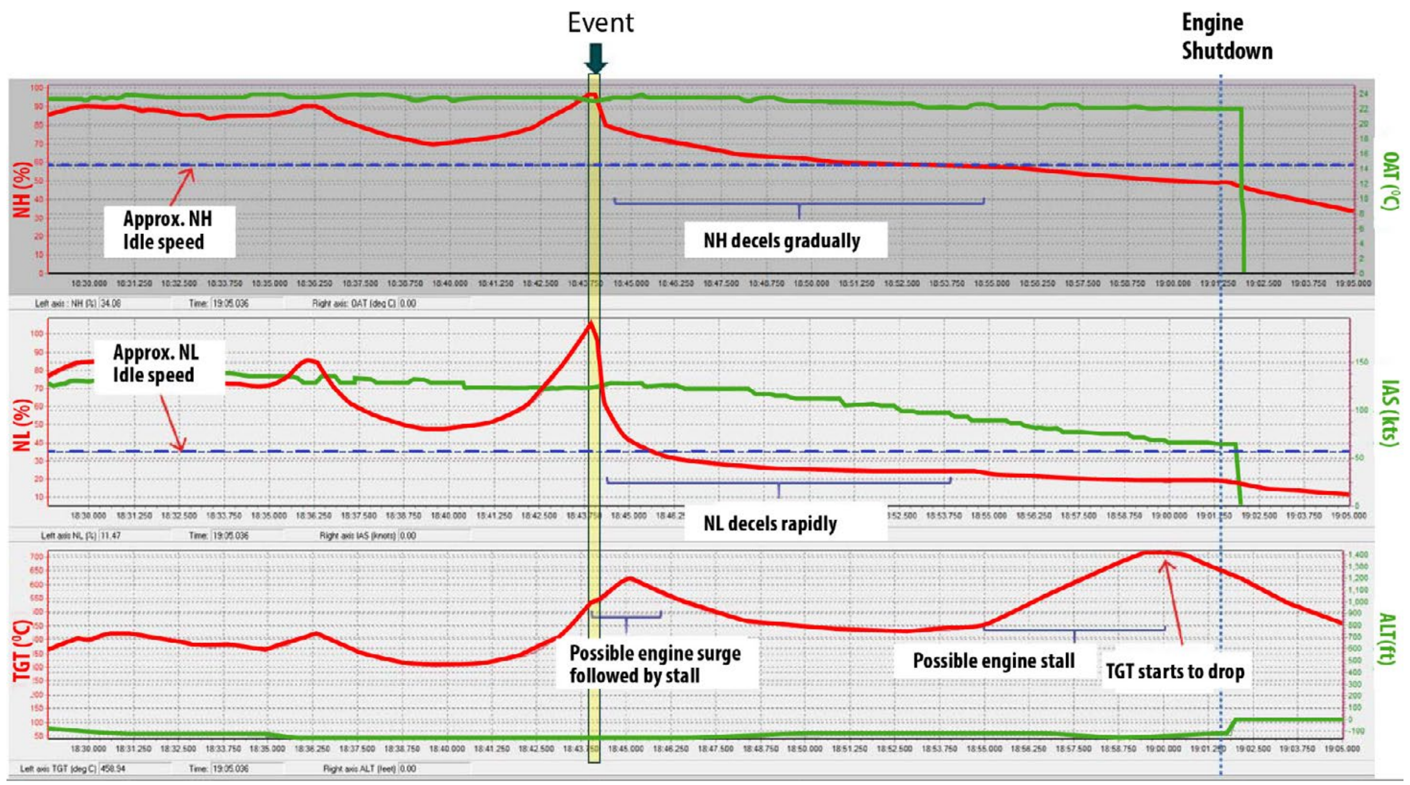
Damage to the engine

The onsite visual inspection by BAE identified damage to the LPT where a number of the blades appeared to have been released, damaging (non-penetrative) and puncturing the fuselage. The engine was removed from the airframe and air-freighted to the UK for an investigative strip by the OEM.

Installed engine inspection. Visual examination of the engine's intake identified scoring marks to the outermost tips of a number of fan blades.[14] Examination down the exhaust revealed



Event timeline/mapping (RAAF Base Pearce)



HUMS data portraying event sequence

severe damage to a number of the LPT blades, some of which had aerofoil loss down to the blade platform. BAE's borescope identified a fractured blade that had separated in the firtree below the platform.

There was also damage to the outer (sixth) serration of the mating disc post to the right of the fractured blade.[15]

As a result of the uncontained engine-failure, the air turbine starter completely detached from the engine external gearbox and was found in the bottom of the engine bay.

The v-band clamp and remnants of the ATS mating flange were still attached to the gearbox but the mating flange had fractured around the circumference. The ATS drive shaft had also fractured, and the engine side of the drive shaft was found in the bottom of the engine bay. [16]

Engine strip. The engine strip was conducted by Rolls Royce's Air Safety Investigation (ASI) engineers with representatives from BAE Australia (acting as agents for DFSB), BAE UK and the RAAF acting as witnesses.

Over five days the majority of the engine was stripped down to piece part for the damage/mapping assessment prior to detailed examination of fracture surfaces, stress analysis/modelling and research into the loss of containment and blade-off dynamics.

LPT blades. Due to the considerable damage sustained, the individual LPT blades were removed from the disc while Module 08 was still installed. The blade identified (via borescope inspection) to have failed below the platform was confirmed as blade #69.

Clockwise from blade #69, 13 sequential blades had lost all of their aerofoils down to the platform. There were no undamaged blades in the set; however, the level of damage reduced moving anticlockwise back towards blade #69.

The majority of the blades throughout the set had lost their shrouds; however, blades #52 through to #68 had their shrouds mostly intact. Initial examination of the fracture face of blade #69 revealed an area of fatigue banding followed by an area of overload.

Debris. Debris collected from the runway and from within the engine/engine bay was dispatched to DST for examination and analysis. This debris included a fragment that appeared to be an LPT blade root (found on the runway).

DST sorted this debris into blade aerofoil fragments, blade shroud tip fragments and other small, unidentified debris. In addition, the turbine bearing magnetic plug, an oil sample, four fan casing plugs, generator plug pieces and the ATS were also dispatched.

DST believed that the LPT blade root remnant was part of the primary failed LPT blade, containing the mating half of the fracture surface. Examination of the LPT blade root fragment revealed that the fracture surface appeared consistent with fatigue originating from the convex side at the top of the fifth serration.

The crack appeared to have originated midway along the firtree root. Fatigue cracking appeared to extend over approximately 70 per cent of the cross section. Comparison of the fracture surface of the LPT blade root with the BAE borescope images of the fractured LPT blade indicated that they were the mating halves of the same fracture.

