Australian Government

Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY REPORT

Aviation Occurrence Investigation – AO-2008-078

Final

Wirestrike
13 km north of Murray Bridge, SA
19 November 2008
VH-PLJ
McDonnell Douglas 369D

Australian Government

Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY REPORT

Aviation Occurrence Investigation

AO-2008-078

Final

Wirestrike
13 km north of Murray Bridge, South Australia
19 November 2008
VH-PLJ
McDonnell Douglas 369D

Released in accordance with section 25 of the *Transport Safety Investigation Act 2003*

Published by: Australian Transport Safety Bureau
Postal address: PO Box 967. Civic Square ACT 2608
Office location: 62 Northbourne Ave, Canberra City, Australian Capital Territory, 2601
Telephone: 1800 020 616, from overseas +61 2 6257 4150
Accident and incident notification: 1800 011 034 (24 hours)
Facsimile: 02 6247 3117, from overseas +61 2 6247 3117
Email: atsbinfo@atsb.gov.au
Internet: www.atsb.gov.au

ISBN and formal report title: see 'Document retrieval information' on page v

CONTENTS

DOCUMENT RETRIEVAL INFORMATION

Report No.	Publication date	No. of pages	ISBN
AO-2008-078	November 2010	72	978-1-74251-116-0

Publication title

Wirestrike – 13 km north of Murray Bridge, South Australia - 19 November 2008 - VH-PLJ, McDonnell Douglas 369D

Prepared By

Australian Transport Safety Bureau
PO Box 967, Civic Square ACT 2608 Australia
www.atsb.gov.au

Reference Number

ATSB-Nov10/ATSB147

Acknowledgements

AMSAFE Aviation USA: Reproduction and then testing of a sample of the lineworker's harness

Abstract

On the morning of 19 November 2008, the pilot of a McDonnell Douglas 369D helicopter, registered VH-PLJ, and two lineworkers were conducting airborne joint-testing operations on an electricity transmission line between Mannum and Mobilong, South Australia. Joint testing involves closely approaching the transmission line to check joints in transmission wires. At about 1150 Central Daylight-saving Time, when about 13 km north of Murray Bridge, the helicopter's main rotor blades contacted a transmission line conductor. The pilot lost control and the helicopter impacted the ground. One lineworker was fatally injured, the other lineworker received minor injuries and the pilot received serious injuries. The helicopter was seriously damaged.

The investigation found that the crew was not aware before the flight that there were transpositions (changes in the relative positions of individual wires) in the line and that they did not detect such a transposition during the approach for the joint test that led to the accident.

Following the occurrence, the helicopter operator amended the guidance for conducting joint-testing and expanded training and supervision of new crews. The powerline owner reviewed the risk profile of its airborne operations and revised a number of hazard treatment options. The powerline maintenance provider made a number of operational changes and contracted an external auditor to examine its operation. All of the recommendations from that audit were adopted by the maintenance provider.

In response to the failure of the recording lineworker's shoulder harness, the shoulder harness repair facility has upgraded relevant repair equipment and provided a replacement program for any incorrectly-stitched harness in the operator's helicopter fleet. In addition, the Civil Aviation Safety Authority took action to have a number of seat belt harnesses recalled and examined. No issues were found with any of the seat belts that were examined and they were able to be re-released without further rework.

THE AUSTRALIAN TRANSPORT SAFETY BUREAU

The Australian Transport Safety Bureau (ATSB) is an independent Commonwealth Government statutory agency. The Bureau is governed by a Commission and is entirely separate from transport regulators, policy makers and service providers. The ATSB's function is to improve safety and public confidence in the aviation, marine and rail modes of transport through excellence in: independent investigation of transport accidents and other safety occurrences; safety data recording, analysis and research; fostering safety awareness, knowledge and action.

The ATSB is responsible for investigating accidents and other transport safety matters involving civil aviation, marine and rail operations in Australia that fall within Commonwealth jurisdiction, as well as participating in overseas investigations involving Australian registered aircraft and ships. A primary concern is the safety of commercial transport, with particular regard to fare-paying passenger operations.

The ATSB performs its functions in accordance with the provisions of the *Transport Safety Investigation Act 2003* and Regulations and, where applicable, relevant international agreements.

Purpose of safety investigations

The object of a safety investigation is to identify and reduce safety-related risk. ATSB investigations determine and communicate the safety factors related to the transport safety matter being investigated. The terms the ATSB uses to refer to key safety and risk concepts are set out in the next section: Terminology Used in this Report.

It is not a function of the ATSB to apportion blame or determine liability. At the same time, an investigation report must include factual material of sufficient weight to support the analysis and findings. At all times the ATSB endeavours to balance the use of material that could imply adverse comment with the need to properly explain what happened, and why, in a fair and unbiased manner.

Developing safety action

Central to the ATSB's investigation of transport safety matters is the early identification of safety issues in the transport environment. The ATSB prefers to encourage the relevant organisation(s) to initiate proactive safety action that addresses safety issues. Nevertheless, the ATSB may use its power to make a formal safety recommendation either during or at the end of an investigation, depending on the level of risk associated with a safety issue and the extent of corrective action undertaken by the relevant organisation.

When safety recommendations are issued, they focus on clearly describing the safety issue of concern, rather than providing instructions or opinions on a preferred method of corrective action. As with equivalent overseas organisations, the ATSB has no power to enforce the implementation of its recommendations. It is a matter for the body to which an ATSB recommendation is directed to assess the costs and benefits of any particular means of addressing a safety issue.

When the ATSB issues a safety recommendation to a person, organisation or agency, they must provide a written response within 90 days. That response must indicate whether they accept the recommendation, any reasons for not accepting part or all of the recommendation, and details of any proposed safety action to give effect to the recommendation.

The ATSB can also issue safety advisory notices suggesting that an organisation or an industry sector consider a safety issue and take action where it believes it appropriate. There is no requirement for a formal response to an advisory notice, although the ATSB will publish any response it receives.

TERMINOLOGY USED IN THIS REPORT

Occurrence: accident or incident.

Safety factor: an event or condition that increases safety risk. In other words, it is something that, if it occurred in the future, would increase the likelihood of an occurrence, and/or the severity of the adverse consequences associated with an occurrence. Safety factors include the occurrence events (e.g. engine failure, signal passed at danger, grounding), individual actions (e.g. errors and violations), local conditions, current risk controls and organisational influences.

Contributing safety factor: a safety factor that, had it not occurred or existed at the time of an occurrence, then either: (a) the occurrence would probably not have occurred; or (b) the adverse consequences associated with the occurrence would probably not have occurred or have been as serious, or (c) another contributing safety factor would probably not have occurred or existed.

Other safety factor: a safety factor identified during an occurrence investigation which did not meet the definition of contributing safety factor but was still considered to be important to communicate in an investigation report in the interests of improved transport safety.

Other key finding: any finding, other than that associated with safety factors, considered important to include in an investigation report. Such findings may resolve ambiguity or controversy, describe possible scenarios or safety factors when firm safety factor findings were not able to be made, or note events or conditions which 'saved the day' or played an important role in reducing the risk associated with an occurrence.

Safety issue: a safety factor that (a) can reasonably be regarded as having the potential to adversely affect the safety of future operations, and (b) is a characteristic of an organisation or a system, rather than a characteristic of a specific individual, or characteristic of an operational environment at a specific point in time.

Risk level: The ATSB's assessment of the risk level associated with a safety issue is noted in the Findings section of the investigation report. It reflects the risk level as it existed at the time of the occurrence. That risk level may subsequently have been reduced as a result of safety actions taken by individuals or organisations during the course of an investigation.

Safety issues are broadly classified in terms of their level of risk as follows:

- **Critical** safety issue: associated with an intolerable level of risk and generally leading to the immediate issue of a safety recommendation unless corrective safety action has already been taken.
- **Significant** safety issue: associated with a risk level regarded as acceptable only if it is kept as low as reasonably practicable. The ATSB may issue a safety recommendation or a safety advisory notice if it assesses that further safety action may be practicable.
- **Minor** safety issue: associated with a broadly acceptable level of risk, although the ATSB may sometimes issue a safety advisory notice.

Safety action: the steps taken or proposed to be taken by a person, organisation or agency in response to a safety issue.

FACTUAL INFORMATION

History of the flight

On the morning of 19 November 2008, the pilot of a McDonnell Douglas 369D (369D) helicopter, registered VH-PLJ, and two lineworkers were conducting airborne mid-span joint resistance testing (joint testing) on the powerline between Mannum and Mobilong, South Australia. At about 1150 Central Daylight-saving Time,[1] when about 13 km north of Murray Bridge, the helicopter's main rotor blades contacted one of the powerline's conductors. The pilot lost control of the helicopter and it impacted the ground. One lineworker was fatally injured, the other lineworker received minor injuries and the pilot received serious injuries. The helicopter was seriously damaged.[2] There was no fire.

The operator had about 10 helicopters and sufficient crew to fulfil contracts for a variety of helicopter services with powerline maintenance providers, or electrical powerline system asset owners.[3] In South Australia, the helicopter operator was contracted to the maintenance provider, who in turn was contracted by the asset owner.

The helicopter operator was tasked by the maintenance provider to conduct joint testing[4] on a number of transmission lines,[5] including the Mannum to Mobilong line. The helicopter operator was given a project brief[6] of the work to be performed and, from that information, a job package[7] was compiled in order for the personnel involved to prepare for the task, and to use during the joint-testing operation. Three days prior to commencing the testing, the relevant personnel assembled in Adelaide to prepare for the task.

Joint testing involved a platform[8] lineworker sitting on the left side of a platform that was attached to the helicopter's lower fuselage and skid-type landing gear. The platform lineworker operated the joint-testing equipment, which involved placing a probe on the joint that was being tested and on the conductor[9]. A second lineworker

---

1 The 24-hour clock is used in this report to describe the local time of day, Central Daylight-saving Time (CDT), as particular events occurred. Central Daylight-saving Time was Coordinated Universal Time (UTC) + 10.5 hours.

2 The definition of 'serious damage' includes the destruction of the transport vehicle.

3 The private company or statutory authority that owns and manages an electrical distribution network.

4 Testing of the powerline conductor joints for connectivity.

5 Any power line (usually of high voltage) that is used to convey electricity from a power station to the distribution line.

6 A document that explains a job and contains project or task information such as plans, charts, information on danger areas and no fly zones, joint location data, and any other information considered relevant to assist in carrying out the task.

7 A number of documents compiled by a helicopter operator to assist the pilot and lineworkers to carry out airborne tasks.

8 A metal structure that is fitted to a helicopter to enable work outside the helicopter.

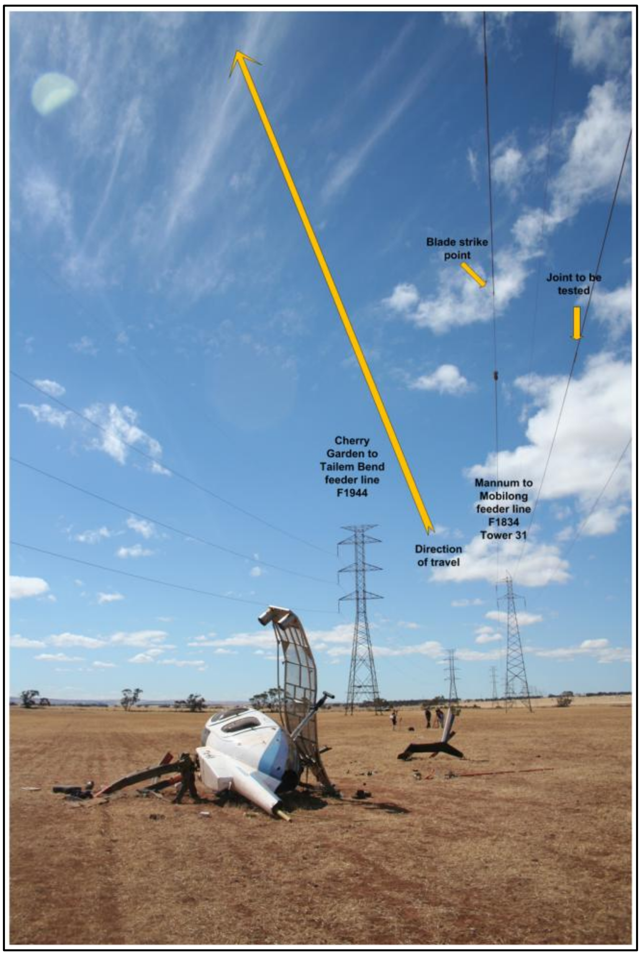
9 A wound wire cable used to conduct electricity.

(the recording lineworker) occupied the right front seat beside the pilot,[10] and was responsible for recording joint information and test data on a laptop computer.

At 0600 on 19 November 2008 the crew met the helicopter operator's chief pilot at Parafield Aerodrome to plan the day's operation. Due to an unfavourable weather forecast for the area where the operations were initially planned to start, it was decided to test the Mannum to Mobilong powerline where the weather conditions were considered suitable for the activity. The helicopter was flown to Mannum and a ground support vehicle followed. After the platform was attached to the helicopter, and the crew had completed final preparations, the helicopter was flown to the Mannum sub-station and the joint-testing operations began.

The Mannum to Mobilong line (feeder line[11] F1834) was parallel to and east of an adjacent line, the Cherry Gardens to Tailem Bend line (feeder line F1944). The operator's procedures required the pilot to fly along the right side of the relevant transmission line so the crew could visually locate all joints in the conductors. Consequently, as the helicopter proceeded south toward Mobilong, it flew between the two sets of transmission lines (Figure 1).

Figure 1: Accident site and powerlines



---

[10] The design of the MD369D helicopter required the pilot in command to occupy the left front seat.

[11] A section of transmission line consisting of a series of towers with conductors joining two points.

The pilot and recording lineworker reported experiencing intermittent problems with the joint-testing equipment that day, which required resetting of the equipment by the platform lineworker as they tested joints along the powerline. At tower STR0027, the inspection and testing was halted to enable the helicopter to be refuelled at a prearranged point, near tower STR0030. Once refuelled, the helicopter was flown back to tower STR0027 to resume testing and the ground support vehicle proceeded towards the next refuelling point.

A witness who was travelling north along the Murray Bridge to Mannum Road reported intermittently observing the progress of the helicopter. The witness reported that the helicopter was at about the same level as the conductors when it ‘rocked from side to side and went up and down.’ During that sequence, the witness observed the ejection of an object from the helicopter. The witness then saw the helicopter roll on its side and impact the ground. The witness reported that the helicopter’s tail section broke off upon impact.

The pilot advised that he did not have a clear recollection of the events immediately before the occurrence. However, he remembered that the crew had visually located three joints between towers STR0031 and STR0032, and that he was positioning the helicopter to test the joint in the lower conductor preceding the wirestrike. He could not recall whether the test equipment needed to be reset by the platform lineworker at that time. However, he was confident that the severe vibration began before they were at the stage of placing the test equipment on the joint. His next recollection was that the helicopter was lying on its side on the ground. He was still secured by his safety harness and could hear the helicopter’s engine running. He asked the recording lineworker to operate the fuel shut-off control to stop the engine.

The recording lineworker also advised that he did not have a clear recollection of the events immediately before the occurrence. He recalled that the joints between towers STR0031 and STR0032 had been visually located and that the pilot was slowing towards a hover in preparation for testing the joint in the lower conductor. The lineworker turned his attention to the laptop computer to commence logging the joint details. As he did so, he felt ‘an enormous vibration in the rotor hub’. His next recollection was that the helicopter was lying on its side on the ground and that he was suspended by his safety harness. He undid the harness and assisted the pilot from the wreckage before rolling the throttle to OFF.[12] He said that he was unable to operate the fuel shut-off control because it was damaged.

