Australian Government

Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY INVESTIGATION REPORT
Aviation Occurrence Investigation 200404590
Final

Bell 206B, VH-CSH Dunedoo, NSW

22 November 2004

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

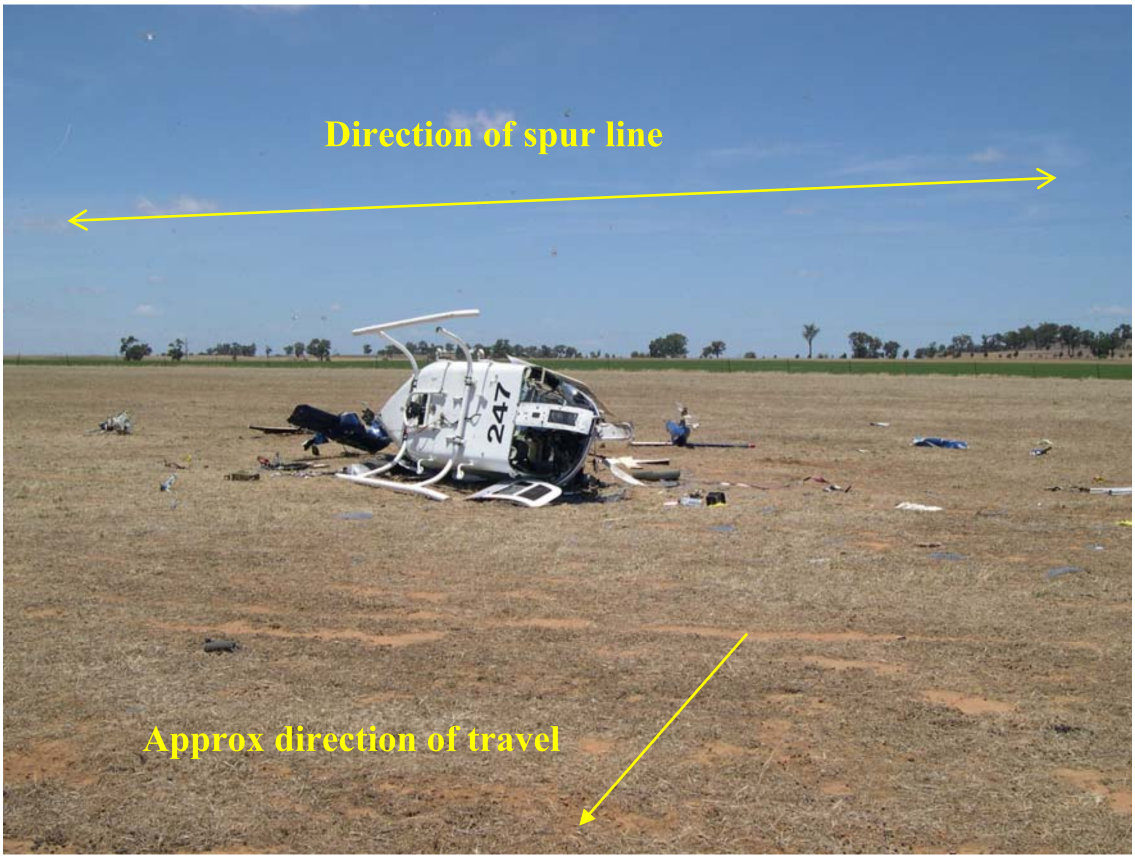
FACTUAL INFORMATION[1]

History of the flight

At about 1440 Eastern Daylight-saving Time[2] on 22 November 2004, the pilot of a Bell Helicopter Company 206B, registered VH-CSH, was conducting aerial work in support of the Dubbo area plague locust control campaign that was being administered by the NSW Department of Primary Industries (DPI). A Dubbo Rural Lands Protection Board (RLPB) ranger was seated in the left front seat of the helicopter, and an RLPB ranger was seated in the rear cabin. The pilot was conducting low-level locust spotting about 10 km south-west of Dunedoo, NSW, when the helicopter struck powerlines and impacted the ground heavily on its right side, before rolling onto its left side (see Figures 1 and 2). There was no fire, but the helicopter was destroyed by impact forces. The pilot who was seated in the front right seat and the passenger who was seated in the rear cabin were fatally injured. The front left seat passenger was seriously injured.