DST did not conduct any destructive testing on the debris they received from DFSB. On completion of their examination of the material, all of the debris, appropriately packed to maintain integrity of the pieces, was air-freighted to Rolls Royce for additional/ongoing OEM analysis.

Exhaust and rear by-pass duct

Aligned to the blade-containment issue, the resultant debris from the LPT blade failure travelled downstream from the LPT disc, causing damage to the exhaust mixer casing and the rear by-pass duct.[17]

Suspension to Hawk 127 flying

Following the engine failure, the Officer Commanding 78 Wing chose to suspend Hawk 127 flying operations. The suspension was instigated to allow the ASIT to deliver preliminary information on why the engine suffered its uncontained failure, thereby mitigating any ongoing risk to aviation safety.

The teardown of the event engine by Rolls Royce determined that the cause of the event was due to a LPT blade firtree root failure. Upon that determination, the ASIT noted that neither Rolls Royce nor the Hawk Design Authority (BAE Systems) issued any advice to Hawk operators globally to cease flying or to recommend any subsequent limitations or restrictions.

On examination of the engine logbook, Rolls Royce identified the LPT disc was from the same machining batch as another LPT disc currently under investigation for firtree cracking. As a result, the locations of the remaining discs from this machining batch were identified. In addition, after the engine-strip phase had identified which blade had fractured, the locations of the remaining blades from the same machining batch were also identified.[18]

Conclusion

While the cause was unknown to the pilot, the emergency was resolved by making split-second decisions to successfully deal with a significant aircraft malfunction. This event highlights some of the factors faced by aircrew when making quick decisions in safety-critical scenarios. Tailored risk assessment and management are critical to eliminate hazards or reduce them SFARP.

ENDNOTES

1 The pilot had calculated the following speeds for the event sortie: 120 kts rotate speed, 130 kts lift off, 155 kts maximum abort speed. Note: the Head-up-Display (HUD) utilises KCAS.
2 During interview, the pilot, when pressed, did not recollect that there was a noticeable loss of thrust.
3 The pilot did not elect to declare a 'PAN' call to ATC.
4 Runway 36R at RAAF Base Pearce has a barrier system capable, if required, of arresting the Hawk 127.
5 T6NL caption indicates an engine over speed (low pressure turbine RPM)/over temperature (turbine gas temperature) and as a 'red warning' (Reference J, Part 1, Chapter 11) indicates a malfunction that requires immediate attention.
6 When a T6NL malfunction is detected the applicable 'red warning' caption is accompanied by the 'attention getters' flashing and an audio tone/voice message ('T6NL' stated twice).
7 Gleaned from the HUD recording and pilot testimony.
8 As per the Defence Aviation Safety Regulation, the Flight Authorisation Officer provided *'unambiguous instructions and guidance to allow the Aircraft Captain to make well-balanced decisions, while avoiding unnecessary interference with the Aircraft Captain's legitimate decision-making responsibilities'.*
9 Ascertained during ASIT interview.
10 While on the runway, the pilot did not consider ejecting
11 Numerous aborts are practiced by on-course students in the Hawk simulator.
12 It was during the initial inspection of the event aircraft, while in quarantine, that BAES staff confirmed that the engine-failure was uncontained.
13 Substantial damage (IAW the *Defence Aviation Safety Manual* [Reference D]): Aircraft sustained substantial damage or structural failure that requires extensive inspection but is economically repairable.
14 The blades of the LP compressor (LPC) showed evidence of tip-rub and blade-to-blade strikes.
15 Demonstrated at Figure 25 (ESN7511 damaged disc post) of Reference G (Rolls Royce Final Report). Ref G reveals that two cracks were found in posts #51 and #93 towards the rear of the disc post on the convex side.
16 The ATS is not a Rolls Royce component and, as such, is not discussed at length in Reference F (interim report).
17 Two USN Goshawks suffered similar damage during their uncontained engine-failures (see paragraphs 66 to 68).
18 Daily situation reports were provided by Rolls Royce to interested Commonwealth parties throughout the engine-strip phase.

Director DFSB comment:

There are two important parts to this case study – the technical aspects of the uncontained engine failure and; the actions of the pilot immediately following the engine failure. The technical aspects of the failure are a matter for continuing examination by Rolls Royce and for risk management by Air Combat Group and 78 Wing, so they won't be the subject of further comment here. However, the actions of the relatively inexperienced pilot are an excellent example of how decisions are made in quick time … in this case, just four seconds elapsed between the failure and the abort actions being exercised.

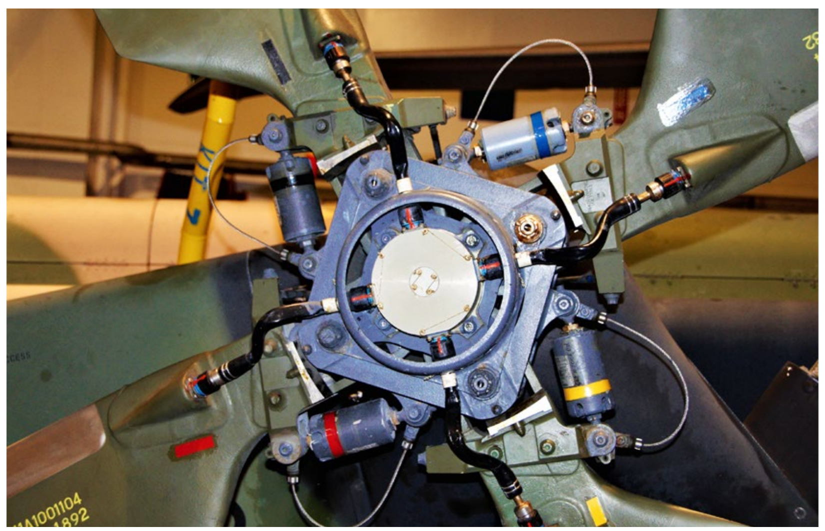
Technicalities aside, the pilot reacted quickly and correctly and kept the aircraft on the ground where it needed to be. Could the same primed decision-making process have led to a poor outcome? Perhaps.

Practising drills correctly in simulators and simulated scenarios played an important role in this good outcome. Perfect practice makes perfect.

Tail-rotor damage

ON 11 JULY 2019, two Army MRH90 aircraft departed HMAS *Adelaide* for transit to Brisbane metropolitan area. Approximately 14 minutes into the transit flight, the aircrew of Aircraft 1 identified abnormal vibrations throughout the airframe. After conducting a handling check, the crew elected to return to HMAS *Adelaide*.

On final approach to the ship the vibrations increased significantly – an alarming contrast to the normally smooth operation of the aircraft – necessitating a PAN call by the aircraft captain and an immediate shutdown. Inspection of the tail rotor identified that the red blade had sustained significant damage. There were no injuries to personnel.