The pilot and the recording lineworker confirmed that the helicopter had been operating normally prior to the occurrence and that all crew members were wearing flight helmets that were fitted with a serviceable intercom. They also confirmed that all safety harnesses were worn throughout the flight. The recording lineworker’s shoulder harness failed during the impact sequence.

[12] In the 369D helicopter, the engine can be shut down by rolling the throttle off, or by activating the roof-mounted fuel shutoff control.

Personnel information

Pilot

The pilot had held an Australian Commercial Pilot (Helicopter) Licence since July 2005 and a Grade 1 Helicopter Instructor Rating since April 2005. The pilot's total flying experience was 3,744.2 hours, of which 3,624.6 hours was on helicopters. His total experience on 369D helicopters was 1,374.6 hours.

The pilot had been employed by the helicopter operator for 4.5 years and had conducted helicopter instruction, including employment as chief flying instructor, with the company's flight school. Prior to moving to the powerline operations section of the company, the pilot undertook ferrying duties to gain the required number of flying hours on the 369D. The pilot completed 12 months of airborne patrolling, followed by a 3-month period of insulator washing before progressing to platform work. That platform work entailed about 27 hours of earth wire[13] maintenance at the line towers.

The helicopter operator's chief pilot confirmed that he had previously assessed the pilot as being competent to perform platform work, and reported that the pilot was '...a good pilot doing a good job'. On the day before the occurrence, the chief pilot completed a series of training exercises with the pilot and lineworkers (see the section titled *Crew preparation for task* later in this report).

The pilot's flying logbook indicated that he flew 22.8 hours in the 5 days before the occurrence (Table 1).

Table 1: Flying hours in the previous 5 days

Date	Hours flown	Type of task
14 Nov 2009	7.7	Emergency inspection
15 Nov 2009	8.2	Emergency inspection
16 Nov 2009	3.4	Emergency inspection
17 Nov 2009	0.6	Sling check
18 Nov 2009	1.9	Platform training

The helicopter operator's fatigue management system[14] suggested that the roster and actual hours flown should not have exposed the pilot to roster-induced fatigue. The pilot reported that he felt fit and well on the day of the occurrence, and did not feel tired.

13 A wire that is placed above electrical conductors to protect them from lightning strikes.

14 The operator's fatigue management system gave the relevant pilot a score depending on that pilot's duty periods and hours flown. It took account of a pilot's length of duty, time of that duty (day or night), and so on. The score was colour coded and presented in 'green', 'orange' or 'red'. In this case, the pilot's score was 'green'.

Platform lineworker

The platform lineworker had worked with the helicopter operator for about 18 months. Prior to that, he had carried out extensive transmission line work in New Zealand. He recommenced duty on 16 November 2008 after a 2-week rest period. The operator's fatigue management system suggested that the platform lineworker should not have been exposed to roster-induced fatigue.

Recording lineworker

The recording lineworker had worked for the company for 12 months and had previously carried out extensive bare hand, live line work[15] in New Zealand. The operator's fatigue management system suggested that the recording lineworker should not have been affected by roster-induced fatigue. The lineworker reported that he felt fit and well on the day of the occurrence, and did not feel tired.

Combined crew task-specific qualifications and experience

Qualifications and training

Company records showed that all crew members had completed the necessary training and exceeded the minimum experience requirements as specified in the operations manual.

As part of the pilot's and lineworkers' training, they attended a 1-day crew resource management (CRM) course in May 2006 and 'flying the wire' training in August 2008. The 'CRM in the Wire and Obstruction Environment Course' discussed the hazards of flying in the wire environment and the management of the associated risks. One of the topics covered was situational awareness, which was defined in the course material as maintaining a 'thorough understanding of all the risks associated with the environment you are operating in.' The material listed five important factors in preventing wire strikes:

- The required knowledge specific to that environment.
- Being able to apply that knowledge.
- Maintaining that knowledge over time.
- Recognising that a lineworker has more chance of preventing a wirestrike than a pilot.
- Standard phraseology must form part of a crew's procedures.

Airborne experience

A breakdown of the total flying hours by task for each crew member is at Table 2.

---

15 Where a lineworker is bonded to a live electrical conductor, making them the same electrical potential as the conductor. This enables the lineworker to touch and work on the conductor while it is live.

Table 2: Crew member's total flying hours

Type of operation	Pilot (hours)	Platform lineworker (hours)	Recording lineworker (hours)
Flight instruction	1,760.5	N/A	N/A
Ferry	88.9	4.0	1.2
Inspection/patrol	1,112.4	479.7	296.9
Insulator washing	83.2	53.4	55.9
All platform work	27.0	72.0	137.4

The pilot reported that he understood before the occurrence that the two lineworkers were experienced in joint testing and had assumed that to mean testing from an airborne platform. Information received by the pilot after the occurrence led him to understand that the only joint testing previously carried out by the lineworkers was from a fixed platform at the training farm,[16] and not from a helicopter. Later, the operator advised that the two lineworkers had completed platform-based work, similar to joint testing, prior to the accident.

About 1 month before the accident, the operator's Adelaide senior base pilot expressed concern to the project manager about the experience level of the crew that were nominated for the task. In response, the operator's management reviewed the experience levels of the crew and confirmed the selections.

The recording lineworker reported that he and the platform lineworker were familiar with transpositions as they had worked on them previously. The pilot stated that prior to the accident, he had no knowledge of what a transposition was.

Helicopter, platform and joint-testing equipment information

Helicopter

The helicopter was manufactured in the United States (US) in 1978 and had accumulated 20,536 hours time in service by 18 November 2008.

The last 100-hourly maintenance was conducted on 19 October 2008. There was nothing in the helicopter's maintenance documentation to suggest that the maintenance or serviceability of the helicopter was a factor.

Recording lineworker's seat harness

The recording lineworker's shoulder harness was fitted to the helicopter in June 2008. After installation, a minor adjustment was made to the inertia reel due to it not retracting or allowing free movement in normal operations. The weakest point of the harness assembly was the stitching interface that connected the shoulder harnesses to the inertia reel webbing.

16 A facility at which different types of power distribution and transmission lines were set up for lineworker training.

Maintenance records indicated that the recording lineworker's restraint was repaired on 6 September 2005 by a Civil Aviation Safety Authority (CASA)-approved restraint repair facility and was rated to a minimum breakage strain of 2,000 lbs (909 kg). The restraint repair facility owner reported that the repair was authorised by CASA approval 4148 and reweb authority EA AC 43.131A & 2A, which complied with Civil Aviation Order 108.42. This procedure entailed copying the stitch pattern from the original restraint.

However, the repairer stated that when he received the harness for repair, the harness identification tag did not indicate whether a previous repair had been carried out. He stated that he copied the stitch pattern on the harness as he received it. The repairer could not recall if the restraint had, in accordance with the servicing requirements, been load tested to half its rated strength following the repair.

Platform

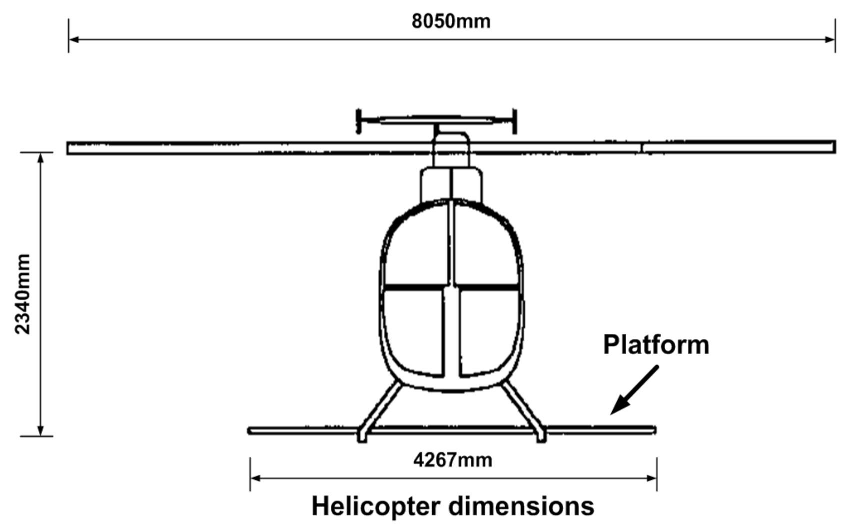
The platform that was attached to the helicopter was built and operated in accordance with a Supplementary Type Certificate issued by the US Federal Aviation Administration and was approved by CASA. The lineworker sat on the left side of the platform, adjacent to the pilot (Figure 2). All operations were carried out with the helicopter positioned to the right of the component to be tested. If work or testing was to be done on a line on the opposite side of the tower, the helicopter approached the line from the other side and in the opposite direction.

Figure 2: Platform installation

The front elevation and dimensions of the helicopter and platform are shown at Figure 3. To maintain the helicopter's lateral centre of gravity (c.g) in limits, a number of counterweights were positioned on the right side of the platform (facing forward, Figure 2). It was estimated that at the time of the occurrence, the helicopter's c.g was in limits.

To maximise the helicopter's hover out of ground effect performance, the operation was carried out with reduced fuel loads. This meant that the interval between refuelling was about 30 minutes.

Figure 3: Helicopter front elevation – principal dimensions



Joint-testing equipment

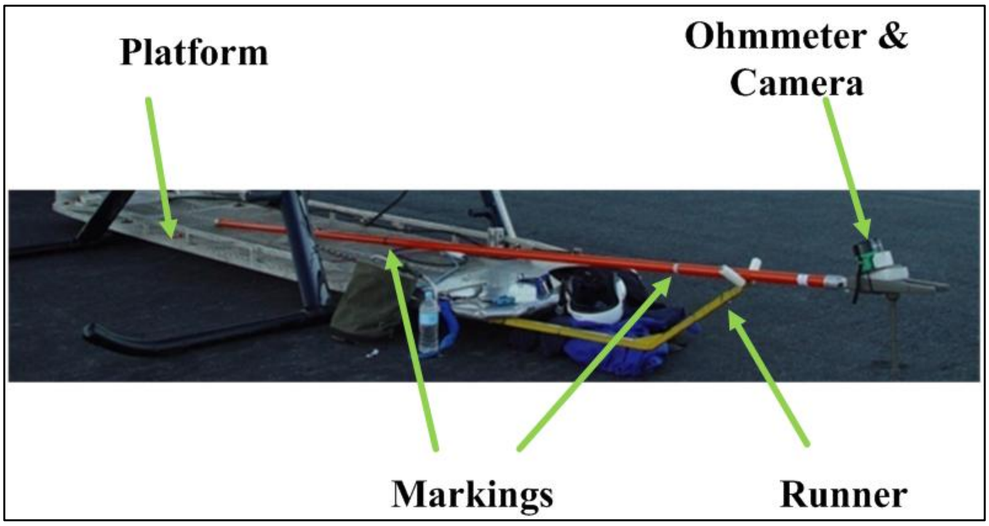
The helicopter was equipped with specialised equipment for joint testing, including:

- A fibreglass pole (generally referred to as a Hotstik[17]) that was used by the platform lineworker to position an ohmmeter and a digital camera with an integral transmitting device (Ohmstik) on the joint to be tested (Figure 4). The Ohmstik had a fork-type probe, which was placed on the conductor and joiner to measure the resistance in the joint. The camera relayed the Ohmstik micro ohms resistance reading via a transmitter to the on board laptop computer.
- A laptop computer into which the test data was entered and stored by the recording lineworker.

---

[17] A stick of insulating material, normally 4.5 or 5 m long, that was specifically designed, approved and tested for the use in physically bridging the distance between a line worker and energised components, between energised components and earth, between adjacent phases, or to enable load measurements to be taken or tools to be applied.

Figure 4: Hotstik in runner cradle



During joint-testing operations, the platform lineworker rolled the Ohmstik out on the runner to a marked position on the Hotstik. That position ensured that the Hotstik, with the Ohmstik attached, extended 2.5 m horizontally beyond the arc of the main rotor blades. Once the ohmmeter was in the correct position and displayed a reading, the camera transmitted the relevant images to the laptop for recording by the lineworker.

Originally, a 5.0 m Hotstik was to be used for the job. However, pre-flight functional testing of that Hotstik indicated that it was faulty, so a 4.5 m Hotstik was used. Use of the 4.5 m Hotstik did not affect the minimum safe horizontal clearance between the end of the Hotstik and the main rotor blade tips. The use of the different length Hotstiks depended on the line voltage to be tested. The lineworker had previously used both length Hotstiks.

Powerline information - mid-span transposition

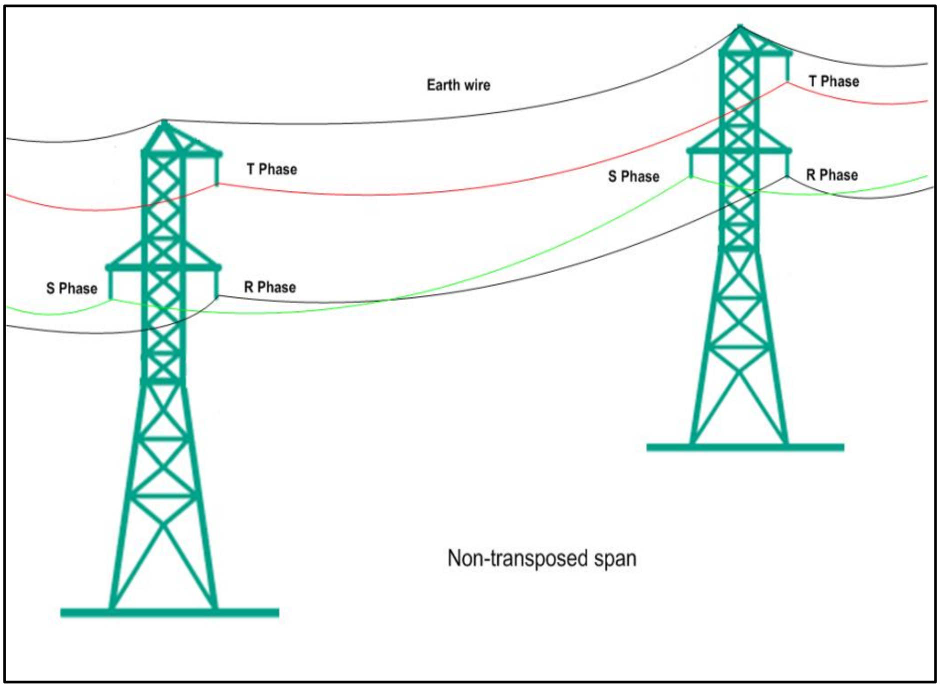
When electricity is transmitted through conductors, an electromagnetic field is created around the conductors. Depending on the configuration of the power conductors and supporting towers, there can be a loss of conductor efficiency or a large heat build-up within the power transmission system. To counteract those effects, the power conductors have their relative positions transposed; that is, their positions relative to each other changed. This is done in a number of ways; either electronically at the substation, by cable switching at the tower itself, or as a mid-span (between two towers) transposition. The electricity asset owner advised that the majority of transmission lines in the South Australian grid have transpositions[18] and other phase changes but these only account for less than 10% of the structures on these lines.