Prior to the accident, the pilot had conducted an aerial reconnaissance of the property where the accident occurred, with the property owner seated in the rear cabin. At the conclusion of that reconnaissance, the pilot landed to return the property owner to a homestead, before resuming locust spotting operations. Maps depicting the accident location are at Figures 3 and 4.

Figure 1: Accident site



1 Only those investigation areas identified by the headings and subheadings were considered to be relevant to the circumstances of the occurrence.
2 Eastern Daylight-saving Time was Coordinated Universal Time (UTC) + 11 hours.

Figure 2: Accident site

Figure 3: Map depicting accident location

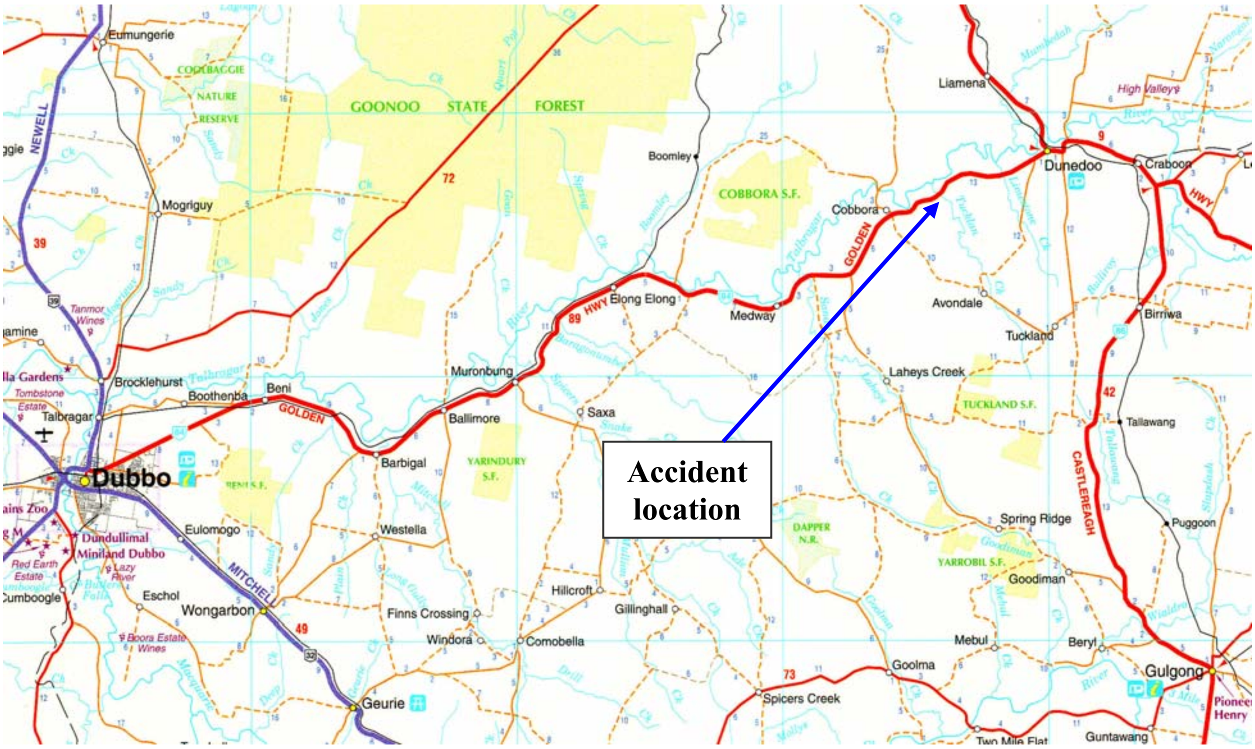
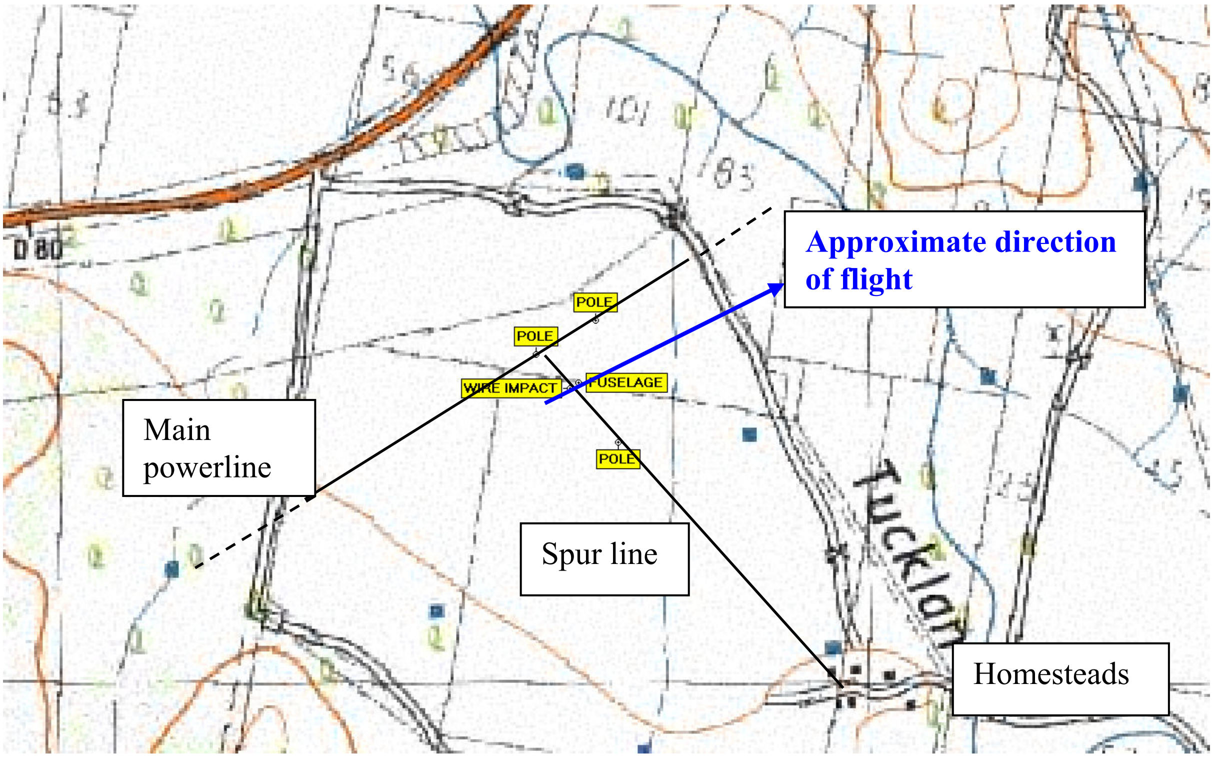


Figure 4: Accident site map



Personnel information

The pilot held a commercial pilot (helicopter) licence and a restricted private pilot (aeroplane) licence. Prior to the day of the accident he had accumulated a total of about 10,092 flying hours, of which about 10,007 hours were on helicopters, about 2,882 hours were on the helicopter type and about 23 hours were in the preceding 30 days. He was appropriately qualified for aerial work operations in the helicopter and was approved for low-level operations. He had accumulated a total of about 3,500 hours low-level flying experience.