History of the flight

After normal pre-flight checks, both aircraft started engines and engaged rotors using the rotor quick-start procedure. During embarked operations and in high-wind conditions, a rotor quick-start procedure is utilised. This is to reduce the chance of damage to the main rotor flapping system and the main rotor blades due to blade sailing[1] during rotor engagement. Both aircraft launched at approximately 0630 without incident.

Crew response to vibrations

Despite conducting a handling check, the aircrew members could not identify the primary cause of the abnormal aircraft vibrations and were unable to fully assimilate the nature or severity of the tail-rotor malfunction. The fly-by-wire system does not provide any physical feedback to the aircrew (as per physical control runs, rods, et cetera). Consequently, it was difficult for the aircrew to identify the source of the abnormal vibrations, which were initially thought to be emanating from the main rotor head.

The lack of feedback available to the aircrew was compounded by insufficient correlating information from sensors, pick-ups, captions or warnings, resulting in the inability of the aircrew to fully understand or identify the location of the malfunction.

This lack of feedback resulted in the decision to return to HMAS *Adelaide* without declaring a PAN.

The crew members informed HMAS *Adelaide* of their intention to return due to an unserviceability, not portraying the severity of the underlying malfunction. HMAS *Adelaide* personnel prepared themselves for a normal recovery via a standard approach.

Aircraft 1 was allocated 'one spot', which requires higher-than-normal power settings because of wind flow around the super structure and is not normally associated with an aircraft returning with a malfunction.

There was another MRH90 positioned on 'two spot' at the time of the recovery. Landing directly ahead of an occupied spot during an emergency landing is permissible but usually avoided.

HMAS *Adelaide* was within a take-off/landing Ship Helicopter Operating Limitation (SHOL) for the return of Aircraft 1; however, the ship had not yet manoeuvred into a SHOL that catered for shutdown. Upon landing, the vibrations markedly increased.

Aircraft 1 requested an immediate shutdown but was informed by flying control that the ship was not within limits of a SHOL to permit shutdown. This resulted in the aircraft captain declaring a PAN for immediate shutdown.

While the rotor Nr was decaying, HMAS *Adelaide* made its preparations to manoeuvre into a suitable SHOL for shutdown. Flying control also broadcast the nature of the PAN call to the flight deck.

Post event, once the aircraft captain was fully aware of the seriousness of the malfunction, it was acknowledged that declaring a PAN would have been appropriate.

After the event, once the aircraft captain was fully aware of the seriousness of the malfunction, it was acknowledged that declaring a PAN would have been appropriate.

While Aircraft 1 aircrew informed HMAS *Adelaide* of their intention to return to the ship, *Adelaide*'s personnel did not interrogate them as to the reason for the return and missed an opportunity to better understand the nature of the malfunction.

Damage

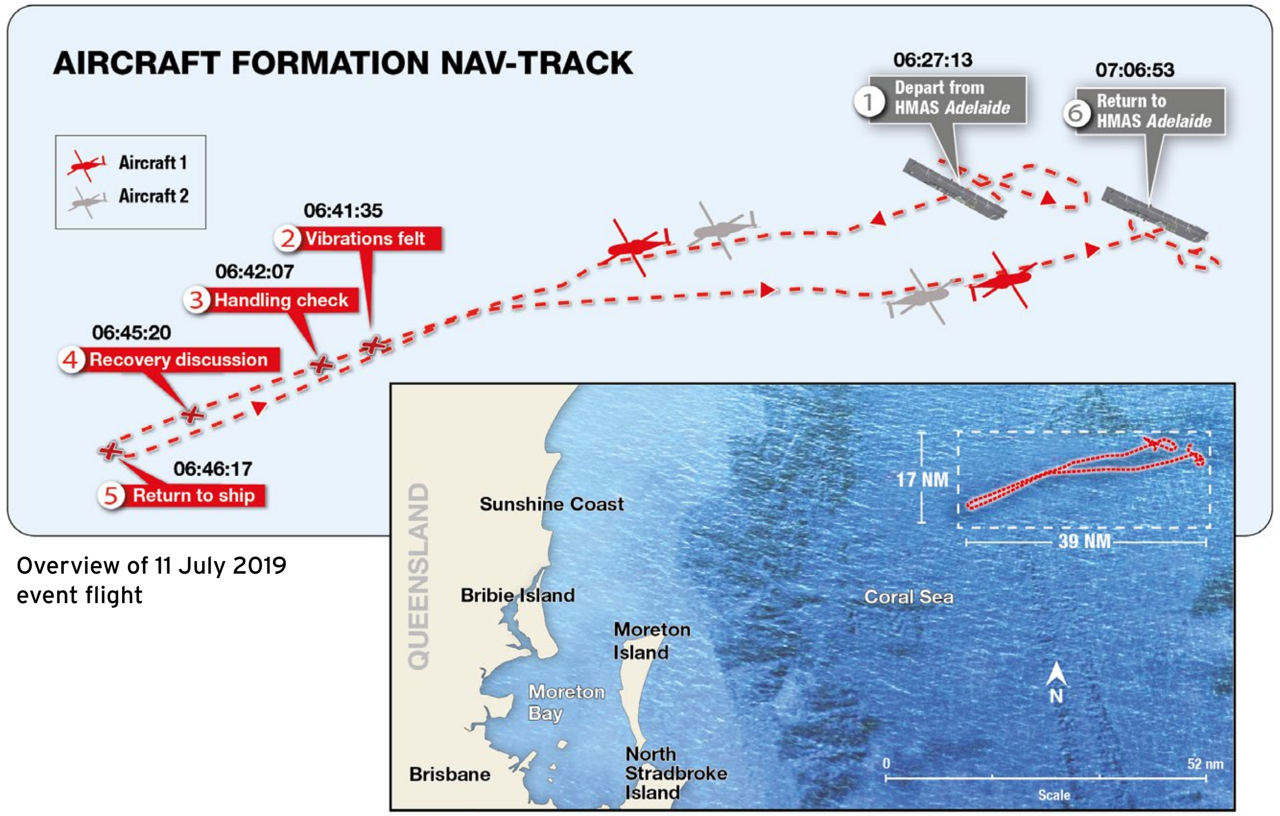
Full assessment of the damage caused by this event required the tail rotor hub and blades to be removed and dismantled. These components were sent to Defence Science and Technology (DST) Group for further analysis and investigation. Initially, the primary areas of damage were identified as follows:

- the trailing edge of the red-blade roving strap had significant damage from contact with the tail rotor hub
- the leading edge of the yellow-blade roving strap was damaged by the portion of the red-blade locking stop having been jammed between the roving strap and tail rotor hub
- a portion of the red-blade locking stop separated from the back of the roving strap
- two impact damage areas on the tail rotor slant shaft.