The Mannum to Mobilong line consisted of three conductors and an earth wire. The conductors were suspended from towers that were about 30 m high and about 440 m apart. On a typical, non-transposed span, individual conductors were strung between insulators occupying the same position on consecutive towers. On a

18 Where the position of the conductors on one tower is changed relative to another tower.

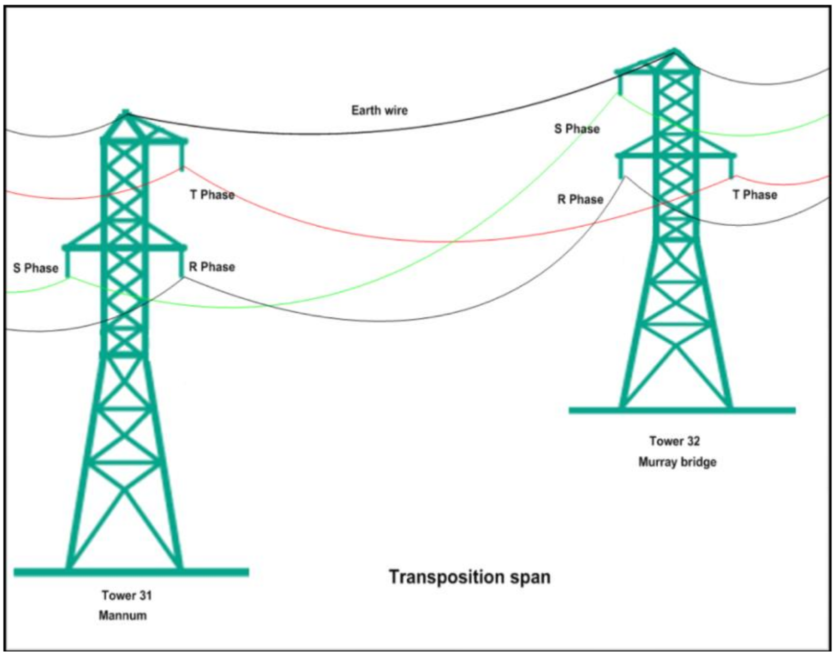
non-transposed span the ‘R’ and ‘T’ phase conductors were parallel, with the ‘R’ phase conductor located directly below the ‘T’ phase conductor (Figure 5).

Figure 5: Typical non-transposed span showing conductors suspended on consecutive towers



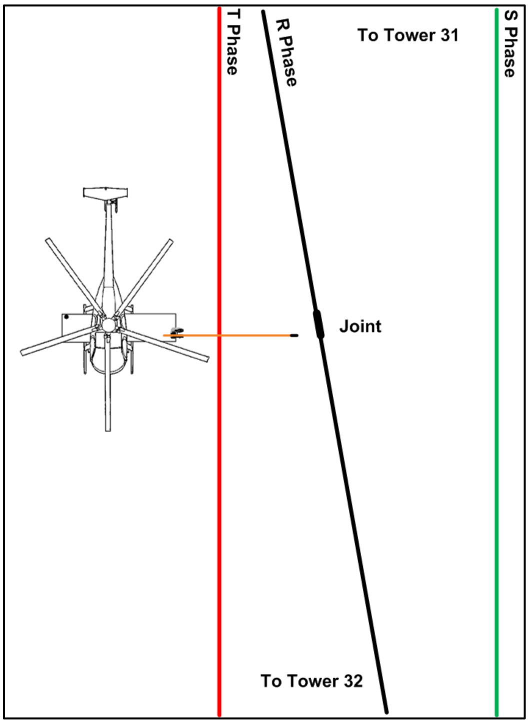
In the case of a mid-span transposition, the insulator arrangement on consecutive spans is rotated, allowing the ‘R’ phase conductor to pass underneath the ‘T’ phase conductor to an insulator on the opposite side of the next tower. Similarly, the ‘S’ phase position is changed from bottom to top on the same side of the two affected towers. That was the situation between towers STR0031 and STR0032 on the Mannum to Mobilong line (Figure 6). A mid-span transposition results in structural differences between adjacent towers and electrical industry personnel indicated that the best means of identifying mid-span transpositions was through the in-flight recognition of those differences.

Figure 6: Mid-span transposition



A plan view representation of the position of the helicopter and conductors adjacent to the 'R' phase conductor joint between towers STR0031 and STR0032 is at Figure 7.[19] The consequence of the 'R' phase diverging from underneath the 'T' phase was that, in order to joint test the 'R' phase, the helicopter's main rotor blades were placed closer to the 'T' phase.

Figure 7: Relative positions of the helicopter and conductors



[19] The representation is not to scale and the angle that the 'R' phase crosses from the side of one tower to the other tower has been expanded for clarity.

There were no tags or similar attachments to the towers, conductors or joiners to alert crews to a transposition section, nor was there any standard or other regulatory requirement to do so.

Meteorological information

The pilot reported that the weather in the area was 'fine' with broken[20] cloud and a light westerly wind.

The position of the sun was examined via the Geoscience Australia website at www.ga.gov.au. That examination established that, at the location and time of the wirestrike, the sun was at an azimuth[21] of about 074° and an elevation[22] of about 054°. That meant that the sun was slightly north of and high in the sky from where the crew were looking as the helicopter progressed from Mobilong to Mannum.

Wreckage and impact information

Damage to the helicopter

The helicopter impacted the ground banked 90° to the left and in a slightly nose-high attitude. The left side of the platform and four of the helicopter's five main rotor blades were damaged by the impact with terrain. The helicopter's fuselage came to rest on its left side facing north-north-west, opposite to the direction of flight. The tail boom separated from the fuselage during the impact sequence and was found about 10 m from the main wreckage.

The No 1 main rotor blade had separated from the main rotor hub and was found 126 m north-east of the main wreckage. The associated main rotor blade damper was found 147 m east of the main wreckage. Three main rotor blades remained attached to the hub, but exhibited significant damage consistent with contacting the ground while under power. The fifth blade separated 27cm outboard of the hub and was lying amongst the other blades in the wreckage (Figure 8).

---

[20] Cloud amounts are reported in oktas. An okta is a unit of sky area equal to one-eighth of total sky visible to the celestial horizon. Few = 1 to 2 oktas, scattered = 3 to 4 oktas, broken = 5 to 7 oktas and overcast = 8 oktas.

[21] The clockwise horizontal angle from the sun to true north, measured in degrees.

[22] The vertical angle to the sun from an ideal horizon, measured in degrees.

Figure 8: Main rotor blade and hub damage

Wirestrike witness marks were evident near the tips of two of the main rotor blades (Figure 9).

Figure 9: Main rotor blade witness mark tip damage

The platform was buckled in an 'S' shape and had partially detached from the skid landing gear (Figure 1). The forward left plexiglass cockpit window and part of the right side had burst outwards from where the pilot was seated.

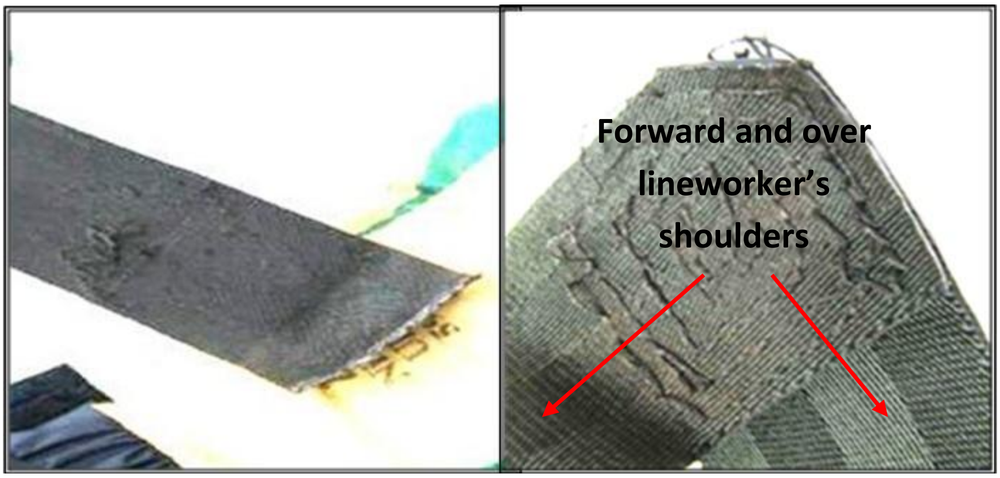
There was no evidence of any pre-existing mechanical or other system condition that might have contributed to the accident.

Damage to the recording lineworker's shoulder harness

The 'V' section of the recording lineworker's shoulder harness had separated from the inertial reel section (Figure 10). The design of the lineworker's shoulder harness was such that the inertia reel webbing that ran from the inertia reel connected to an inverted ‘V’ webbing to form a ‘Y’ behind the lineworker’s shoulders. In use, the two ends of the ‘Y’ were passed over the lineworker’s shoulders and secured to the lap harness.

Figure 10: Separated sections of the recording lineworker’s harness

Inertial reel webbing section **‘V’ webbing section**



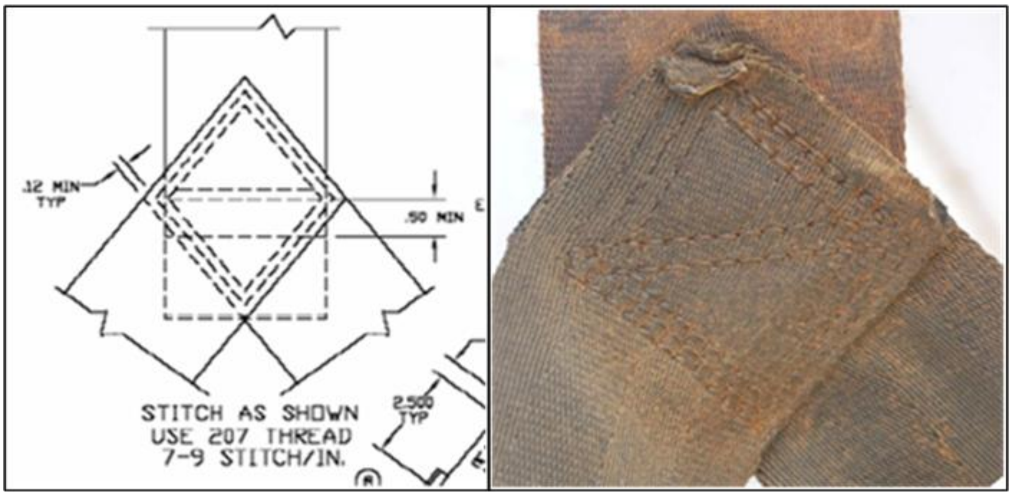
Technical examination of the recording lineworker’s shoulder harness

The recording lineworker’s shoulder harness was removed from the wreckage for technical examination. There were no deficiencies in the harness webbing; however, it was permanently rippled in some areas, indicating that it had been subjected to forces beyond its point of elasticity.

Harness photographs, measurements and technical information were sent to an overseas test facility for further analysis. That analysis established that the:

- restraint lap joint stitch pattern did not conform to [the] applicable [drawing] as the drawing specified a diamond pattern and the provided field article did not have the top of the diamond pattern completed [Figure 11]
- restraint lap joint stitch density did not conform to applicable drawings for the restraint and had less stitches per inch that the drawing specified
- correct thread material was used during the repair.

Figure 11: Stitch pattern as specified (left) and a correctly-stitched harness (right)



The testing facility fabricated a test sample of the joint using the stitch pattern and density that was found in the recording lineworker's harness. During testing, the average strength of the replicated harness joint was 1,009 lbs (459 kg). That was less than half the average strength of 2,500 lbs (1,336 kg) for a joint that was fabricated in accordance with the approved restraint drawings.

The testing facility also commented on the load testing of repaired restraints and noted:

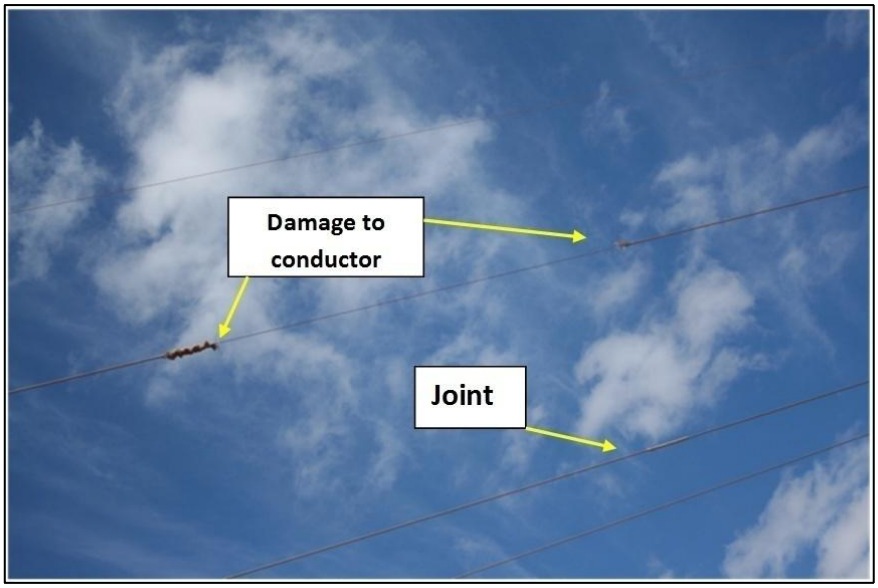
> Lastly, we note that a proof load test is performed in accordance with British ARB / CAA Spec. No 4. We do not recommend taking repaired restraints to their rated load and then issuing them to the field. The proof load may potentially introduce non-obvious and or latent damage that may pre-weaken the restraint. In production, we do destructively test samples to verify the restraint's structural integrity in a build. We also sample test sub-components such as webbing at the material level.

Damage to the powerline

On-site examination

An examination of the powerline overhead the accident site revealed joints in close proximity to each other in all three conductors, of which one was damaged (Figure 12). The damaged conductor was 10 m above ground level.

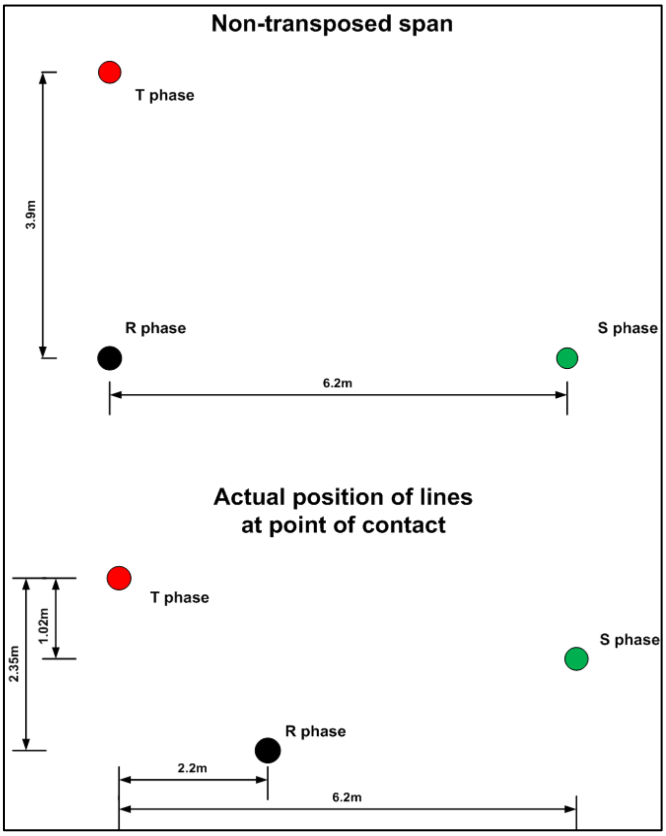
Figure 12: Damaged conductor



Before repairs to the conductor were undertaken, measurements were taken by the powerline maintenance provider to establish the relative positions of the conductors in the vertical plane (depicted in Figure 13). Also shown, is a vertical cross-section of the conductor positions at a typical non-transposed span, compared to the position of the damaged conductor.

The damaged conductor was retained for technical examination.