The pilot had commenced employment with the operator three days prior to the accident. On that day he completed the operator's induction requirements and a line check with the chief pilot, which included locust spotting procedures, and low flying and powerline avoidance techniques. The chief pilot noted on the pilot's check and training trip report:

> Excellent skills demonstrated through all procedures. A high level of situational awareness displayed from a very experienced pilot.

Prior to commencement of employment with the operator, the pilot had last flown on 12 October 2004. He had flown for each of the 3 days prior to the accident, accumulating a total of 8.6 hours. For each of those three days, he had been on duty for 9, 3.5 and 9 hours respectively. There were no reports of any activity or physiological condition in the 3 days prior to the accident, which might have contributed to the accident.

The Dubbo RLPB ranger reported that, during the 2004 plague locust control campaign, she had conducted aerial operations in several areas from helicopters engaged in both spraying and spotting operations over a number of weeks prior to the accident. She indicated that she had not flown during the two days prior to the accident and had not conducted aerial operations prior to the 2004 plague locust control campaign.

She was not able to confirm the extent to which the rear-seat ranger had been involved in aerial operations prior to the flight during which the accident occurred.

Helicopter information

Manufacturer	Bell Helicopter Company
Model	B206B
Serial number	358
Registration	VH-CSH
Year of manufacture	1969
Maintenance release (A17905)	Valid to 14,482.9 hrs or 3 November 2005
Total time in service	14,445.0[3]

At the time of the accident, the helicopter was not fitted with a wire-strike protection system[4], and nor was it required to be by regulation. The helicopter weight and balance was within the helicopter manufacturer's published limits.

Examination of the helicopter's maintenance documentation indicated that all applicable CASA Airworthiness Directives had been complied with, and did not reveal anything that could have contributed to the accident.

The front-seat RLPB ranger reported that the helicopter appeared to be operating normally up to the time that it struck the powerlines.

Powerline information

A spur line consisting of two three-strand high-tensile steel wires[5] extended about 80-90 degrees from a main powerline (see Figures 5 and 6). The wires had a calculated minimum breaking load of 22.2 kN and spanned about 300 m. The relative position of the powerlines, support poles and the helicopter's direction of flight, are depicted at Figure 4. The front-seat RLPB ranger reported that, when the property owner was returned to the homestead, all the occupants of the helicopter were aware of the existence of powerlines in the vicinity.

Track data recovered from a hand-held Global Positioning System unit, which had been mounted in the helicopter, revealed that the reconnaissance of the property included flight along a number of powerlines, including the spur line involved in the accident (see Figure 7).

[3] Total time in service sourced from the helicopter's maintenance release from the finish of the last flight on 21 November 2004, and does not include flight time on the day of the accident.

[4] Equipment installed on aircraft to reduce the lethality of an impact with power or other cables.

[5] The wires consisted of 3/2.75 mm galvanised steel, constructed to AS1222 Part 1 standards.