A review of maintenance documentation determined that there had been three occurrences on the event aircraft where a locking stop had been found cracked during maintenance. Two instances on the black blade and one on the yellow blade.

Tail-rotor system

The MRH90 flight control system (FCS) is a fully fly-by-wire system, incorporating the tail-rotor system. The tail-rotor system receives electrical input from the pilot via the rudder pedals to hydraulic actuators.



Overview of 11 July 2019 event flight

The tail-rotor system comprises a four-bladed tail rotor, and spheriflex-type hub allowing for pitch, flap and drag which is provided by a single laminated spherical thrust bearing. The tail-rotor system provides main rotor anti-torque and yaw control of the aircraft.

Vibration

Vibration information and other data from the VFDR were analysed to help understand the abnormal vibration event. A review of the VFDR parameters from previous flights showed that prior to the incident, there were no recorded indications of abnormalities in the tail-rotor system.

Slant shaft

Because of this incident, penalty maintenance inspections were carried out in the tail pylon area of the aircraft. Damage to the slant shaft, as a result of impacting the tail-rotor system hydraulic pipeline standoffs was identified. This was attributed to the excessive vibrations induced by the tail-rotor imbalance.

Anti-fretting cloth analysis

The anti-fretting cloth was damaged at its extremities due to contact with the spherical thrust bearing. Samples were collected from the anti-fretting cloth for analysis of any potential contamination present. Analysis indicated the samples were similar in composition to each other and there was no indication of any liquids/greases.

Spherical thrust bearing

Examination of the red-blade spherical thrust bearing revealed significant damage to the rubber/steel laminate section and wear to the leading face of the aluminium attachment block.

The size and shape of the damage was consistent with the damage to the internal face of the leading side of the roving strap. Additionally, the lower surface of the attachment block was distorted .

Examination of the titanium contact surface of the spherical thrust bearing revealed significant wear to the paint surface, with the green coloured primer from the spherical thrust bearing wearing away allowing the blue coloured undercoat of the blade transferring to the roving strap. This paint transfer was consistent with movement between the spherical thrust bearing surface and the anti-fretting cloth of the roving strap.

This movement should not occur in a serviceable tail rotor.

Locking stop

Examination of the locking stop identified that a portion of the trailing half had fractured and separated from the red blade. Inspection of the bonding surface between the roving strap and the locking stop revealed the presence of a pink/purple-coloured adhesive identified as EA 9309.3NA.

If the adhesive process is not carried out correctly, through incorrect preparation of the surfaces or use of adhesive incompatible with one or both surfaces, the bond can fail. This failure mechanism is known as adhesive failure.

Conversely, cohesive failure occurs when there is a fracture through the adhesive, leaving adhesive material on both of the fracture surfaces. Cohesive failure occurs when a suitable bond is overloaded.

The red blade adhesive was predominantly present on the surface of the roving strap with only a small area present on the locking stop. The bond contained large voids and exhibited adhesive failure.[2]

Examination of the surface of the locking stop revealed evidence of progressive failure, with crack arrest marks present on the fractured surface. These arrest marks aligned with arrest marks also present on the surface of the adhesive. Examination of the surface of the adhesive indicated that the disbond between the adhesive and the locking stop progressed over numerous cycles.

It is likely that this disbonding originated along the inboard area of fracture in the locking stop, and progressed outboard and aft, until the locking stop was fully fractured.

Cracking then progressed aft over multiple cycles as indicated by the light-coloured arrest marks observed on the adhesive surface. During examination 14 arrest marks were identified.

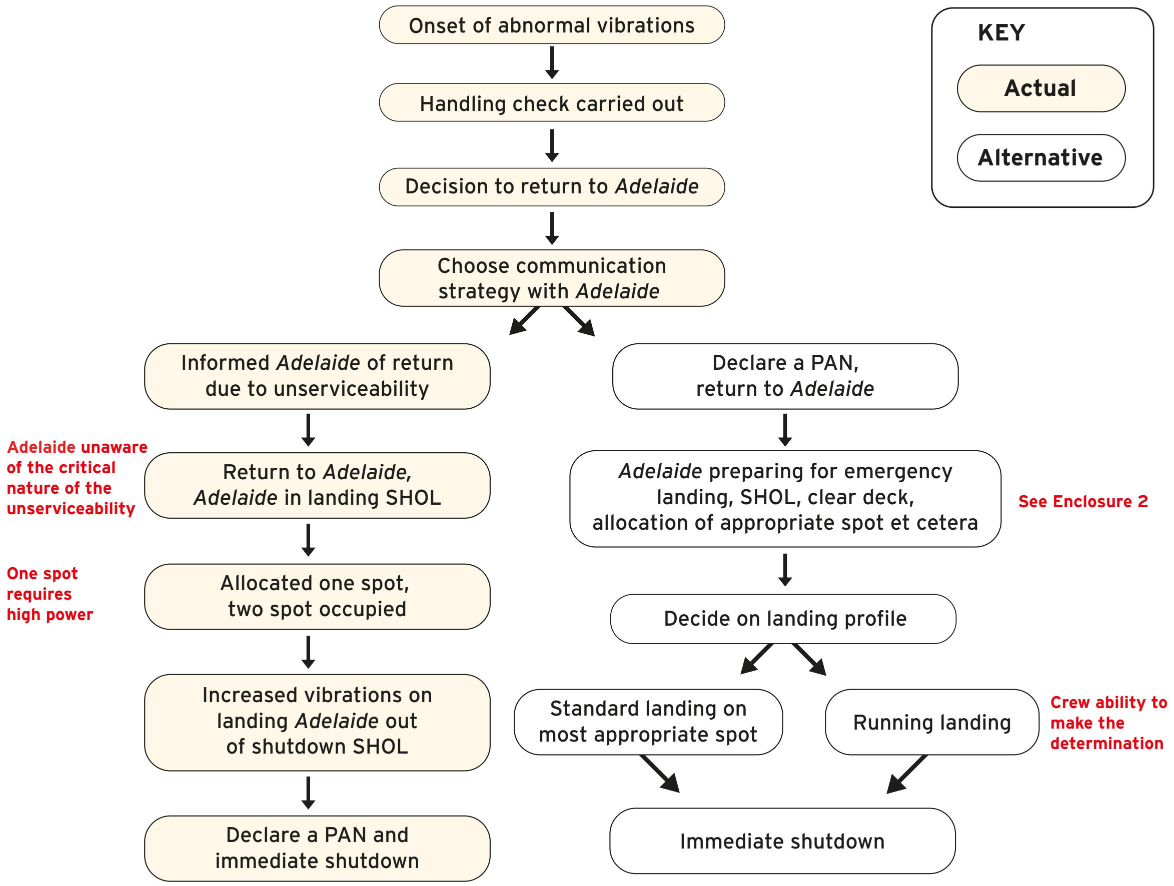
Uncontained blade movement

Examination of the red blade revealed significant damage to the composite roving strap on the internal surface and on the leading face and the external surface of the trailing face. Measurements of the damage at the leading face of the internal surface revealed that, at its thinnest, the roving-strap damage resulted in a reduction from 12.2 mm to 4.2 mm, with a corresponding cross sectional area reduction of 45 per cent at that point.