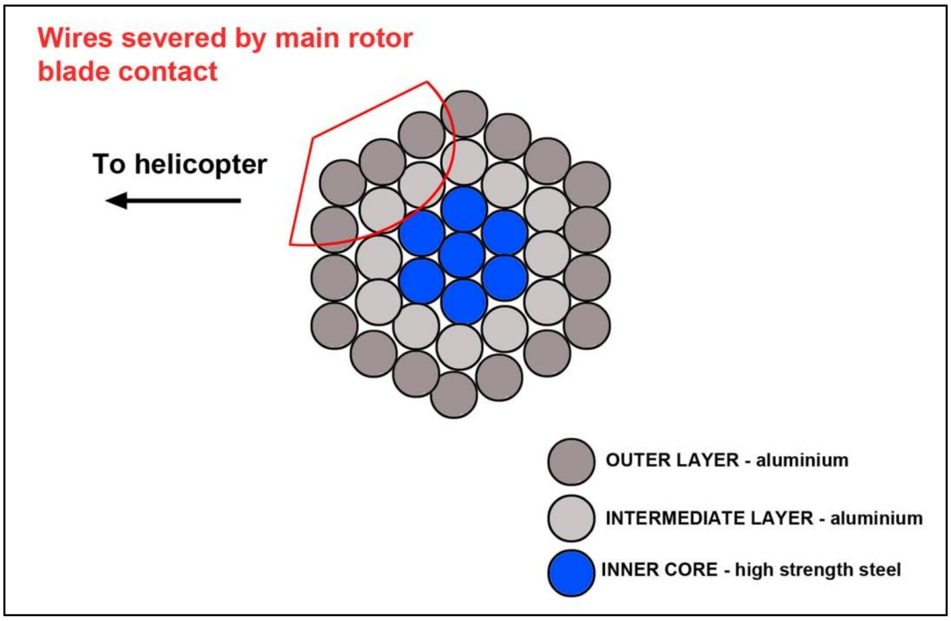
Figure 13: Comparison of mid-span conductor positions in the vertical plane



Technical examination of the damaged conductor

The damaged conductor was comprised of outer and intermediate layers of 18 and 12 counter-woven aluminium alloy wire strands respectively, and an inner core of seven high strength steel wire strands. The aluminium alloy wires were used for their electrical conductivity properties, while the steel wires provided the strength necessary for suspension between the transmission towers (Figure 14).

Figure 14: Conductor cross-section



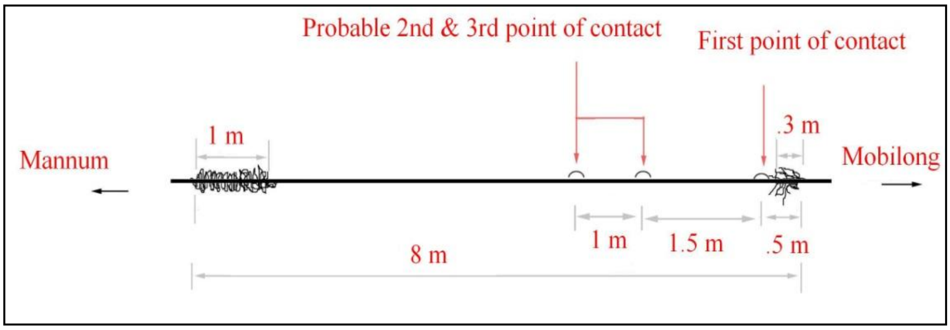
All of the severed wires at the first point of contact with the main rotor blade were grouped at the same weave location, near the upper-outer quadrant. A total of about 8 m of conductor was damaged from the contact with the helicopter.

The majority of the damage to the conductor was to the outer and intermediate layers of aluminium wire. The aluminium wires at the Mobilong end were severed and splayed outward from the main weave, while those at the Mannum end were bunched into a loosely coiled, 1 m length (Figure 15). That damage was consistent with the anti-clockwise rotation (when viewed from above) of the helicopter's main rotor blades.

Two distinct failure modes for the aluminium wires were identified at the point of the initial contact with the main rotor. Fourteen of the aluminium wires were severed cleanly, while the remaining 16 wires failed from tensile overload. That was consistent with the first main rotor impact severing the 14 wires, while the remaining 16 were stretched until failure.

The high strength steel wire was kinked in three separate locations along the 8 m damage zone. Some deformation was observed to the steel weave at each kink. Due to the very high strength and tight weave of the steel wire, it was unlikely that the kinks were introduced from handling damage when the line was removed and transported to the Australian Transport Safety Bureau (ATSB) for technical examination.

Figure 15: Profile of the damaged section of conductor



Medical and pathological information

The platform lineworker received fatal head injuries and fractures to the pelvis and right ankle as a result of impact forces. Toxicology testing for the presence of drugs or alcohol was negative.

The pilot received serious injuries to his left arm, pelvis, and back. The recording lineworker received minor injuries and was able to exit the cabin without assistance.

Survival aspects

Cabin

The principal damage was to the forward-left fuselage. The cabin space retained its integrity and contributed to the survival of the pilot and the recording lineworker.

Platform lineworker's helmet

An examination of the outer shell of the platform lineworker's helmet showed damage to both sides of the helmet around the temporal and ear cup region as a result of the impact. That included evidence of paint transfer from the helicopter to behind the left ear region of the helmet, and the disruption of some of the helmet's white-coloured composite (glass fibre reinforced) outer shell.

There were no obvious manufacturing defects or pre-existing damage to the helmet.

The helmet was disassembled and the inner foam lining removed. A large crack ran from near the left ear cup to the uppermost section of the helmet. Measurements were taken of the foam liner and it was evident that the foam at both ear cup regions was crushed during the impact sequence. That crushing corresponded with the damage to the outer shell.

Safety harnesses

The platform worker wore a harness that was attached by a lanyard to a fixed point inside the helicopter and a lap belt that was attached to the platform work station.

The pilot and recording lineworker's seats were each fitted with a four-point restraint with an inertia reel shoulder harness. The pilot's harness was examined at the accident site and no defects were found. The recording lineworkers harness had failed at the point where the shoulder harnesses joined the inertial reel section of the webbing.

Organisational and management information

The helicopter operator provided aerial services to the national and international power supply industries. Those services included:

- Powerline inspection and patrol - inspecting powerlines for any defect or breakage.
- Platform work - including marker ball installation and replacement, the installation of spiral dampers, spacer installation and removal, and joint testing.
- Insulator washing - washing the insulators on transmission towers with high pressure water to prevent electrical arcing.
- Sling/long line/precision long line operations – including insulator string replacement and carrying loads under the helicopter, generally into remote or other areas that were difficult to access from ground vehicles.
- Stringing - pulling out the draw line or conductor to string conductors between towers.

The operator was the only Australian company and one of only a few in the world to provide platform-based live line work of the type being conducted during the occurrence flight. The operator's procedures were predominantly developed in-house. The procedures had been reviewed by independent specialist auditors, including from overseas, who reported that the company's operations were to a satisfactory standard.

Helicopter operator's joint-testing procedures and guidelines

In August 1995, the Electricity Supply Association of Australia Limited (ESAA) published *Guidelines for use of helicopters for live line work* that contained 'the recommended minimum industry standard for Helicopter Live Line Work.' In respect of line hazard identification, the guidelines stated that:

> The Authority shall identify any hazards that have the potential to impact on the safe outcome of the work e.g. conductor corrosion, defective insulator types, corroded or defective fittings or structures, and known over-crossing of other lines.

The guidelines defined the Authority as 'the organisation which owns the line to be worked on', but added that 'the responsibilities of the authority may be delegated to another entity where the operational control of the line has been contracted over to another party'. The document did not bind members to follow the guidelines.

The helicopter operator's procedures and guidelines for powerline operations drew on content from the relevant approved flight manual supplement for the helicopter and to the ESAA guidelines. That information was complemented by the operator's operations and powerline procedures manuals.

Operations Manual

The authority for the operations manual was described as follows:

> The instructions, procedures and information contained in this manual have been devised to ensure safety and standardisation in the conduct of [the helicopter operator's] operations. They are to be observed by all operating personnel employed by [the helicopter operator] or under [the helicopter operator's] supervision operationally.

Section OM 0611 of the operations manual was titled *Powerline Inspection, Cleaning and Maintenance* and included a sub-section titled *Platform Linework Operations*. The requirements of that sub-section were generic to all of the operator's operations that employed a helicopter platform. In addition to complying with the limitations and conditions in the relevant flight manual supplement for each helicopter type, the sub-section placed additional requirements on those operations, including that an active intercom system was available and checked for clarity, and that minimum safe working distances were to be calculated for each task. A copy of Section OM 0611 of the operations manual is included at Appendix A to this report.

Powerline Procedures Manual

The authority for the Powerline Procedures Manual was described as follows:

> 1. The Company Flying Operations (Ops) Manual contains guidance in general terms on the conduct of powerline operations. This manual supplements the Company Ops Manual by providing detailed work methods for each area of the specialised powerline activity. Both manuals together provide the policy procedures, and work instructions which all crews are to follow.
>
> 2. These procedures and work instructions are intended to have the same initial reference numbers as the appropriate parent section in the Company Operations Manual (AP-OM).
>
> 3. In addition to these manuals the IEEE [Institute of Electrical and Electronics Engineers] standards and ESAA [Energy Supply Association of Australia] guidelines shall be followed whenever relevant. A copy of the ESAA Guidelines for the use of helicopters in Live Line Operations is provided in this manual.

The Powerline Procedures Manual included procedures for particular tasks, including live line inspections (which included joint testing). A copy of Work Instruction 611/02 – *Positioning of the helicopter horizontally* is included at Appendix B. Pertinent extracts from that document include:

> **POSITIONING HELICOPTER FOR LIVE LINE WORK WHERE A HORIZONTAL APPROACH TO THE CONDUCTOR IS REQUIRED**
>
> 4. PROCEDURE
>
> 4.5 The pilot SHALL manoeuvre the helicopter to a stationary hover adjacent to the work station about approximately 10 metres laterally clear of the conductor to enable clearance verification.
>
> 4.10. The lineworker SHALL conduct an in flight visual check of the structures and conductors including hardware, and earthwire where appropriate prior to the operation commencing.
>
> 4.13 The lineworker SHALL verbally confirm to the pilot that he is ready to bond on to the line before the pilot moves closer to the line. Confirmation SHALL state; Ready to bond on clear to proceed.
>
> 4.14 Upon receiving confirmation, the pilot SHALL verbally confirm "Ready to Bond" and commence hovering sidewards towards the line as per WI 611/05 "Bonding Helicopter to Line".
>
> Safety Note 1.
>
> The airborne crew SHALL use continual communication (constant banter) when approaching, performing and concluding platform maintenance. If communication ceases then the procedure SHALL halt until communication is re-established.
>
> Safety Note 2.
>
> Any one or all crew members can be responsible for terminating operations if conditions of the surroundings, self or vehicle are not favourable.
>
> Helicopter Minimum Vertical Distance (HMVD) is the combined distance from the linesman platform work position to the main rotor. (Detailed in the Auto cad drawing as "Vertical Distance Current Tier Bundled to Main Rotor") and the "Critical Minimum Approach Distance[23]" for the line either energised or de-energised Planning the job.

Pilot experience and training requirements

The operations manual specified the minimum requirements for powerline work, and for training pilots for that work (see Appendix C).

The pilot's logbook indicated that he held those minimum qualifications.

The helicopter operator's chief pilot stated that most pilots progressed within the company from simpler to more complex tasks. Normally, pilots started on aerial surveillance and then progressed to airborne patrols and inspection. They would usually perform those tasks for about 1 year before progressing to insulator washing

---

23 A safe distance at which electrical flashover will not occur. This distance varies with line voltage; the higher the voltage the larger the safe distance.

and then stringing. Once experienced in those roles, pilots progressed to platform work.

There was provision in the operations manual for pilots to be progressed to a more complex task with less than 1 year experience in a particular task. However, the chief pilot was required to approve such cases, provided the minimum experience requirements as stated in the operations manual were met. The chief pilot explained that the occurrence pilot was progressed to mid-span platform work because there was a large amount of platform work scheduled and the operator had a shortage of suitable pilots.

Safety management system

Clause 3.7.1 of the International Civil Aviation Organization (ICAO) Safety Management Manual listed eight basic and generic building blocks that underlie the management of safety:[24]

1. Senior management's commitment to the management of safety
2. Effective safety reporting
3. Continuous monitoring
4. Investigation of safety occurrences
5. Sharing safety lessons learned and best practices
6. Integration of safety training for operational personnel
7. Effective implementation of standard operation procedures
8. Continuous improvement of the overall level of safety

Charter and aerial work helicopter operators in Australia were not required by regulation to have a formal safety management system operating within their organisations. However, an examination of the operator's integrated management system revealed that it addressed the eight basic building blocks that were identified by ICAO as underlying the management of safety.

Additional information

Joint testing – Mannum to Mobilong line

Background

The asset owner owned and managed the South Australian (SA) transmission system in the National Electricity Market. Those assets included all regulated 275 kV and 132 kV transmission lines, transformers, switch gear and cables within SA. The asset owner outsourced most of its asset maintenance requirements to the maintenance provider.

The asset owner stored the transmission line information in a number of databases containing details of the location, age, structure type, maintenance, and technical

---

24 See http://www.icao.int/anb/safetymanagement/DOC_9859_FULL_EN_V2.pdf

details of its transmission lines. The data could be accessed through an interface called 'GRAZER'.[25]

The database information included transmission line schedules and connectivity diagrams. Transmission line schedules were in the form of spreadsheets which included:

- tower numbers and span distance
- ground elevation and terrain type
- tower type and structure details
- insulator details for each tower
- phasing detail codes for each span - a change of phasing detail between two consecutive spans may have indicated that there was a mid-span transposition between those spans.

The maintenance provider was contracted by the asset owner to build, maintain, upgrade and extend the network throughout SA. The maintenance provider in turn sub-contracted the helicopter-related work to the helicopter operator.

The maintenance provider had unrestricted access to GRAZER. In contrast, the helicopter operator did not have access to GRAZER, and reported being unable to gain direct access to any databases that contained asset information prior to the accident.

The helicopter operator advised that it had requested information regarding tower structure and insulator arrangement during the calculation of safe working distances. In response the maintenance provider supplied sample tower structure photographs and drawings. However, some of the information provided was inaccurate and/or incomplete, so additional information was requested regarding line voltage and tower structure that enabled the helicopter operator to complete the safe working distance calculations. One of the sample photographs was of the span between towers STR0031 and STR0032 but, the photographs were not intended to be used to identify hazards, only to confirm tower structure.

Project brief provided to the maintenance provider

On 28 August 2008, the asset owner issued a project brief to the maintenance provider for the airborne joint testing of three feeder lines, including the Mannum to Mobilong line, designated feeder line F1834. The brief indicated the presence of 'new' and 'old' joints on the feeder line[26], and required the location and recording of all joints. In addition, all new joints were to be resistance tested, whereas only 20% of old joints were to be tested. The brief stated that any joints that were not accessible by helicopter were not required to be tested, but their position was to be recorded. The brief stated that, based on the information in the databases, there were 24 mid-span joints in 15 spans in feeder line F1834.

---

[25] GRAZER is a database interface developed by the asset owner that allows access via a central portal for information stored on their databases.

[26] The difference between the new and old joints was readily apparent, according to the brief.

The brief included a section titled *Reference Documentation*, which listed the names of a number of documents, including:

- conductor joint resistance testing procedures for the resistance testing of transmission line conductor joints
- a transmission line coding guide
- a spreadsheet showing the location of the mid-span joints[27] to be tested
- connectivity diagrams
- line schedules.