Figure 5: Junction of spur and main powerlines

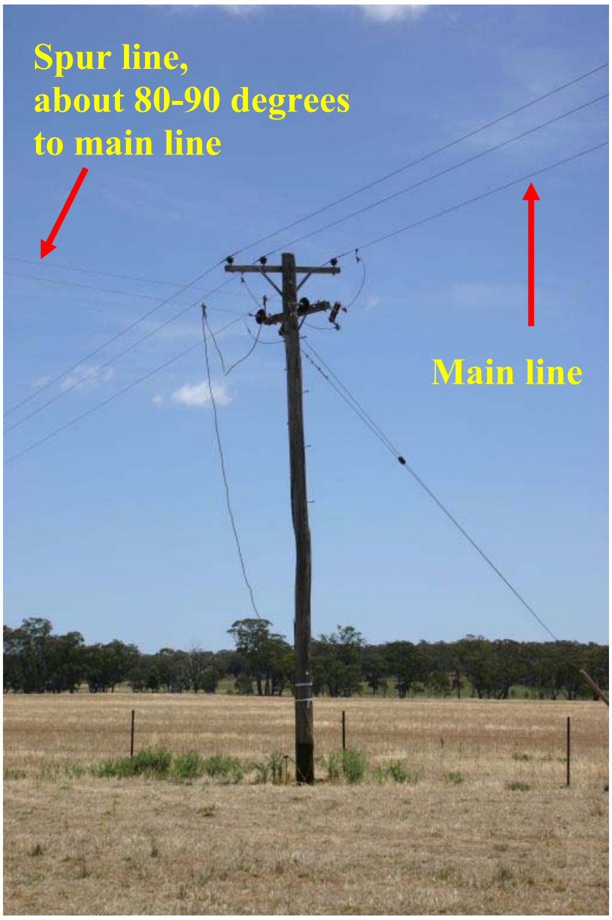


Figure 6: Section of