Examination of the jumper revealed evidence of rubbing between it and the locking stop. There should be no contact between these components when installed.

Clearance between the components is achieved via a shimming procedure, with the specified tolerance being between 0.0 and 0.2 mm. Measurements were taken to confirm the clearance achieved through shims on the red blade in the post-failure condition. The clearance between the jumper and locking stop was between 0.24 mm and 0.45 mm which was out of limits as specified by the OEM.

Wear marks present on both the jumper and the locking stop indicate a period of time where the jumper was centred on the locking stop, and a period where it was offset.



Actual and alternative course of action

Yellow-blade damage from portion of locking stop

Analysis of the incident yellow blade showed damage to the external face of the leading side of the roving strap. The damage found on the leading edge roving strap of the yellow blade corresponds to contact with the liberated portion of the red-blade locking stop in regards to size and location of the damage. Additionally, damage to the liberated piece of the red-blade locking stop is similar to contact with the yellow blade due to increased vibrations during flight.

Red-blade roving strap thickness

Examination and preliminary measurements of the red-blade roving strap identified a possible difference in thickness of the strap in the area containing the anti-fretting cloth that contacts the spherical thrust bearing. The roving strap was sectioned and a region towards the trailing edge had an increased thickness of epoxy (approximately 0.40 mm thicker than adjacent areas) that is used to adhere the anti-fretting cloth.

Additionally there was a corresponding reduction in glass fibre thickness (reduced by 0.2 mm from approximately 1.8 mm to 1.6 mm). [3] This thickness variation caused the section to protrude from the surface of the roving strap.

Authorised tool V64800 was used to fit or replace the anti-fretting cloth. This tool is installed against the contact surface of the spherical thrust bearing holding the anti-fretting cloth in place while the epoxy cures. Tool V64800 has the same arc of the contact surface of the spherical thrust bearing that fits in the blade roving strap. Tool V64800 does not control the rotation of the tooling surface relative to the roving strap surface, which can cause uneven epoxy distribution. No checks were required for correct geometry after bonding. Tool V64800 was tested on the roving straps of all incident aircraft blades; the blue, yellow and black blade fitment were all as per OEM specifications.

Tool V64800 was found to have an incorrect fit on the red blade that resulted in a gap between the spherical thrust bearing and the roving strap at the leading edge when the spherical thrust bearing was centred.

Rotation of tool V64800 by approximately 2.6° towards the trailing edge eliminated the gap between it and the roving strap, allowing a snug fit. This indicates that tool V64800, used to facilitate the bonding of the anti-fretting cloth to the roving strap, was very likely installed incorrectly, and subsequently the installed spherical thrust bearing had a gap present during service. From this analysis it is very likely that the tendency of the blade to return to the offset position would have transferred additional loads to the trailing edge of the locking stop.

Conclusion

Both the OEM and the ADF have been aware of issues with locking-stop cracking and disbonding in MRH90 tail rotor blades since 2014. While some early failures may have been attributable to contamination, in particular with Mastinox, this should not have been nor continued to be the immediate assumption, precluding further investigation.

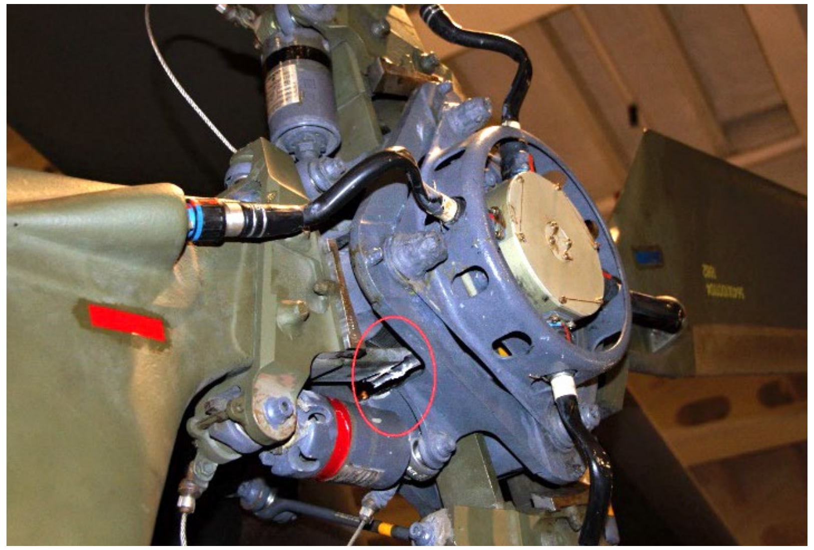
In the case of the event aircraft, tool V64800 was used as per the authorised maintenance procedures to position the anti-fretting cloth against the roving strap. The unintentional incorrect application of this tool led to a local excess of epoxy in the roving strap, which along with associated incorrect geometry induced an increased load on the locking stop.

It lead to fracture and adhesive failure allowing liberation of a portion of the locking stop. With the locking stop no longer holding the blade in its correct position, the blade was then free to move outside of design limits, inducing the abnormal vibration and subsequent damage.

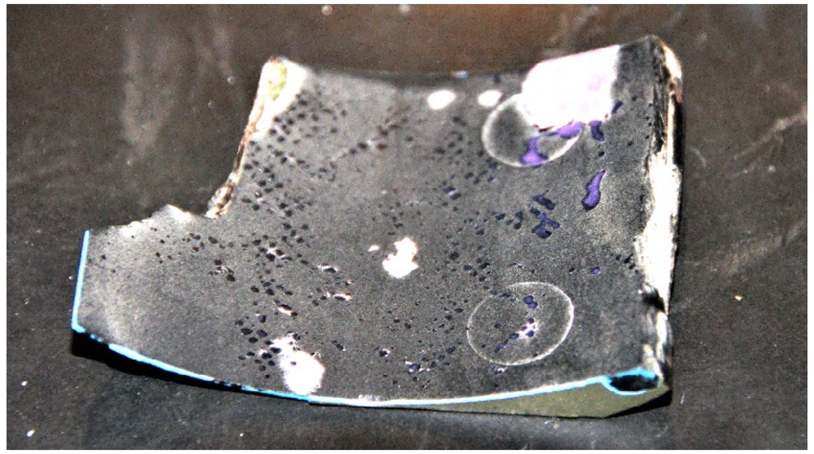
The use of 1108 blades and tool P/N 0400200-69620 for anti-fretting cloth fitment has eliminated the chance of recurrence through this failure mode SFARP. While the decision to return to *Adelaide* was appropriate given the nature of the abnormal vibrations, declaring a PAN would have enabled HMAS *Adelaide* to better prepare for recovery and landing.