The brief stated that the documents were available from the asset owner's database.

The line schedule contained a large amount of information including run distance, ground elevation, actual span details, tower type, and insulator arrangement. Phasing was also described and, in conjunction with the phase coding table, enabled the identification of mid-span transpositions. Connectivity diagrams showed the relationship between supply and demand points and a line phasing notation, and illustrated where changes occurred along the transmission powerline.

The asset owner advised that the connectivity diagrams were developed prior to 2003. The asset owner also advised that, in accordance with normal practice, it met with the maintenance provider to discuss the project brief. During that meeting, the meaning and content of the reference documents was discussed.

The maintenance provider offered the following information in regard to its relationship with, and the provision of information to the helicopter operator:

- The maintenance provider stated that their 'role in relation to transmission lines was to arrange and facilitate the inspection of those lines and provide the contractor [the helicopter operator] with such information and detail as the contractor required'.
- The maintenance provider advised that it was 'not expert in identifying any transmission line hazards associated with helicopter airborne work' and 'did not consider itself qualified to determine the relevance or importance of particular data base information to the joint testing task and any request for further information by the helicopter operator would be granted'.
- The maintenance provider advised that it 'had been previously made aware that the contractor [the helicopter operator] was familiar with and could identify any hazards associated with mid-span joint inspections'.
- The maintenance provider advised that it had not previously provided connectivity diagrams to the operator but they 'could have been made available had the contractor requested them'.
- The maintenance provider advised that 'some individual documents referred to in the project brief were discussed with, and made available to, the operator'.
- The maintenance provider advised that 'as the project was essentially a new task for [the maintenance provider] it may not have been aware of the contents of all of the documents referred to in the brief. It would have been aware of the

---

27 A point where the conductor ends are joined to make a continuous piece of wire.

contents of those documents which were sought by and provided to [the operator].'

- [The maintenance provider] advised that it had 'received no request from [the operator] regarding information on line hazards or transpositions'.
- [The maintenance provider] advised that it 'did not provide connectivity diagrams but did provide photographs including a photograph of the span where the accident occurred. However, the only way the transposition of lines in that photograph could be identified was by zoom function and close examination of the photograph'.
- The maintenance provider advised that 'no formal scope for the provision of information existed in [the maintenance provider's] dealings with the contractor. Communications were made by telephone and email to determine what information the contractor required. Upon request such information was provided. This practice existed and developed over the period that [the maintenance provider] had worked with [the operator]. [The maintenance provider] was not expert in determining what if any line hazards existed in relation to this project. Its role was to provide the information sought by [the operator] and not to determine or identify line hazards. In this project the only difficulty encountered was the initial provision of erroneous drawings, but this was remedied prior to the commencement of activities.'

The connectivity diagram for the Mannum to Mobilong feeder line showed the 'R', 'S' and 'T' phase positions and tower numbers for that line (Figure 16). From that information, the location of any transpositions could be established by comparing the phase position information (as depicted by the position of the 'R', 'S' and 'T' phases) between consecutive towers.[28] For example, there were transpositions between STR0016 and STR0017, and between STR 0017 and 0018, while the phase positions remained unchanged between STR0018 and STR0031 and STR0001 and STR0015. Similarly, the diagram showed that there were transpositions between STR0031 and STR0032, and STR0032 and STR0033.

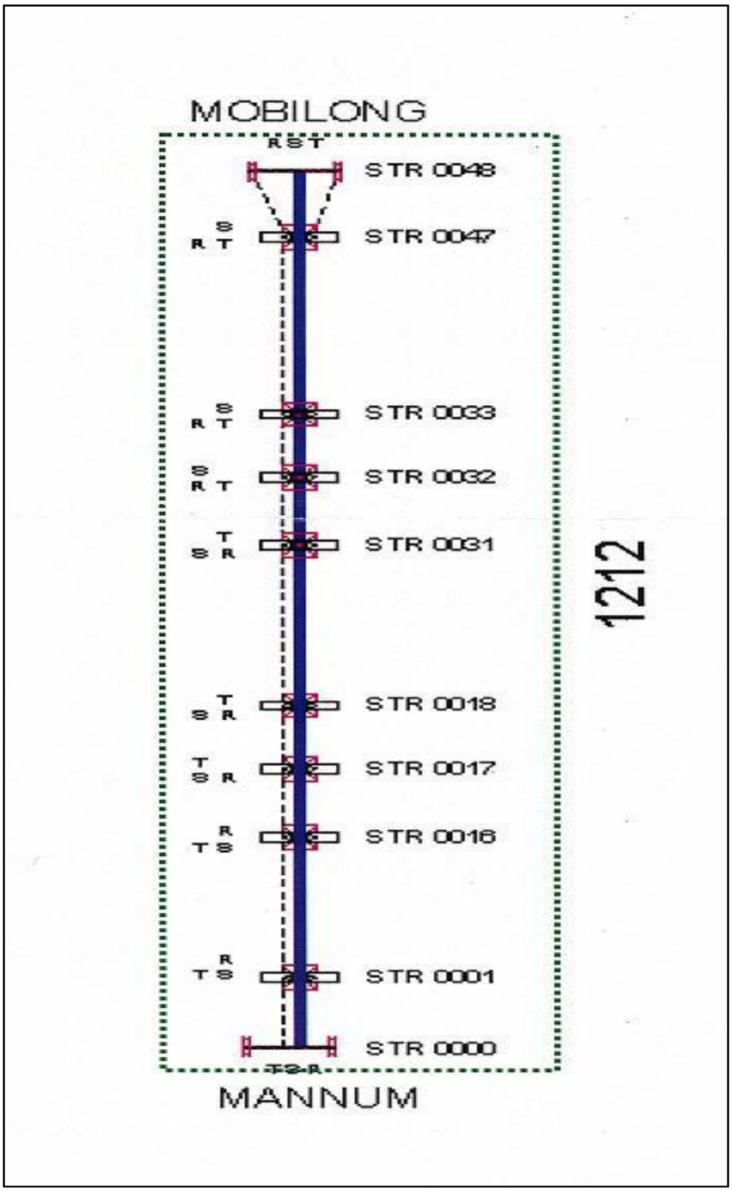
The recording lineworker stated that during a briefing with the maintenance provider prior to the task, the only transpositions that were mentioned were on the Paracombe to Angus Creek line. The maintenance provider used an 'aerial operations assessment sheet' in order to facilitate that brief. There was no reported reference in that brief to any transpositions on the Mobilong to Mannum line. The recording lineworker stated that he was very familiar with transpositions. However, he was not aware that there were any transpositions on the Mannum to Mobilong line, and did not see the transpositions between towers STR0016 and STR0017, or STR0017 and STR0018 during the joint-testing operation. The recording lineworker reported that he had been preoccupied with the data entry task, as it was the first time he had joint tested from a helicopter.

The pilot stated that he was not aware before commencing the job that there were any transpositions in the Mannum to Mobilong line. The pilot said that he had flown the line two or three times previously on patrolling tasks but did not recall anything about any transpositions in that line.

---

[28] Denoted in the connectivity diagram by a change in the plan-view location of the 'R', 'S' and 'T' phases.

Figure 16: Mannum to Mobilong connectivity diagram



Project brief provided to the helicopter operator

The maintenance provider forwarded a copy of the asset owner's project brief to the helicopter operator. The operator advised that they received a spreadsheet detailing the joint locations but had never received a connectivity diagram or line schedule from the maintenance provider prior to the occurrence.

The helicopter operator stated that different electricity asset owners used different naming protocols for their facility diagrams. In one case, an asset owner's connectivity diagrams did not show the position of transpositions, as that information was contained in the asset owner's transmission phase drawings. When the operator noted on the project brief for the Mannum to Mobilong task that one of the reference documents was the connectivity diagram, it was not considered relevant to the compilation of the job package or hazard identification.

The helicopter operator further stated that they had used line schedule spreadsheets in the past for preparing job packages, but that information was used for determining safe working distances. The operator was not aware that information contained in the connectivity diagrams could be used to determine mid-span transposition locations.

After the helicopter operator had assessed the requirements of the job, additional information was sought and received from the maintenance provider in relation to the tower specifications and structural details. The helicopter operator then developed the job package for the helicopter crew. The helicopter operator stressed that mid-span transpositions were one of a number of hazards affecting such operations. The helicopter operator considered electrical flash-over the greatest risk to all of its operations, and therefore spent considerable effort ensuring that the necessary minimum safe working distances were observed. They also considered other hazards but crews were expected to deal with any unexpected hazards as they arose.

Development of the helicopter crew's job package.

The helicopter operator's administration manual included a section on the preparation of job packages. The section stated the conditions under which a job package was to be prepared, a flow chart detailing the steps to be followed in the preparation of a job package, and a checklist of information that should be considered for inclusion in a job package.

The job package that was prepared for the Mannum to Mobilong joint inspection task was in accordance with the administration manual and included the following:

- the details of team members' responsibilities - that section listed the team leader's responsibilities which, amongst other responsibilities, included:
  - ensuring that all team members attended the pre-flight briefing
  - the daily completion of the On Site Safety Management form, and ensuring that all team members signed the form
  - ensuring that the pre-flight briefing included a review of each team member's tasks and responsibilities
- pre-flight actions prior to commencing helicopter tasks
- positioning the helicopter for live line work where a horizontal approach to the conductor is required
- bonding the helicopter to the line
- unbonding the helicopter from a line
- maintenance testing of live line fibre-reinforced plastic insulated sticks
- Ohmstik video camera set-up procedure
- micro ohms (Ohmstik) live line inspection
- drawings and photographs of the transmission lines and towers, and insulator types and configurations
- mid-span joint data showing the position (relative to tower number) and the number of joints in a particular span
- fatigue management system information

- on-site safety management forms
- AutoCAD[29] drawings and helicopter minimum vertical distance (HMVD).

The On Site Safety Management form included the following three sections:

- Discussion and action points. This section listed 13 discussion and action points, including:
  - Point 5. Site has been inspected and all hazards and potential hazards discussed
  - Point 9. Hazard elimination/isolation or minimisation procedures discussed and agreed.
- Hazard identification and control. This section contained a table where the identified hazards, and their control methods, could be listed.
- Work party details. This section contained the signature blocks for team members.

The On Site Safety Management form did not include any other hazards information, such as a list of possible hazards that the team could use as a prompt.

The helicopter crew's preparation for the task

The crew assembled 3 days prior to the planned commencement of testing operations and checked all of the equipment that was to be used. The operator's chief pilot joined the crew to oversight the preparations and to train the pilot in joint-testing operations. That included the review of the job package with the crew, and a discussion of the relevant content of the operations and powerline procedures manuals.

The chief pilot reported that the briefing covered the:

- joint-testing procedures, including all elements in the job package
- correct method for approaching a joint
- positioning of the helicopter for Ohmstik use
- required electrical clearance and safe operating distances as shown in the AutoCAD drawings
- difficulties associated with hovering mid-span, such as line sway, and the pilot's point of focus
- techniques for bringing the helicopter into the correct position for the joint test and what the pilot should be focusing on during that period.

[29] Automatic computer aided drawings. The AutoCAD drawings indicated the clearances at non-transposed spans. They were not intended to indicate the clearances at mid-span transpositions.

On the afternoon before the occurrence, the chief pilot conducted joint-testing training with the pilot. Initially, the joint-testing procedure was simulated with the helicopter on the ground with the lineworkers rehearsing their procedure. The chief pilot then:

- demonstrated two or three joint test sequences airborne from the left seat, with the pilot occupying the recording lineworker's right seat and a lineworker on the platform
- landed the helicopter, and discussed the procedure with the pilot
- oversaw a series of practice joint tests by the full crew complement including the pilot, a recording lineworker and a platform lineworker.

The chief pilot reported that the crew conducted at least three joint test sequences in the helicopter, to what he considered was a satisfactory standard.

Due to deteriorating weather conditions at the test site, the pilot decided to terminate the practice session and to return to Parafield Aerodrome. At Parafield the crew discussed the exercise outcomes with the chief pilot. According to the chief pilot, the pilot and lineworkers were satisfied with their performance during the joint test practice. The pilot later confirmed that he was satisfied with the content and level of instruction that he received.

The chief pilot stated that under normal circumstances, the crew would then have undertaken further practice. However, the chief pilot decided that the crew could commence joint-testing operations the following morning and that he would supervise from the ground.

On the morning of the occurrence, the chief pilot attended the task pre-flight briefing with the crew and, due to the forecast weather conditions, the crew decided to initially work on the Mannum to Mobilong line. The chief pilot recalled his intention to drive to the operating area to observe the crew in operation and to discuss the process and address any questions the pilot may have had. The chief pilot's intent was to then 'sign out' the pilot. However, he decided to complete some administrative commitments at the operator's base before departing for the task area later that morning. The occurrence happened prior to his arrival.

Joint-testing procedure used by the crew

The pilot and the recording lineworker reported that joints could occur randomly along a line, but that when a joint was identified, there were usually three joints in that span. The pilot and recording lineworker described the joint-testing procedure on the occurrence flight as follows:

- The helicopter was flown at a speed of about 60 km/h on the right side of the transmission lines being tested. The pilot's focus was on maintaining the correct spacing from the line being inspected while tracking between the two sets of lines at a slow, steady speed. The platform lineworker's focus was to locate the joints.
- The recording lineworker reported that his role was to scan the area ahead of the helicopter for obstacles, including under-crossing and over-crossing powerlines, and to check that there was adequate clearance with the parallel Cherry Gardens to Tailem Bend line.

- The first crewmember to locate a joint, generally the platform lineworker, informed the other crewmembers. In response, the recording lineworker opened the laptop computer and logged the position of the joint and prepared to enter the test data.
- After a joint had been identified, the helicopter was brought to the hover about 10 m on the right, and level with the joint to be tested. Normally, if there was a grouping of joints to be tested in different conductors, the lowest joint would be tested first.
- The platform lineworker checked for obstacles and line clearance and moved the Hotstik out on the runner to the predetermined distance that was marked on the Hotstik.
- The pilot trimmed the helicopter, scanned the instruments, and reviewed the contingency procedures prior to calling 'Clear to proceed'. After receiving verbal agreement from both lineworkers that they were ready to proceed, the pilot manoeuvred the helicopter sideways towards the joint.
- As the pilot manoeuvred the helicopter slowly towards the conductor, the platform lineworker provided a running commentary to the pilot via the intercom and used hand signals to assist the pilot to manoeuvre the helicopter.
- The pilot advised that, prior to moving in for the joint test between towers STR0031 and STR0032, he could see all three conductors. His technique was to progressively 'walk' the helicopter closer to the line and into the correct position. The closer they got to the joint, the more he and the platform lineworker were concentrating on the joint and the end of the ohmstik.
- Approaching the conductor, the crew's focus was on the end of the Ohmstik (which by that time the platform lineworker had placed in the extended position) and the respective conductor. Closer to the joint, the conductor above the helicopter was no longer in the pilot's peripheral vision.
- Once the helicopter was positioned correctly, the platform lineworker took the required readings with the ohmmeter.
- If all three readings were valid, the pilot manoeuvred the helicopter to a position about 10 to 15 m from the transmission line before positioning for the next joint test. The pilot reported that, while transiting to the next group of joints, he flew level with the lowest conductor. That enabled the easier identification of joints compared to flying above the conductors and looking down towards the ground.
- The crew stated that they tested all of the joints that were identified that day.

The pilot and recording lineworker recalled that, on the day of the occurrence, the Ohmstik switched itself off a number of times. On each occasion, the helicopter was moved 10 to 15 m clear of the conductor while the platform lineworker retracted the Hotstik, reset the Ohmstik, and then extended the Hotstik in preparation to recommence operations.