powerline showing impact mark

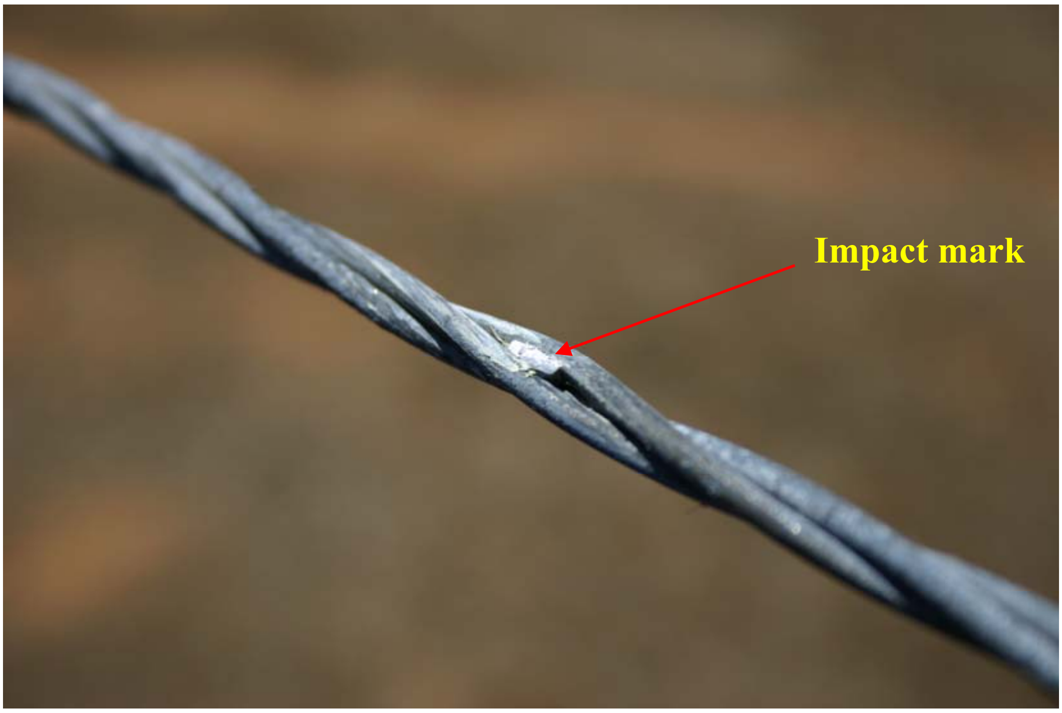
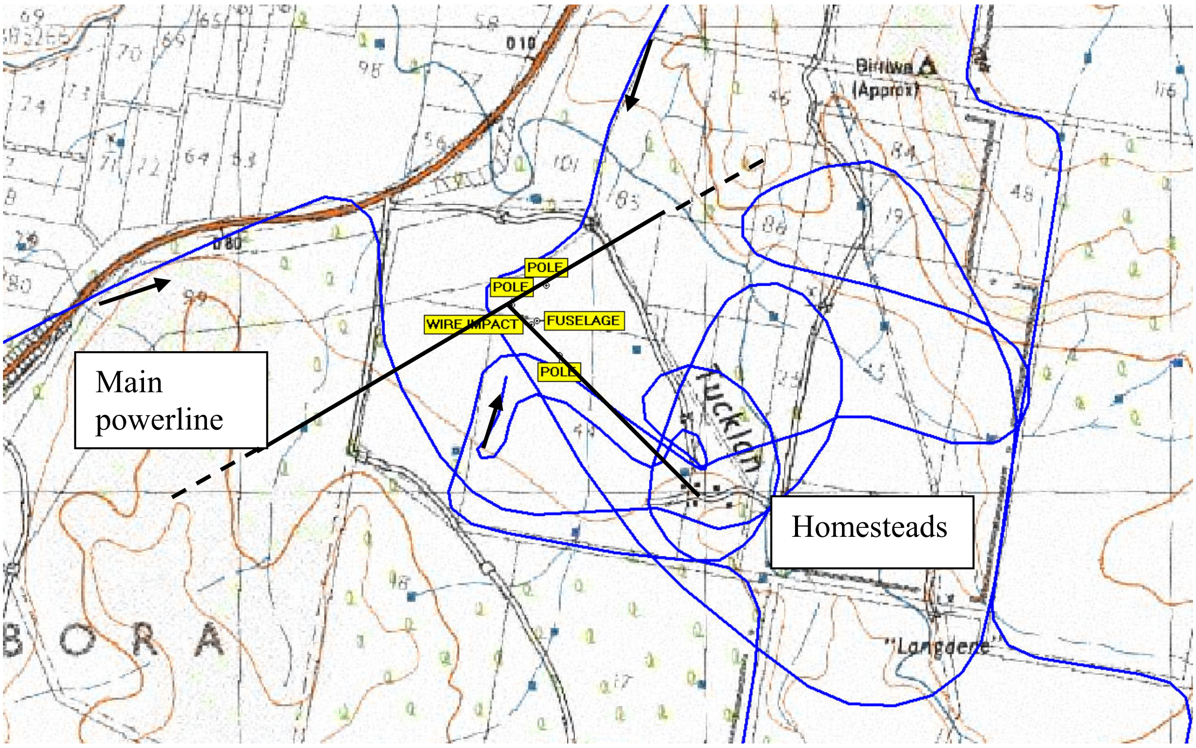