ENDNOTES

1. Blade sail is a phenomenon that occurs when air flow generated from the hull of a ship can force the blades upwards and has the potential to damage the rotor head.
2. ST analysis identified adhesive failure; however, the reason for adhesive failure, vice cohesive failure was not conclusively determined.
3. The reduction in glass-fibre thickness was approximately equivalent to the thickness of one glass-fibre sheet.



Red-blade roving strap showing impact damage



Portion of the detached locking stop showing signs of disbonding and evidence of wear

Director DFSB comment:

Here is another case study where technology has played a role: there are some significant technical aspects relating to the locking stop and maintenance of the tail rotor but this is also a great study of decision making processes, particularly when there is clever technology in play that is obscuring the severity of the issue. When the vibrations were first detected it took about five minutes of fault finding and discussion before the aircraft altered course in order to return to the ship. The following quote is significant.

"The lack of feedback available to the aircrew was compounded by insufficient correlating information from sensors, pick-ups, captions or warnings, resulting in the inability of the aircrew to fully understand or identify the location of the malfunction."

Once again, technology is a double-edged sword.

King Air inadvertent pitch nose-down

A B300 KINGAIR WAS conducting a routine AMCC task from Williamtown (WLM) to Canberra on 9 December 2018 with two passengers on board when it pitched nose-down, dropping a couple of thousand feet in a matter of seconds.

The crew of two pilots – aircraft captain (pilot flying) in the left-hand seat and co-pilot in the right-hand seat – had requested a cruising level of Flight Level 200[1] (FL200) on the flight plan, but just before departure requested an amended level of FL220. The aircraft departed from WLM at 1610 AEDT with an initial clearance to FL120.

The crew contacted Williamtown Approach (WLM APP), which advised they would shortly be cleared to track direct to their first waypoint. Two minutes later, the crew was cleared to resume own navigation direct to LOWEP[2]. The co-pilot acknowledged this clearance and the aircraft began a right-hand turn while passing 3600 ft.

The aircraft was transferred from WLM APP to Brisbane Centre (BN CTR), which advised that they could expect higher in about 90 seconds with a requirement to reach FL140 by YAKKA[3]. BN CTR also informed the flight that they would advise on the final level[4] request shortly. The co-pilot acknowledged this communication and the aircraft continued a normal climb to FL120.

At 1620, with approximately 14 nm to run to LOWEP, BN CTR cleared the flight to climb to FL130, which the co-pilot acknowledged.

The aircraft maintained FL120 for the next 28 seconds before it commenced climb. The aircraft captain recalled entering FL200 into the altitude selection (ALTSEL) function of the autopilot. They then pressed the flight level change[5] (FLC) button to initiate the climb. and selected 140 KIAS on the SPEED knob for max rate climb (MRC) performance[6].

The aircraft captain reported thinking that the aircraft was responding slowly to the climb input and pressed the SYNC[7] switch on the control wheel and began to pull back on the flight controls to manually raise the nose of the aircraft. The aircraft reached FL123 before the rate of climb stagnated. The aircraft captain recalled continuing to pull back on the flight controls in an effort to raise the attitude. Both the aircraft captain and co-pilot noted an elevator mistrim advisory light[8] on the primary display, and the aircraft captain disengaged the autopilot system.

The aircraft immediately pitched nose-down. Radar data shows that the aircraft lost 1700 ft within a four-second increment.[9] Error margins due to aircraft and radar instrument and communication factors mean this increment may be up to 20 seconds. The ASIT determined rate of descent to be between 5100 and 25,000 ft per minute.

As the aircraft descended, the speed was reported by the co-pilot to have reached at least 200 KIAS and was seen on radar to increase from 270 to 290 knots ground speed. The co-pilot alerted the aircraft captain to the increasing speed, and the aircraft captain pulled back harder on the flight controls and instructed the co-pilot to manually re-trim the aircraft. At this time, BN CTR cleared the aircraft to climb to FL220, with the requirement to reach FL140 by YAKKA. The co-pilot acknowledged the clearance.

The crew recovered the aircraft back into a climb profile and continued to FL220, achieving FL148 by LOWEP and FL180 by YAKKA. The crew discussed the pitch nose-down and altitude loss. The aircraft captain described attempting to expedite climb using the SYNC switch and manually setting aircraft pitch.

However, the co-pilot advised that the SYNC switch was not operational with the autopilot engaged in FLC mode. Furthermore, the co-pilot informed the aircraft captain that the aircraft would trim opposite to any pilot control inputs with the autopilot engaged. After this discussion, the crew determined that the aircraft had operated as it should, and that the event was due to operator error.

They continued with the flight to Canberra without further incident.

Passengers

Two passengers were present on the flight. One of which was a pilot who provided assistance to the other passenger during the pitch nose-down and recovery. Once re-established in the climb, the pilot offered assistance to the flight crew, and confirmed the co-pilot's understanding of the SYNC switch functionality.

Recorded information

The B300 Crash Data Recorder System consists of the Cockpit Voice Recorder (CVR) and the Flight Data Recorder (FDR). The CVR provides two hours of audio from the pilot and co-pilot intercom systems and the ambient