Helicopter operator's observations and practices in respect of hazards, including of transpositions

The operator advised that there were many features of the powerline environment, in addition to mid-span transpositions, that could pose a hazard to aviation. The operator indicated that all operations personnel should have been aware of those hazards as a result of its procedures and training. Further, the operator reported that through the company's training system, as operations personnel gained experience and progressed to more complex tasks, they acquired further knowledge regarding hazards and the methods of minimising the risks posed by those hazards.

The operator's job packages could not necessarily include the details of all hazards that could be encountered on a particular job as, in many cases, there was insufficient information available to enable that to happen. Rather, the operator relied on the training and experience of its personnel to enable them to anticipate, recognise and respond to the various hazards, including transpositions, as they arose.

Specifically, the operator's awareness and management of hazards included:

- The operator was aware that the transmission line schedule spreadsheet was available from the maintenance provider and that those spreadsheets contained a large amount of information but, they did not know that they contained transposition information.
- The operator calculated safe working distances based on the tower and conductor information that was provided in the project brief. The operator requested additional information from the maintenance provider to confirm the tower structure dimensions so that an accurate safe working distance calculation could be made. The maintenance provider provided that information via a series of photographs and drawings, which were used to calculate safe working distances and not to identify hazards.
- The operator was not aware of the content of the maintenance provider's line connectivity diagram for the Mannum to Mobilong line.
- A photograph of the predominant tower structures as well as details of insulator types and layout was included in the job package. The operator reported that crews understood that if they came across a tower that was different to the structure that was the basis for the relevant safe working distance calculations, they were not to approach that line.
- The presence of a mid-span transposition invalidated any safe working distance calculations.
- Pilots did not receive specific training regarding transpositions and it was assumed that they would already have or gain the necessary knowledge of transposition and other hazards through their previous experience in the electrical transmission industry or on-the-job.
- The operator expected that experienced lineworkers would have recognised the structural differences between towers STR0032 and STR0031, and concluded that a mid-span transposition existed between those towers. Familiarity with, and recognition of, transpositions was considered by the operator to be 'bread and butter' for experienced lineworkers.
- Opinions varied amongst the operator's pilots, lineworkers, and management as to whether joint testing could or should be done on mid-span transpositions. Reference was made to an 'unwritten rule' within the organisation that mid-span transpositions should be avoided completely. Another view was that testing at some of the joints on a transposition could be carried out provided an on-site safety assessment had been carried out.

- All of the operator's lineworkers were experienced tradespersons, who were familiar with linework, including joint-testing operations from ground-based and airborne platforms. The operator used an independent checking organisation to certify the competency of its lineworkers in airborne linework.
- The operator held a training week each year, during which normal operations ceased and all pilots and lineworkers attended a refresher and completed an ongoing training program. They also renewed the mandatory qualifications in the classroom and practiced task-related scenarios at the training farm. That training involved crews being given simulated job packages and being assessed on job preparation. The assessor, who was from an external assessment and training company, ensured that correct work practices were being adhered to and that the crews were competent at their respective tasks. A strong emphasis was placed on crewmembers working together and the need for good crew resource management.

Overall, the operator indicated that it considered the crew members should have been able to identify transpositions visually by virtue of their industry experience as they progressed along the transmission line.

Physiological and other complexities associated with operating a helicopter in close proximity to obstacles

There were a number of different physiological factors with the potential to have affected the crew's ability to interpret the relevant line information correctly. In particular, carrying out tasks in close proximity to obstacles with small spectral profiles,[30] such as powerlines and conductors, can make the processing of that information difficult. Many of those factors can be summarised under the inter-related topics of target conspicuity, focus of attention and expectancy.

Target conspicuity

Some of the primary factors that increase the conspicuity of a target object include:

- **Visual obstructions.** Obstructions from the aircraft, such as window posts, can obscure some types of targets. In this case, the pilot and the lineworker should have had an unobstructed view of the conductors.
- **Target size.** Under ideal conditions, humans can detect the presence of an object the size of a 20 cent coin at a distance of 200 m. However, in real world conditions a variety of factors will limit the ability to achieve this level of performance. For example, research has shown that pilots find it difficult to detect other aircraft even when their size in the visual field (or subtended visual angle) is 50 or more times greater. Research has also shown that long thin objects (such as conductors) are more difficult to detect than other objects of the same overall size.[31]

---

[30] Long and thin objects, such as wires have a small spectral profile.

[31] Research on this point, target conspicuity and other aspects affecting the detectability of aircraft are summarised in Appendix C of the ATSB Safety Investigation Report 200201846 (*Bankstown midair collision, Piper PA-28-161, VH-IBK Socata TB-9, VH-JTV, 5 May 2002*). See also the ATSB Research Report *Limitations of the See-and-Avoid Principle* (1991). All of the reports are available at www.atsb.gov.au.

- **Contrast.** Contrast is the difference between the luminance (or brightness) of a target and the luminance of its background, and it is a major component of conspicuity. In many situations, powerlines will have a low contrast relative to a terrain background. However, the reflections from the sun or light backgrounds such as a lightly overcast sky can lead to a much higher contrast. In this situation, the contrast between the conductors and the background was difficult to establish because the conductor being tested was in the same horizontal plane as the helicopter, and with the movement of the helicopter would have moved constantly about the horizon.
- **Rate of motion.** The average person has a field of vision of 190° but the quality of vision varies across the visual field. Around the centre of the retina, or the 'line of sight', acuity and colour vision are sharpest. Acuity rapidly decreases as the target moves further from the line of sight. Sensitivity to movement also decreases as the target moves further into the periphery. However, the decrease in sensitivity to movement is less than the decrease in acuity, and movement can therefore appear to be more salient in the peripheral visual field. Overall, target detection ability increases as the velocity of the target across the visual field increases. In this situation, the relative motion of the powerlines across the visual field was relatively minimal and this cue would not have been significant.
- **Environmental factors.** A variety of factors can reduce the apparent contrast between a target and its background. In this case there was no haze. Sun glare was unlikely to be a factor as the position of the sun was located 54° above the horizon.

Overall, in this situation the conductors would generally have been detectable if searched for due to their relatively close distance to the helicopter. However, depending on their background at any particular time, they would generally not have high salience.

Although the conductors would have been readily detectable, their exact distance from the helicopter would not have been easy to determine. Humans use a variety of cues to perceive depth and judge the distance and size of objects (Wickens and Hollands, 2000). These include monocular cues, such as differences in perspective, relative size, overlapping contours and motion parallax. For objects relatively close, they also include 'binocular cues', such as the disparity of the two images received by the two eyes (termed 'binocular disparity' or 'stereopsis').

For a conductor suspended above the ground, these depth cues provide limited information. The conductor's thin shape would make relative size of limited use, and cues such as interposition and overlapping contours were not relevant. Motion parallax, or the relative movement of different objects at different distances as a person moves through space, would provide some information about the relative position of the powerlines as the helicopter approached the conductors, but the effectiveness would be limited due to the relatively low speed of movement of the helicopter as it approached the conductors. Binocular disparity would have limited effectiveness for a long, thin horizontal object. In summary, judging the exact distance of the powerlines from the helicopter would be difficult due to the limited depth cues, and distance judgements therefore could be easily influenced by expectancies regarding the position of the conductor.

Focus of attention

Each person has limited mental resources available to attend to information or perform tasks during any particular time period. In general, if a person is focussing on one particular task, then their performance on other tasks will generally be degraded. The extent of performance degradation depends on many factors, such as the workload involved in each task, the number of tasks being performed at the same time, and/or the similarity of the different tasks.

Wickens and McCarley (2008) note that there are four primary forces that move the attention of a skilled person to selectively attend or sample sources of information:

- salience (target conspicuity factors)
- effort (the amount of cognitive and physical effort it requires to switch attention to and search for the relevant stimulus, and the amount of spare effort available due to other tasks being conducted)
- expectancy (extent that a particular stimulus is expected to occur or be present at a particular time and place)
- value (importance of the stimulus to the person's tasks at that time).

Although collision hazards such as conductors in close proximity would have high importance, the effects of low salience and low expectancy can mean that an imminent collision problem may not be detected.

In the case of a helicopter crew approaching conductors to carry out inspection tasks, each of the crew members has primary tasks that require significant amounts of attention.

Expectancy

Research has shown that human perception and decision making are strongly influenced by expectations, which can be based on past experience or other sources of information. These expectations have been shown to affect where people will search for information, what they will search for, and their ability to detect or recognise stimuli (Wickens and McCarley, 2008). Performance at detecting a stimulus, such as the position of a conductor, is higher if it is expected and worse if it is unexpected. This effect is more pronounced when the stimulus is not salient and attention is focused on other tasks or other areas of the visual environment.

There has been significant research interest in recent years to the phenomenon known as 'inattentional blindness'. Inattentional blindness occurs when a person does not notice an object which is fully-visible, but unexpected, because their attention is engaged on another task. As stated by Chabris and Simons (2010, p.7):

> When people devote their attention to a particular area or aspect of their visual world, they tend not to notice unexpected objects, even when the unexpected objects are salient, potentially important, and appear right where they are looking.

A substantial body of research has shown that people do not detect unexpected stimuli even when they are looking directly at those stimuli. In a well known experiment, Simons and Chabris asked people to watch a video of two teams passing basketballs and to count the number of passes that one of the teams makes. When conducting this counting task, about 50 per cent of people do not notice a gorilla walking across the scene amongst the basketball players. When people were given additional tasks to do, detection performance decreased.[32]

Research has also shown that detection performance is degraded for unexpected stimuli in collision avoidance tasks. For example, several studies have shown that the ability to detect other aircraft is much worse when a pilot has not been provided with information on the presence and location of the other aircraft (known as 'unalerted see-and-avoid') compared to when the pilot has been provided with this information (alerted see-and-avoid).

Chabris and Simons (2010) also refer to examples where collision hazards that are easily detectable when looked for and expected, but were often not observed. In one study, pilots conducting a landing in a flight simulator did not detect the presence of another (unexpected) aircraft entering the runway, even though they were looking at the same part of the runway. In addition, research shows that car drivers are less likely to detect motorcycles because they are unexpected (relative to cars).

If a helicopter crew does not expect to encounter a transposition, they may simply not look for one and behave accordingly. Alternately, they may look for it but not detect it if it was not expected, particularly if it was not salient. In this case, there was no additional identification of the transposition, such as tags or other attachments to the towers, conductors or joiners to indicate a transposition section. As the helicopter approached the powerlines, if the crew were not expecting a transposition, then they would be less likely to detect that a powerline was closer to the helicopter than expected.

Humans overestimate their ability to detect changes or objects in their visual environment (Chabris and Simons, 2010; Levin et al, 2000). When individuals are asked whether they can detect a particular type of change or object, many say that they can. However, actual detection rates are much lower than those expectations. Accordingly, although the presence of a transposition along a span may seem obvious to someone who knows it is there, it is not necessarily salient to someone who does not know of its existence.

Checklists and standard phraseology

In June 1994, the US National Aeronautics and Space Administration (NASA) published a report titled *On the Design of Flight-Deck Procedures*.[33] That publication stated that flight deck and/or cockpit checklists should depict a set of different tasks that crews must perform or verify in order to configure an aircraft and prepare the crew for certain tasks.

The NASA report investigated the use of checklists and standard phraseology. The report listed a number of benefits from the use of checklists, including that they:

- Provide a sequential framework to meet internal and external cockpit operational requirements.
- Allow mutual supervision (crosschecking) among crew members.

---

32 Chabris and Simons (2010) provide an extensive review of this research.

33 NASA Contractor Report 177642 dated June 1994. http://www.bluecoat.org/reports/Degani_94_Flight_Deck.pdf

- Enhance a team (crew) concept for configuring an aircraft by keeping all crew members 'in the loop'.
- Dictate each crew member's duties to facilitate optimum crew coordination, as well as the logical distribution of cockpit workload.

The following possible consequences of not employing standard phraseology in checklists were also listed:

- The other crew member(s) might not detect a checklist error.
- The other crew member(s) might not be able to follow the sequence of the checklist procedure.
- The other crew member(s) might confuse the checklist callout with other intra-cockpit communications.

The helicopter operator sent its crew members to the *CRM in the wire environment course*, which recommended the use of standard phraseology both in normal operations and in critical or emergency situations.

The work instruction used by the crew for this operation was *WI 611/70 Micro Ohms (Live line inspection)*, which directed the crew to another work instruction *WI 611/02 Positioning helicopter for live line work where a horizontal approach to the conductor is required*. This work instruction included one standard phrase – 'ready to bond on clear to proceed'. It also included the following safety notes:

> Safety Note 1
>
> The airborne crew SHALL use continual communication (constant banter) when approaching, performing and concluding platform maintenance. If communication ceases then the procedure SHALL halt until communication is re-established.
>
> Safety Note 2
>
> Any one or all crew members can be responsible for terminating operations if conditions of the surroundings, self or vehicle are not favourable.

At interview the recording lineworker and chief pilot stated that there were no formalised standard phrases used and that crews agreed on certain phrases prior to the commencement of the task.

Audits of the helicopter operator

Civil Aviation Safety Authority

As part of its Aviation Safety Surveillance Program, CASA determined that full audits of the operator would be carried out every 3 years and that a safety trend indicator audit would be conducted every 6 months. Safety trend indicator audits involved a review of the company's operations from the documentation held by CASA, together with the examination of any other information that had come to hand in the previous 6 months. Every second safety trend indicator audit was carried out at the operator's office. None of the audits included the observation of the operator's flying activities.

CASA conducted the last 3-yearly audit of the operator in October 2008. Only minor deficiencies were noted.

Electrical industry

As a contractor to a number of state electrical authorities and mining companies, the operator underwent external audits by independent auditing companies.

The most recent audit was conducted in April 2008. The scope of that audit included the examination of the operator's:

- organisational/management structure
- safety management system
- operational facilities, training, procedures, flight and duty times and quality assurance for operations
- engineering facilities and associated procedures
- aircraft.

The audit found that the operator was capable of providing a satisfactory and professional standard of operation in accordance with general industry standards. It recommended that the operator:

- exercise its emergency response plan at least annually
- adhere to its quality audit schedule
- provide threat and error management courses for its pilots.

The auditor noted that 'A formal safety management system is to be produced which will improve the existing safety programme.'

ANALYSIS

Introduction

It was apparent from the examinations of the helicopter and the damaged 'T' phase conductor that the helicopter's main rotor blades struck the conductor as the crew was preparing to test a joint in the 'R' phase conductor in a mid-span transposition between towers STR0031 and STR0032.

There was no evidence that a pre-existing mechanical or other helicopter system condition was a factor in the development of the occurrence; nor was there any evidence that the helicopter's operating weight or centre of gravity position exceeded normal limits. The benign environmental conditions that existed at the time of the occurrence indicated that weather was unlikely to have contributed to the occurrence.

The investigation revealed a number of operational, organisational and human performance issues that were likely to have influenced the outcome. This analysis will discuss the:

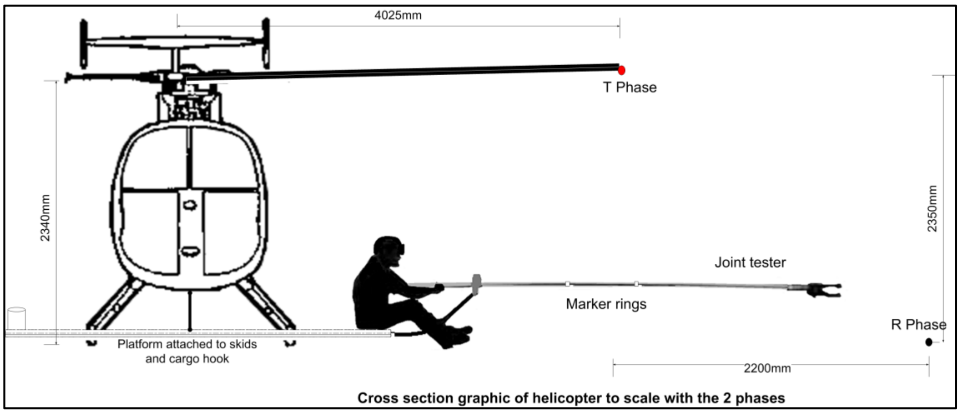
- geometry of the collision
- influences on the crew's performance
- issues that affected the survivability of the platform lineworker.