Figure 7: Recovered GPS track data



Wreckage information

Examination of the powerlines and the helicopter skid landing gear revealed that the helicopter had struck both wires, while crossing at about 85-90 degrees relative to the powerline (see Figure 8), at a point between the skid landing gear and the fuselage floor. Impact markings on the helicopter's skid landing gear front crosstube and the forward, upper surface of both landing gear skids, indicated that the helicopter had contacted the powerlines more heavily on the right side than the left (see Figure 9). There was also evidence of electrical arcing on the surface of both wires and on the right side of the helicopter's skid landing gear.

Figure 8: Approximate positioning of power lines in relation to the helicopter at impact

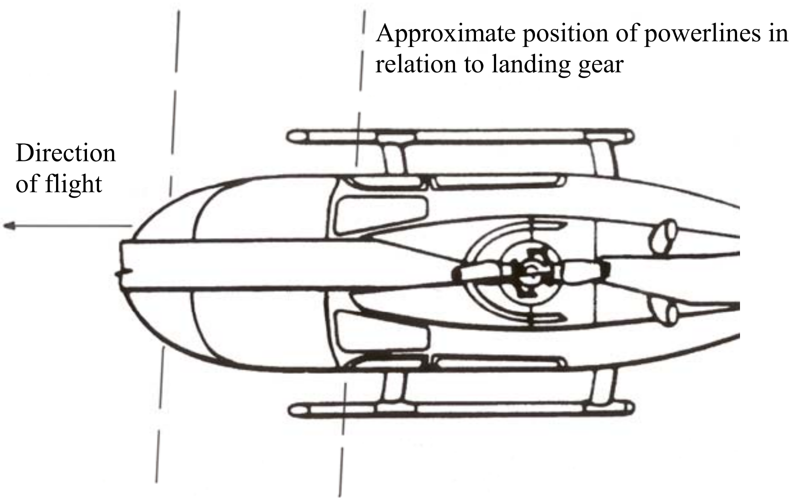
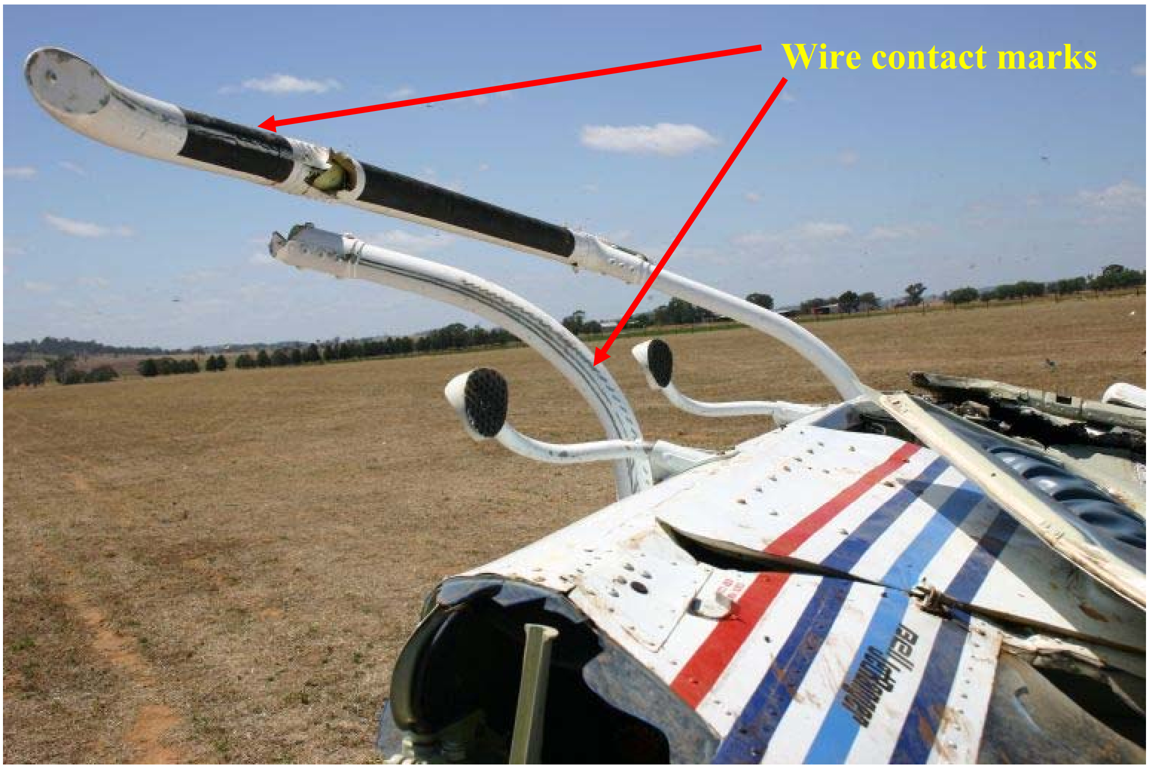
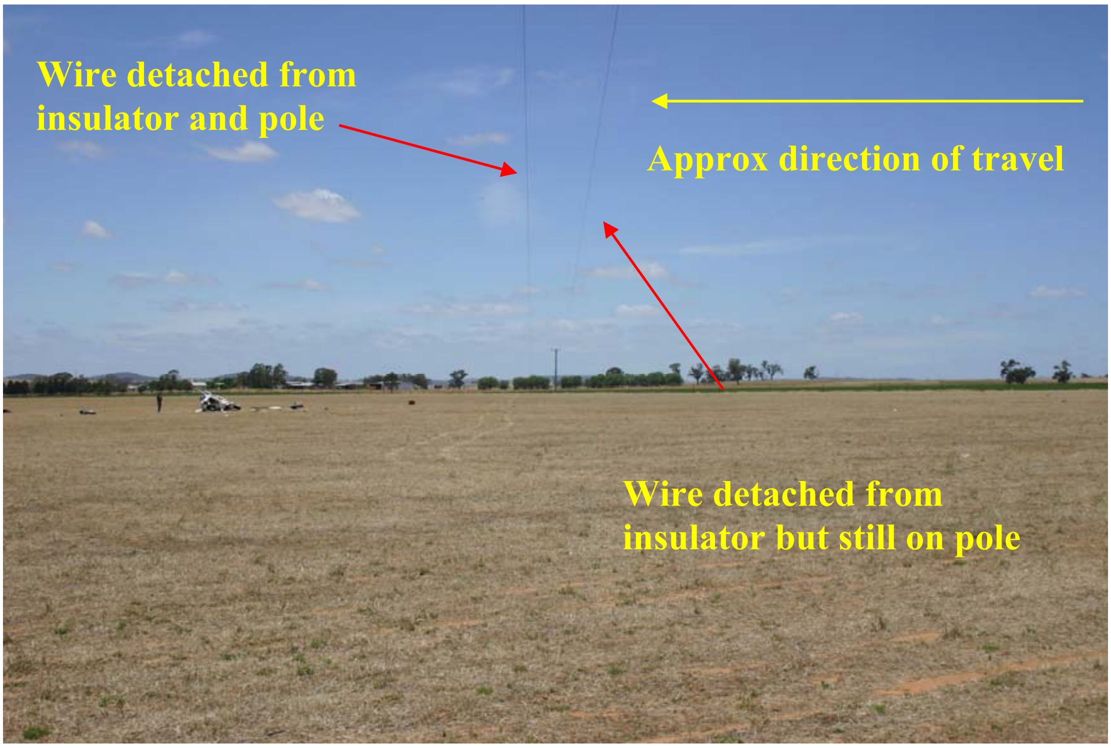