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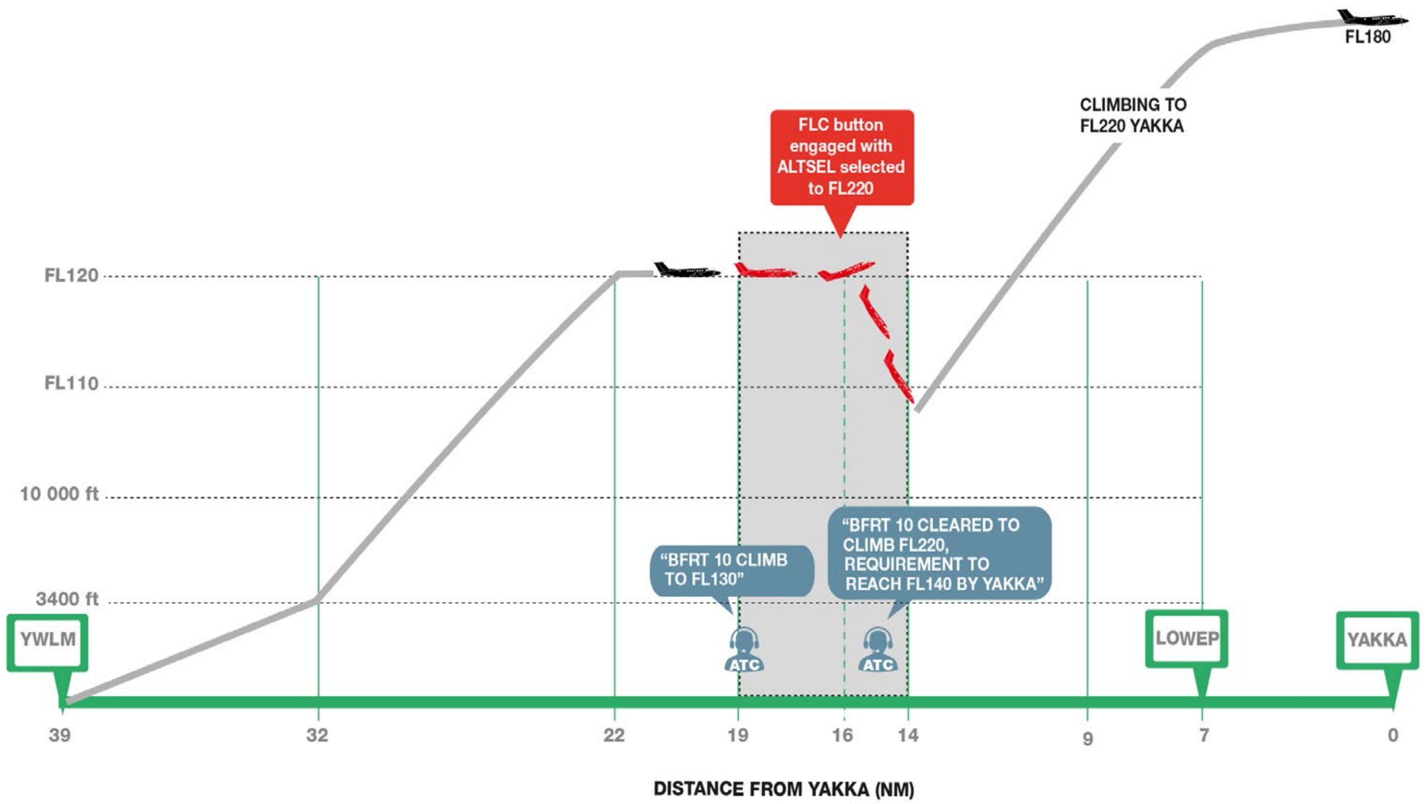

BFRT 10 flight path, altitude and ATC cleared level

cockpit sound. The FDR stores 27 recorded and derived parameters. The FDR will record more than 25 hours of data in a continuous loop.

DFSB requested CVR and FDR data from the event. The flight had continued after the event and the aircraft was not quarantined on arrival in Canberra. It also continued to fly for several days before a decision was made to categorise the event as a Class B. As a result, the crew communications during the event were overwritten.

FDR data was provided to DFSB; however, it was subsequently identified that the information did not come from the event aircraft. By this time, the event aircraft had flown in excess of 125 hours since the event flight, and the FDR data for the event had been overwritten.

In-flight planning

Due to the proximity to Sydney airspace, departure from Williamtown required a stepped climb[10] to cruising level. Once established at FL120, BN CTR advised the aircraft to expect further climb soon, and to anticipate a requirement to reach FL140 by YAKKA. The aircraft captain told the ASIT they were not aware of the distance remaining to LOWEP, but knew it was 7 nm between LOWEP and YAKKA.

The flight management system (FMS) provides a visual guide to the expected top of climb for the altitude selected in the ALTSEL function along current heading. Due to the flight path corner at LOWEP, the display would not correctly show the top of climb along the flight-planned route.[11] At the time of the clearance, the aircraft had approximately 19 nm to run to YAKKA.

A simple in-flight calculation would have identified to the crew that at constant cruise climb setting, they would reach FL140 in about one minute, and after travelling 3 nm (16 nm to run to YAKKA)[12].

Neither the aircraft captain nor the co-pilot conducted any in-flight forecast calculations.[13] Furthermore, both reported that they seldom conduct in-flight planning manually for climb performance, as the autopilot conducts climb and navigation calculations during flight. The Aviation Safety Investigation Team (ASIT) discussed in-flight planning with multiple aircrew and determined that it was common practice to rely on the Flight Management System (FMS) calculations.

The benefits of aircraft automation are well recognised but there are limitations and disadvantages to its use. For example, overreliance on automated systems can generate complacency, loss of skill and a reduction in situation awareness. Reliance on FMS performance calculations during climbs probably influenced the crew to omit manual verification of climb performance. Conduct of a manual calculation could have challenged the aircraft captain's inaccurate perception that there was insufficient distance to meet the anticipated air traffic control (ATC) requirement.

Misperception of cleared altitude

When ATC cleared the flight to climb to FL130, the aircraft captain was anticipating clearance to FL220 and was feeling increasingly anxious about the expected ATC requirement to reach FL140 by YAKKA. The aircraft captain recalled the BN CTR communication, but did not recall hearing the cleared altitude as FL130. The aircraft captain recalled responding to the clearance by setting FL200 on the Flight Level Change (FLC)[14].

Human-performance limitations

Increased stress can lead to human-performance limitations such as filtering and increased susceptibility to cognitive biases such as expectation bias. The aircraft captain's increasing anxiousness could have contributed to the following:

- **Filtering.** Filtering is the rejection of certain tasks because of overload, for example, not identifying a navigation aid when setting up for an instrument approach, or failing to comprehend a radio transmission.
- **Expectation bias.** Expectation bias is where an individual's expectations about an event influence their judgement, decision-making and behaviour.

It is likely that the expectation of receiving a clearance to a higher level, coupled with increasing anxiety, led the aircraft captain to hear the clearance (to FL130), but to process it as per their expectation.

Crew communication

The co-pilot correctly acknowledged the clearance to FL130, but did not recall conducting an altitude check with the aircraft captain. Squadron crew members are required to comply with the following documents.

- Squadron SIs, which require the ALTSEL function be set to all cleared or planned altitudes. Whenever the pilot flying selects the ALTSEL, the pilot not flying is to check the setting.
- Aircraft handling notes specify that a change of cruising level or altitude require the pilot not flying to verbally confirm the pilot flying's selection.

Due to the absence of CVR and FDR recordings, the ASIT was unable to determine what was selected on the ALTSEL and what checks were conducted.

It is probable that if the ALTSEL and altitude checks were conducted in accordance with requirements, the crew would have identified any misunderstandings or incorrect ALTSEL settings. The ASIT therefore determined that the ALTSEL and altimetry checks were not effective.