Collision geometry

If there had been no mid-span transposition between towers STR0031 and STR0032, the 'T' and 'R' phase conductors would have been aligned vertically. In that case, the tips of the helicopter's main rotor blades would have been about 2.6 m from the overhead 'T' phase conductor when the platform was positioned correctly for testing the joint in the 'R' phase conductor.

However, the presence of the mid-span transposition meant that the 'R' phase conductor diverged away from its previous vertical alignment with the 'T' phase conductor. That required the pilot to approach closer than intended to the 'T' phase conductor in order to be able to test the 'R' phase joint. That increased the risk that the main rotor blade would contact the 'T' phase conductor as the pilot manoeuvred into position for the test (Figure 17).

Figure 17: Front elevation showing the probable relationship between the helicopter and 'R' and 'T' phase conductors



The contact occurred near the main rotor blade tips, and the resultant out-of-balance forces destabilised the main rotor system to the extent that one of the main rotor blades detached from the rotor hub. That failure removed any prospect of the pilot being able to control the helicopter as it descended to the ground.

The investigation was unable to establish the helicopter's flight path and speed immediately before the collision. However, the position of the wreckage relative to the conductors, and the nature of the damage to the conductors and helicopter, supported the surviving crew members' recollections that the helicopter was moving slowly at the time of the wirestrike.

Influences on the crew's performance

Prior knowledge of the transposition

If the operator had known that mid-span transposition information for the Mannum to Mobilong line was available from the asset owner's database, it could be expected that the operator, and thus the crew, would have accessed that information. In hindsight, the relevance of that information to the occurrence was readily apparent; however, prior to the occurrence, that was not the case.

The transposition may have been able to have been identified 'by [the application of a] zoom function and close examination' of the photograph that was provided to the operator by the maintenance provider. However, the operator's focus on the line voltage and structure-type information in the photographs to establish minimum safe working distances, rather than to identify hazards to the operation, reduced the likelihood that the operator would examine the photographs to that detail.

The asset owner's and maintenance provider's reliance on the helicopter operator to advise of any specific database information requirements assumed that the operator was aware of all types of information that was in the data base. However, the promulgation of the contents of the reference documents in the project brief, including the connectivity diagrams, may have prompted the helicopter operator to request additional hazard information.

Overall, the maintenance provider and helicopter operator took steps to provide and obtain hazard information that each considered relevant and appropriate. However, the divergent interpretation of the information by both organisations resulted in differing relevance and significance being placed on the information by each organisation. That appeared largely to have been a function of the different role, function and expertise of the organisations.

Expectation

The absence of any prior knowledge by the crew of the existence of the transposition would have lowered their expectation of encountering a mid-span transposition during the task. In that context, the extent of any active search for transpositions by the crew, such as looking for differences in the insulator configuration between successive towers, would have been adversely affected. In consequence, the likelihood of the transposition being detected, even if it had been seen, was reduced.

The probable influence of the crew's expectation, and risk of relying on their visual detection of any transpositions in flight, appeared to be confirmed by the fact that the crew did not detect two earlier transpositions between spans STR0016 and STR0017, and STR0017 and STR0018.

Visual detection

The absence of any information on the transposition in the job package meant that visual detection was the sole means by which the crew could become aware of the hazard. The factors influencing human performance in terms of avoiding collision hazards meant that there was a risk that the crew would not detect the transposition.

Critically, once the platform lineworker had identified the 'R' phase joint, his attention was likely to have been focused on that joint and providing information to the pilot as he manoeuvred the helicopter towards the test position. The pilot's attention also would have been focused on the 'R' phase joint. The recording lineworker's attention would have been directed increasingly to the laptop computer in preparation for recording the test data. In other words, the closer the helicopter came to the joint-testing position, the less likelihood there was of a crew member seeing the 'T' Phase conductor. Therefore, there was increasing risk that as the crew's attention was allocated to other tasks, vital visual stimuli would be missed.

Although not required by regulation, the inclusion of a tag or other marker on the relevant tower, conductor or joint to visually indicate a 'transposition' section would have improved the likelihood that the crew would recognise the change in conductor configuration.

Experience and training

The crew met the operator's minimum experience requirements, and had completed the necessary training for the task. In addition, the chief pilot indicated that he was satisfied with the standard demonstrated by the pilot during the practice session the day before the occurrence. The pilot also reported being satisfied with that training.

However, the crew did not receive the planned 'further practice' after weather interrupted their practice session on the afternoon before the occurrence. The successful conduct by the crew of several joint tests on the Mobilong to Mannum line would suggest that the lack of additional practice was not a factor in the occurrence.

It was only when they came to test an unalerted and unseen mid-span transposition joint that problems arose.

Supervision

Had the chief pilot been able to supervise the task on the day of the occurrence as planned, it was possible that he may have detected one or more of the earlier mid-span transpositions and alerted the crew to the hazard. That would probably have forewarned the crew to anticipate other mid-span transpositions along the line, and increased the likelihood that they would detect the transposition between towers STR0031 and STR0032.

Joint-testing procedures

Overall, the operator's joint-testing procedures were comprehensive and prescribed each crew member's duties. However, the addition in those procedures of a hazard/obstacle checklist for crews to use before the helicopter was moved in to test a joint would focus crews' attention at a critical stage of the joint-testing procedure. In this instance, the application of such a checklist may have resulted in the recognition of the mid-span transposition by the crew.

In addition, the procedures did not include any information or guidance as to the type of information that should be part of the stipulated 'constant banter', or what information and terminology should be used by a lineworker to 'assist the pilot as to the proximity of obstacles.' Further, there was no standard, unique and unambiguous word or phrase for crew members to use to terminate operations.

As the results of research by the United States National Aeronautics Space Administration indicate, and as recommended in cockpit resource management training, the use of checklists and standard phrases enhance a crew's ability to function as a team, and maximise the effectiveness of intra-crew communications. It could be expected that the safety of complex operations, such as joint-testing operations would increase by the adoption and enhancement of relevant checklists.

Survivability

The location of the platform lineworker external to the main structure of the helicopter, and the orientation of the helicopter at the time of the initial impact were such that the platform lineworker's chances of survival were low.

Platform lineworker's helmet

The purpose of the helmet's foam inner lining was to crush on impact, effectively reducing the deceleration forces acting on the head/brain, and minimising injury to the wearer. It was evident that the forces sustained by the platform lineworker's helmet during the accident sequence exceeded the helmet's capability.

Recording lineworker's shoulder harness

While the design loadings of the recording lineworker's shoulder harness were only specified along the length of the harness, the loads associated with the ground impact were primarily lateral. It was not established whether the harness failed as a result of those lateral impact forces, the incorrect stitch pattern and density, or a combination of those factors.

FINDINGS

From the evidence available, the following findings are made with respect to the wirestrike that occurred 13 km north of Murray Bridge, South Australia on 19 November 2008 and involved McDonnell Douglas 369D helicopter, registered VH-PLJ and should not be read as apportioning blame or liability to any particular organisation or individual.

Contributing safety factors

- Neither the powerline maintenance provider, nor the helicopter operator, fully comprehended the potential significance of the non-availability of mid-span transposition information to the joint-testing task. *[Minor safety issue]*
- The crew was unaware that there were mid-span transpositions in the Mannum to Mobilong line.
- The crew did not recognise the transposition between towers STR0031 and STR0032 and did not detect that the 'T' and 'R' phase conductors were not vertically aligned.
- The main rotor blades contacted the 'T' phase conductor.

Other safety factors

- There was no clear and comprehensive allocation of hazard identification and risk mitigation responsibilities among the asset owner, the maintenance provider and the helicopter operator.
- The operator's joint-testing procedures were not comprehensive with respect to hazard identification and the use of standard phraseology. *[Minor safety issue]*
- There was no direct supervision of the joint-testing operations. *[Minor safety issue]*
- The recording lineworker's shoulder restraint had been repaired using an unapproved stitch pattern and density. *[Minor safety issue]*

SAFETY ACTION

The safety issues identified during this investigation are listed in the Findings and Safety Actions sections of this report. The Australian Transport Safety Bureau (ATSB) expects that all safety issues identified by the investigation should be addressed by the relevant organisations. In addressing those issues, the ATSB prefers to encourage relevant organisations to proactively initiate safety action, rather than to issue formal safety recommendations or safety advisory notices.

All of the responsible organisations for the safety issues identified during this investigation were given a draft report and invited to provide submissions. As part of that process, each organisation was asked to communicate what safety actions, if any, they had carried out or were planning to carry out in relation to each safety issue relevant to their organisation.

Appreciation of the significance of transpositions

Minor safety issue

Neither the powerline maintenance provider, nor the helicopter operator fully comprehended the potential significance of the non-availability of mid-span transposition information to the joint-testing task.

Action taken by the powerline maintenance provider

The powerline maintenance provider advised that, immediately following the accident, it:

> Suspended all operations of the helicopter operator until it was satisfied that all appropriate safety procedures were in place.
>
> Commissioned an independent audit to report on certain aspects of [the helicopter operator's] operations including safety management systems and training procedures.

In addition, the powerline maintenance provider advised of the following amendments to its operational procedures:

> Operational changes
>
> Prior to the incident a debrief was held with [the helicopter operator's] crew prior to the commencement of each planned maintenance job. We now require that [the helicopter operator] is to provide a formal documented debrief to [us] and the [asset owner] after each planned maintenance job. The exceptions to this directive are that and incident occurring during flight must be reported immediately and that because of work load the maximum time within which to hold a debrief is one week.
>
> Auditing
>
> As advised earlier [we] have retained an external auditor to report on the safety and operational practices of [the helicopter operator]. Audit recommendations have been adopted.

ATSB assessment of response/action

The ATSB is satisfied that the action taken by the powerline maintenance provider adequately addresses the safety issue.

Action taken by the helicopter operator

In response to this accident, the operator has indicated that it will:

> Communicate with individual power companies to obtain their known hazard locations for with respect to Airborne Operations.
>
> Information on transposition locations is now included in the job package

ATSB assessment of action/response

The ATSB is satisfied that the action taken by the helicopter operator adequately addresses the safety issue.

Helicopter operator

Checklists and standard phraseology

Minor safety issue

The operator's joint-testing procedures were not comprehensive with respect to hazard identification and the use of standard phraseology.

Action taken by the helicopter operator

In response to this accident, the operator has:

> [Introduced] a STOP procedure for platform work. (Stop before moving towards the conductor. S = stop T= talk, O= observe, P= proceed).
>
> Updated and upgraded company Work Instructions to a new format which is more detailed and better highlights caution and warning points and includes detailed risk assessments. Initial upgraded focused on Platform procedures WI 611/01, 02 05, 06, and 22
>
> Ordered electronic cockpit voice prompt machines. And review a black box voice recorder.

ATSB assessment of response

The ATSB is satisfied that the action taken by the helicopter operator adequately addresses the safety issue.

Supervision

Minor safety issue

There was no direct supervision of the joint-testing operations.

Action taken by the helicopter operator

Immediately following the occurrence, the helicopter operator halted all platform operations and commenced a review of operations. That included reviewing the procedures for joint testing, having an independent auditor review the company's operations, and having the chief pilot of one of the industry leaders in the field visit from the US and review the operation.

On 2 November 2009, the operator advised that:

> The following items which have been introduced at [the operator] since the November 2008 accident (VH-PLJ):
>
> - Initially discontinued all platform work until internally satisfied that the company was ready to safely resume.
> - Appointed a Safety Manager (WHSO).
> - Safety Manager undertakes Qld OH&S Training courses.
> - Appoint a Training Manager.
> - Appoint a Senior Manager to [the operator's] Management team General Manager- Aviation. (Company structure reviewed).
> - Enforced the role of the Safety Observer (Pilot and Linesman).
> - Introduced new training programs:
>   - Electrical theory for pilots, which now starts at the insulator washing level practical and written test.
>   - New, more detailed presentation for platform workers (pilots and line workers), which covers many more subjects.
>   - Several new training topics have been developed which are to be introduced at the training week.
>   - On the job training task specific which includes both practical and written test for the pilots.
> - [The helicopter operator] Staff attend the "CRM Wire Environment Training Course Australia wide".
> - Gathered US powerline accident information into a booklet for staff to learn from.
> - A full training week scheduled for all staff and invitee. November 30th 2009.
> - Updated and upgraded company Work Instructions to a new format which is more detailed and better highlights caution and warning points and includes detailed risk assessments. Initial upgraded focused on Platform procedures WI 611/01, 02 05, 06, and 22.
> - More emphasis on internal auditing and increase the frequency, audit training course conducted for senior [helicopter operator] management staff.
> - Created a comprehensive company Risk Management register. Relevant extracts are placed into the work procedures which are at every job site.

- Created a Incident and Accident register to learn of trends etc and used as a training aid.
- Appoint Third Party Pilot to conduct flight training of all [of the helicopter operator's] pilots (general flight review).
- Platform work approval to recommence September 2009.
- Designated specific trainers for specific training topics/tasks.
- Compliance to AS9001:2008 November 2008.
- Third party consultant employed to obtain "Company Compliance to NSW OH&S", which will be the model for the future National OH&S 4801 March 2009.
- Review of [Fatigue Risk Management System] FRMS system, new system developed and sent to CASA. Removal of [Fatigue Audit InterDyne®] FAID which is not suitable for our operation. Revised FRMS is built under the recommended of "prior sleep wake rule". (Awaiting approval CASA). Currently on CAO 48 [Flight Time Limitations].
- Implementation of new "Emergency Response Plan" Handbook.
- Implementation of CASA [Drug and Alcohol Management Plans] DAMP policy.

ATSB assessment of response/action

The ATSB is satisfied that the action taken by the helicopter operator adequately addresses the safety issue.

Other action taken by the helicopter operator

Although not identified as a safety issue as a result of the investigation, the helicopter operator has advised of the following proactive training and operational-related initiatives:

> [The operator has] Selected only 3 pilots as the company "core" platform specialists to undertake detailed training with the (helicopter operators) senior platform linesman's and a specialist platform pilot from an (America affiliate)
>
> [The operator has] Re-trained and evaluate[d] the 3 pilots using the assistance of the [operator's US affiliate], training included
>
> - Knowledge from experience
> - Pilot evaluation
> - Discussed USA accident data
> - Compared USA to Australian systems
> - Practical emergency procedures
> - Reviewed and identify areas for improvement with in initial platform training.

> Additional platform pilots now go through a more rigid selection process, which involves the Chief Pilot and the Training Manager, and only after internally satisfied that the pilot meets the new desirable criteria.
>
> Lineworker selection for platform tasks [has been] tightened
>
> Crew selection for platform tasks (especially) is much more stringent (entire crew has to be the right mix)

Harness repair facility

Shoulder harness repair

Minor safety issue

The recording lineworker's shoulder restraint had been repaired using an unapproved stitch pattern and density.

Action taken by the harness repair facility

The owner of the harness repair facility has advised that the manufacturing facility was upgraded with a computerised sewing machine in about 2005. The repairer also accessed the original manufacturer's drawing of the harness, enabling the repairer to manufacture harnesses more accurately, rather than copying the design from a harness by hand. Since that time only a very small percentage of the repair facility's work is done manually and only then if the particular harness drawings are not available.

The harness repairer also advised that since the harness failure, he had requested the helicopter operator to examine all of the harnesses in its fleet and to return any belts that did not comply with the known stitch pattern. The repairer committed to the replacement of any such harnesses with the correct harness.

ATSB assessment of response/action

The ATSB is satisfied that the action taken by the harness repair facility adequately addresses the safety issue.

Powerline asset owner

Although there were no safety issues identified for which the powerline asset owner might have had or shared ownership, the asset owner has advised of the following proactive safety actions in response to this accident:

> **(A) Short-Term "Risk Avoidance" Actions**
>
> 1. Immediate grounding of all Aerial Services pending an internal investigation.
>
> 2. Review of the [asset owner's] operational processes pertaining to aerial services.
>
> 3. Consultation with [the maintenance provider] to determine if/how a resumption of aerial services could be effected.
>
> 4. Detailed review of [the helicopter operator's] capabilities and processes to establish a confidence level on [the helicopter operators] ability to deliver aerial services in the future.
>
> The purpose of these actions was to immediately eliminate the risk of any further incident whilst the necessary process reviews were undertaken.
>
> The grounding of aerial services was ultimately lifted on 24th April 2009 with the limitation that only non-platform work could be undertaken, a limitation that remains in place at the time of writing.
>
> A key outcome of the various process reviews was that a direct interface between [the asset owner] and [the helicopter operator] would enhance communication and information exchange between the parties.
>
> **(B) Long-Term "Risk Mitigation" Actions**
>
> 5. Procurement of direct-contracted helicopter operators, further to the key outcome above.
>
> 6. To complement the change in contracting strategy, incremental enhancements of [the asset owner's] process framework for aerial services management, particularly in the areas of Audit, Work Planning, Route Map Generation, Hazard Identification & Asset Information Exchange.
>
> 7. Appointment of a dedicated resource with specific responsibilities for managing the [the asset owner/service provider] interface.
>
> [The asset owner's] procurement process addressed service providers in Australia and New Zealand and involved comprehensive technical and commercial evaluations of the bidders, including site visits by a transmission line specialist. The Safety & Quality Management capabilities of bidders featured highly in the final assessments.
>
> The incremental process changes and dedicated "interface resource" are currently being finalised in cooperation with the preferred service provider to ensure that the processes between the organisations are as compatible as practically possible. The finalisation of this work will enable the current restriction on platform-work to be removed.

The asset owner has also advised that they have considered placing some type of marker on the line or joint at mid span transpositions and have formed the opinion that it is not a practical solution. They believe that they will be able to develop another 'last line of defence' that will serve the same purpose.

Civil Aviation Safety Authority

The Civil Aviation Safety Authority (CASA) advised that:

> ...as a result of a review of the harness repair facility procedures, a direction was given to the harness repairer to recall or rectify 139 seat belts within 90 days. CASA has received regular status reports on the progress of seat belt assemblies that are being recalled and rectified. While the seat belts under recall were identified as being released to unapproved data, these were not the issues identified in the report.
>
> Not all of the seat belts identified have been recalled, however, with regards to the harnesses that have been re-inspected, CASA is satisfied that there have been no identified issues, and the seat belts were able to be re-released without further rework.

APPENDIX A: OPERATIONS MANUAL, SECTION OM 0611

The Operations Manual, Section OM 0611 – *Powerline Inspection, Cleaning and Maintenance* included a sub-section titled *Platform Linework Operations*. In addition to complying with the limitations and conditions in the relevant flight manual supplement for each helicopter type, the sub-section placed the following additional requirements on those operations:

e. Before commencing operations and or each daily inspection, check the following:

(1) Proper installation and integrity of the platform.

(2) Activate intercom system, check for clarity.

Note: Operations will not be conducted if intercom is inoperative.

(3) Check linesman's seat belt and harness for integrity and correct attachment.

(4) Ensure no loose items are in the cabin area.

(5) Consult flight manual and confirm operational requirements and centre of gravity calculations.

f. Operational Procedures

(1) Minimum safe electrical working clearances are to be calculated for each task.

(2) Operational duration should not exceed 2 hours.

(3) Operation will cease immediately if a tingling sensation is felt or muscle spasm occurs.

(4) When operating in high temperatures the crew will maintain adequate fluid intake to prevent dehydration.

(5) Beware of minimum clearances between parallel structures and carefully evaluate trailing or quartering wind conditions.

(6) Communications will be maintained with the ground crew at all times.

(7) It is advisable to use trim as little as possible whilst on station. It is suggested the trim not be changed from the lateral position hover configuration.

g. The specific detailed procedures for each type of platform maintenance contained in the Company Powerline Procedures Manual must be followed unless locally developed, documented and approved procedures have been adopted instead.

APPENDIX B: WORK INSTRUCTIONS 611/02 AND 611/70

Work Instruction 611/02

Work Instruction 611/02 – *Positioning of the helicopter horizontally* stated:

POSITIONING HELICOPTER FOR LIVE LINE WORK WHERE A HORIZONTAL APPROACH TO THE CONDUCTOR IS REQUIRED 611/02

1. **PURPOSE**

This work instruction describes the procedure for positioning the helicopter prior to commencing airborne maintenance work where a horizontal approach to the earthwire or phase conductors is required.

2**. SCOPE**

2.1 Applies to any operation where the helicopter is required to be positioned on an earthwire or outer phase conductor in readiness for bonding on as per WI 611/05.

2.2 Where washing or platform hot stick work is required and no bond on occurs then the laser validation of conductor separation shall be omitted.

3**. RESPONSIBILITY**

3.1 The pilot is responsible for controlling the helicopter with sufficient accuracy to ensure that all required physical clearances to the helicopter are maintained throughout the procedure and the lineworker is provided with a stable work platform.

3.2 The lineworker is responsible for confirming serviceability of all equipment and tools required, assisting the pilot to be aware of proximity of obstacles, and for carrying out the procedure as described.

4**. PROCEDURE**

4.1 The crew SHALL carry out WI 611/01 Pre-flight Actions before commencing this procedure.

4.5 The pilot SHALL manoeuvre the helicopter to a stationary hover adjacent to the work station about approximately 10 metres laterally clear of the conductor to enable clearance verification.

4.10. The lineworker SHALL conduct an in flight visual check of the structures and conductors including hardware, and earthwire where appropriate prior to the operation commencing.

4.11. The pilot SHALL review emergency actions including available forced landing areas.

4.12. The pilot SHALL trim the aircraft for hover, check power requirements, and confirm aircraft operations are normal.

4.13 The lineworker SHALL verbally confirm to the pilot that he is ready to bond on to the line before the pilot moves closer to the line. Confirmation SHALL state; Ready to bond on clear to proceed.

4.14 Upon receiving confirmation, the pilot SHALL verbally confirm "Ready to Bond" and commence hovering sidewards towards the line as per WI 611/05 "Bonding Helicopter to Line".

4.15 The crew SHALL carry out required tasks following the appropriate work instruction for that task.

4.16 Upon completion, and after bonding off the line, as per WI 611/06 the pilot SHALL move the helicopter horizontally away from the conductor to a point at least 10 metres clear before commencing other activities.

Safety Note 1.

The airborne crew SHALL use continual communication (constant banter) when approaching, performing and concluding platform maintenance. If communication ceases then the procedure SHALL halt until communication is re-established.

Safety Note 2.

Any one or all crew members can be responsible for terminating operations if conditions of the surroundings, self or vehicle are not favourable.

General Note 1.

Recording of the laser measurement can be either saved within the laser software package or within one of the other [company] software packages as appropriate (ohmstik package).

General Note 3.

Helicopter Minimum Vertical Distance (HMVD) is the combined distance from the linesman platform work position to the main rotor. (Detailed in the Auto cad drawing as "Vertical Distance Current Tier Bundled to Main Rotor") and the "Critical Minimum Approach Distance[34]" for the line either energised or de-energised Planning the job.

Work Instruction 611/70

Work Instruction 611/70 - *Micro Ohms Live Line Inspection* stated:

MICRO OHMS (OHMSTIK) LIVE LINE INSPECTION 611/70

1. PURPOSE

This work instruction describes the work method for conducting micro ohms (Ohmstik) live line inspection on full tension joints.

2. SCOPE

Applies to this task where the work is to be carried out on a line using both "live line stick" method and live line bare hand platform method.

3. RESPONSIBILITIES

34 A safe distance at which electrical flashover will not occur. This distance varies with line voltage; the higher the voltage the larger the safe distance.

3.1 The pilot is responsible for controlling the helicopter with sufficient accuracy to ensure that all required clearances are maintained throughout the procedure and the lineworker is provided with a stable work platform.

3.2 The lineworker is responsible for confirming serviceability of all equipment and tools required, assisting the pilot to be aware of proximity of obstacles, and for carrying out the procedure as described.

4. PROCEDURE

4.1 The crew shall carry out WI 611/01 Preflight Actions before commencing this procedure.

4.2 The pilot shall position the helicopter as per WI 611/02.

4.3 The crew shall maintain the critical minimum approach distances in accordance with ESAA standards.

4.4 (a) Hot Stick

The Lineworker shall slide the stick down the runner and locate the Ohmstik over the full tension joint left side, hold the workstation for 10 seconds.

(b) Platform

The bonding on procedures as per WI 611/05[35] shall be carried out at the full tension joint. The lineworker shall record details from the ohmstik as required. Upon completion of the test, the unbonding procedures shall be carried out as per work instruction WI 611/06[9].

4.5 The Lineworker shall retract the Hot Stick as required and record the ohmstik measurement taken. (Radio, etc)

4.6 The lineworker shall slide the stick down the runner and locate the ohmstik over the full tension joint, right side. Hold the work station for 10 seconds.

4.7 On completion of obtaining the measurements, the pilot shall move the helicopter clear of the work area to 10 metres from the structure. The Lineworker shall retract the Hot Stick as required and record the ohmstik measurement taken. (Radio, etc)

4.8 The Lineworker shall retract the Hot stick to the platform.

NOTE 1: Lineworker shall ensure that he/she is fully conversant with all of the relevant documentation and requirements of the ohmstik.

NOTE 2: The Lineworker shall ensure adequate battery supply is available to complete the project.

NOTE 3: The lineworker shall ensure that the hot stick is not allowed to rise above horizontal when extended.

NOTE 4: The lineworker shall utilise the work instruction within paragraph 4.4 (b) when working on the overhead top phase of the double circuit structure with no earth wires are installed.

---

[35] Although included in the job package, WI 611/05 and WI611/06 have not been included in this investigation report because they did not apply to the type of joint testing being undertaken.

APPENDIX C: MINIMUM POWERLINE TRAINING REQUIREMENTS

The operator's minimum powerline training requirements were specified in the operations manual as follows:

MINIMUM POWERLINE TRAINING REQUIREMENTS

a. Training and Assessment to be conducted by the training pilot.

(1) On completion of training the Pilot Training Record AP-FO 0801-9 is to be completed and entered in the helicopter operators Pilot Training Records (Chief Pilots Records).

(2) On completion of training the pilot is to be rostered with at least one experienced helicopter operators linesmen (signed off as competent or 2 on more tasks) until considered competent.

PILOT REQUIREMENTS

The pilot in command of the helicopter shall:

a. Hold a current commercial or higher category helicopter pilot licence;

b. Have at least 1500 hours in command, 500 hours low flying, and 10 hours aeronautical experience on the type of helicopter to be used; and

c. Hold an agricultural rating helicopters, mustering approval helicopters, or have satisfactorily completed an approved course of low flying training;

d. The Chief Pilot may approve a pilot with less experience after consultation with management and a review of current contracts minimum requirements.

PLATFORM[36]

- Minimum 100 hours on type as per AP-OM 0601-13;

- Refer to AP-OM 0611;

- Initial training including demonstration platform work while observing from the helicopter and then being observed by the training pilot from the helicopter;

- If considered suitable for further platform work, his training in accordance with AP-OM 0801-9 will be completed on the job, supervised and crewed with an experienced linesman (current on specific task);

36 The operator advised that a US operator involved in platform work gave its pilots 10 hours flying training in platform operations before deeming the pilot qualified for the task.

APPENDIX D: SOURCES AND SUBMISSIONS

Sources of information

The sources of information during the investigation included:

- the crew of VH-PLJ
- the Civil Aviation Safety Authority (CASA)
- the operator of VH-PLU
- Robert A. Feest Utilities/Aviation Specialist Inc.
- Amsafe Aviation USA
- the Queensland Emergency Services
- the South Australian Coroner and Police
- Dr. Warren DeHaan, Colarado USA
- the powerline asset owner
- the electricity provider
- the United States National Aeronautics and Space Administration.

References

D.H. Brennan Chapter 23 Vision in flight, John Ernsting, Peter King (1988) Aviation Medicine Second Edition, Butterworth-Heinemann Ltd, Oxford p.347

Chabris, C., & Simons, D. (2010). *The invisible gorilla and other ways our intuition deceives us*. Hammersmith, UK: HarperCollins.

De Haan Chapter 18 Depth Perception 1982 The Optometrist's and Ophthalmologist's Guide to Pilot's Vision, The American Trend Publishing Company, Boulder, Colorado

Degani A., & Wiener E.L. (1990). *Human factors of flight-deck checklists: The normal checklist*. NASA Contractor report 177549. Moffett Field, CA: NASA Ames Research Center.

Gray, R., & Regan, D. (2007). Glare susceptibility test results correlate with temporal safety margin when executing turns across approaching vehicles in simulated low-sun conditions. *Ophthalmic and Physiological Optics*, 27, 440-450.Levin, D. T., Momen, N., Drivdahl, S. B., & Simons, D. J. (2000). Change blindness: The metacognitive error of overestimating change-detection ability. *Visual Cognition*, 7, 397-412.

Mack, A. & Rock, I. (1998). *Inattentional Blindness*. Cambridge: MIT Press.

Levin, D. T., Momen, N., Drivdahl, S. B., & Simons, D. J. (2000). *Change blindness: The metacognitive error of overestimating change-detection ability*. Visual Cognition, 7, 397-412.

Simons, D.J., & Levin, D.T. (1998). Failure to detect changes to people during a real-world interaction. *Psychonomic Bulletin and Review*, 5 (4), 644-649.Warren V.

Transportation Safety Board (1998). *Safety at passive grade crossings*. *Volume 1: Analysis*. Safety study NTSB/SS-98/02. Washington DC: NTSB.

Wickens, C.D., and McCarley, J.S. (2008). *Applied attention theory*. Boca Raton, FL: CRC Press.

Wickens, D. D., & Hollands, J. G. (2000). *Engineering psychology and human performance* (3rd Ed.). Upper Saddle River, NJ: Prentice-Hall.

Submissions

Under Part 4, Division 2 (Investigation Reports), Section 26 of the *Transport Safety Investigation Act 2003*, the Australian Transport Safety Bureau (ATSB) may provide a draft report, on a confidential basis, to any person whom the ATSB considers appropriate. Section 26 (1) (a) of the Act allows a person receiving a draft report to make submissions to the ATSB about the draft report.

A draft of this report was provided to the pilot, the recording lineworker, the helicopter operator, CASA, the maintenance provider and the powerline asset owner.

Submissions were received from the pilot, the recording lineworker, the helicopter operator and CASA. The submissions were reviewed and where considered appropriate, the text of the report was amended accordingly.

Wirestrike, 13 km north of Murray Bridge, SA
19 November 2008
VH-PLJ
McDonnell Douglas 369D