Action to expedite climb

Once the ALTSEL was set, the aircraft captain selected the FLC switch to initiate climb. The aircraft captain reported thinking that the aircraft was responding slowly to the climb input. Anxious about complying with the interpreted ATC clearance and requirement, the aircraft captain recalled a previously observed method of expediting climb, pressed the SYNC switch on the control wheel and began to pull back on the flight controls to manually raise the nose of the aircraft.

Out-of-trim condition

The aircraft captain's actions in attempting to override the autopilot caused the automatic electric pitch trim to trim the aircraft nose-down and respond with an elevator mistrim advisory. As the aircraft captain's input continued, the elevator trim wheel reached the maximum forward position and the red trim advisory annunciated.[15]

Management of unexpected aircraft response

The aircraft captain recalled the force required to pull back and hold the flight controls was high but continued to pull back until the elevator mistrim advisory light illuminated[16] on the warning panel. At that point, the aircraft captain recalled reaching across the flight controls and disconnecting the autopilot with their right hand.[17]

The aircraft captain identified that they would normally perform this action with their left hand[18]; however, felt that due to the strength required to hold the yoke, they were unable to take their left hand from the controls.

In interviews post event, the aircraft captain confirmed that the correct action (IAW squadron procedures) when confronted with an abnormal or unexpected response is to disconnect the autopilot.

Had the aircraft captain disconnected the autopilot when they first identified the aircraft was not responding as expected, the out-of-trim condition would have likely been less severe.

Aircraft recovery

When the aircraft captain disengaged the autopilot, the trim setting caused the aircraft to pitch immediately nose-down. The aircraft captain was unable to physically input the control force required to maintain the aircraft in a nose-up attitude, and as a result the aircraft began to lose altitude.

The aircraft captain instructed the co-pilot to manually re-trim the aircraft; however, the aircraft descended 1700 ft before the aircraft captain was able to re-establish control.

Unexpected event training

Regular emergency training is used in most high-risk industries as a means to develop instinctive, rapid responses to critical situations.

Research has shown that while individuals respond well to emergencies that match those practiced in training, when faced with emergencies that have not yet been encountered, they frequently struggle or make critical errors.

This highlights the importance of varied, new and unpredictable training situations to ensure individuals are given opportunities to practice recognition skills, critical problem solving, effective decision-making and appropriate response.

Conclusion

There are a number of deficiencies in decision-making, systems knowledge and organisational risk controls within 32SQN. The ASIT noted the following:

- The Aircraft Captain perceived a requirement to expedite climb, influenced by a lack of inflight planning calculations and a misperceived clearance
- Conduct of the required ALTSEL and altimetry checks was not effective, reducing risk controls
- The Aircraft Captain used a B300 PL2 technique to expedite climb when flying a B300 PL21 aircraft.

The investigation found a lack of standardisation across the 32SQN pilot body, resulting from the use of different training pathways, and sub-optimal CRM training. Significant potential for improvement in 32SQN training and standardisation exists, including:

- **Automation.** The benefits of automation are well recognised, but there are limitations and disadvantages to its use. Overreliance on automated systems can introduce complacency and loss of skill. Incorporating in-flight manual-planning tasks during training will ensure this important skill-set is not lost.
- **Unexpected event training.** Introducing varied and unpredictable situations and incorporating NTS practice into practical training scenarios will provide individuals with opportunities to practice recognition skills, critical problem solving, effective decision-making and effect appropriate responses.
- **Standardisation.** The use of a number of different providers to train pilots for B300 PL 21 operations has led to a lack of standardisation across the pilot body, notably systems knowledge differences, and varied exposure to autopilot emergencies and abnormal events.

ENDNOTES

1 At altitudes above the transition layer (10,000-FL110 in Australia), an aircraft's height above 1013 hPa reference pressure is referred to as a Flight Level (FL). FL200 equates to 20,000 ft.

2 LOWEP is an instrument flight rules (IFR) waypoint 34 nm on a bearing of 230 degrees magnetic from Williamtown airfield, along the planned route Williamtown to Canberra.

3 YAKKA is an IFR waypoint 7 nm on a bearing of 170 degrees magnetic from LOWEP, along the planned route Williamtown to Canberra.

4 The previously requested altitude of FL220.

5 The FLC button activates climb to the altitude entered in the ALTSEL function at the speed selected on the SPEED knob.

6 Maximum rate of climb for the B300 is flown at 140 KIAS and can be used to meet ATC height requirements.

7 The autopilot/flight director SYNC switch is used to synchronise the flight director lateral and vertical references to the current aircraft attitude.

8 An elevator mistrim (E) advisory light on the primary flight display indicates that the aircraft is in a 'mistrimmed' condition.

9 ATC recordings indicate time in four second increments. The aircraft lost 1700 ft within one increment as demonstrated in Figure 3.

10 A stepped climb is an incremental climb to final altitude, in this event, stepped climb was used by ATC to facilitate traffic separation.

11 This visual guide would have indicted where the aircraft would reach top of climb (as selected in the ALTSEL) on current heading.

12 Of note, the aircraft was only cleared to climb to FL130 at the point. The requirement to reach FL140 by YAKKA was not passed by ATC until after the nose pitch event (14 nm to run YAKKA).

13 Calculations conducted by the aircrew to estimate climb, desent, speed and distance performance.

14 The aircraft captain stated in the self-administered interview form following the event that FL200 was set in the FLC. The ASIT was unable to determine the actual FLC setting or what the aircraft captain's actual expected altitude was.

15 These actions were determined by the ASIT reproducing the in-flight scenario in the 32SQN flight simulator, as the FDR was unavailable for this flight

16 The elevator trim advisory (TRIM) light indicates that the autopilot pitch trim system has failed. In this case it is likely that the trim had reached the extent of full forward trim but was still getting opposing input, thus activating a trim failure mechanism.

17 Annunciation of the red trim advisory should cause the autopilot to automatically disconnect. The ASIT was unable to determine whether this happened prior to or concurrent with the aircraft captain's actions to manually disconnect the autopilot.

18 The aircraft captain autopilot disconnect switch is on the control yoke in vicinity of the left hand.

Director DFSB comment: The key lesson for many aviators is mid-way through the article: "The benefits of aircraft automation are well recognised but there are limitations and disadvantages to its use". We all live in an aviation community and a world in which automation plays an ever-increasing role. We've seen some devastating outcomes because of automation within some high-profile airline accidents so we're aware of how badly these things can go. To balance the argument, there are also significant benefits to the use of automation and other technologies ... as long as they are used correctly and with a full knowledge of their limitations. This type of issue will not rest exclusively with the King Air, nor that particular crew.

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