Figure 9: Powerline contact with the right skid landing gear



The helicopter had pulled both powerlines from their attachment to the porcelain insulators on the power pole situated to the right of the helicopter's flight path. Both wires remained intact; one cable remained attached to the top of the power pole cross-member and the second cable was situated at a low height above the ground (see Figure 10).

Figure 10: Powerline span showing final position of wires



When the powerlines were subsequently restored to their correct position by power company technicians, the wires were about 6.4 metres above ground level at the point where the helicopter struck them. The technicians estimated that this height would have been similar to the pre-accident height of the wires.

The front seat ranger and the property owner reported that, prior to the wire strike, the helicopter had been operating at very low level and low speed in the field adjacent to the powerlines.

The first ground impact mark was a 2 metre long main rotor blade strike, 26.4 m from a point directly beneath the first powerline impact point and 3.4 m from the main wreckage (see Figure 11). Subsequent ground impact marks were from the main rotor blades and the fuselage. The fuselage had impacted the ground heavily on its right side and right nose area in a slightly nose-down attitude, and rolled onto its left side before coming to rest. The impact had significantly distorted the right side and front of the fuselage structure and resulted in the rupturing of the fuselage-mounted fuel cell bladder (see Figures 12 to 15).

Damage to the main rotor blades was consistent with the blades having high rotational energy at the time of ground contact, with both blades fracturing immediately outboard of the blade doublers. The fracture surface damage to the main rotor mast indicated primarily bending overload with some indications of torsional overload failure.

At some point during the accident sequence, both powerlines were freed from their position between the floor and the skid landing gear, with both wires remaining intact.

Figure 11: Diagram of accident site

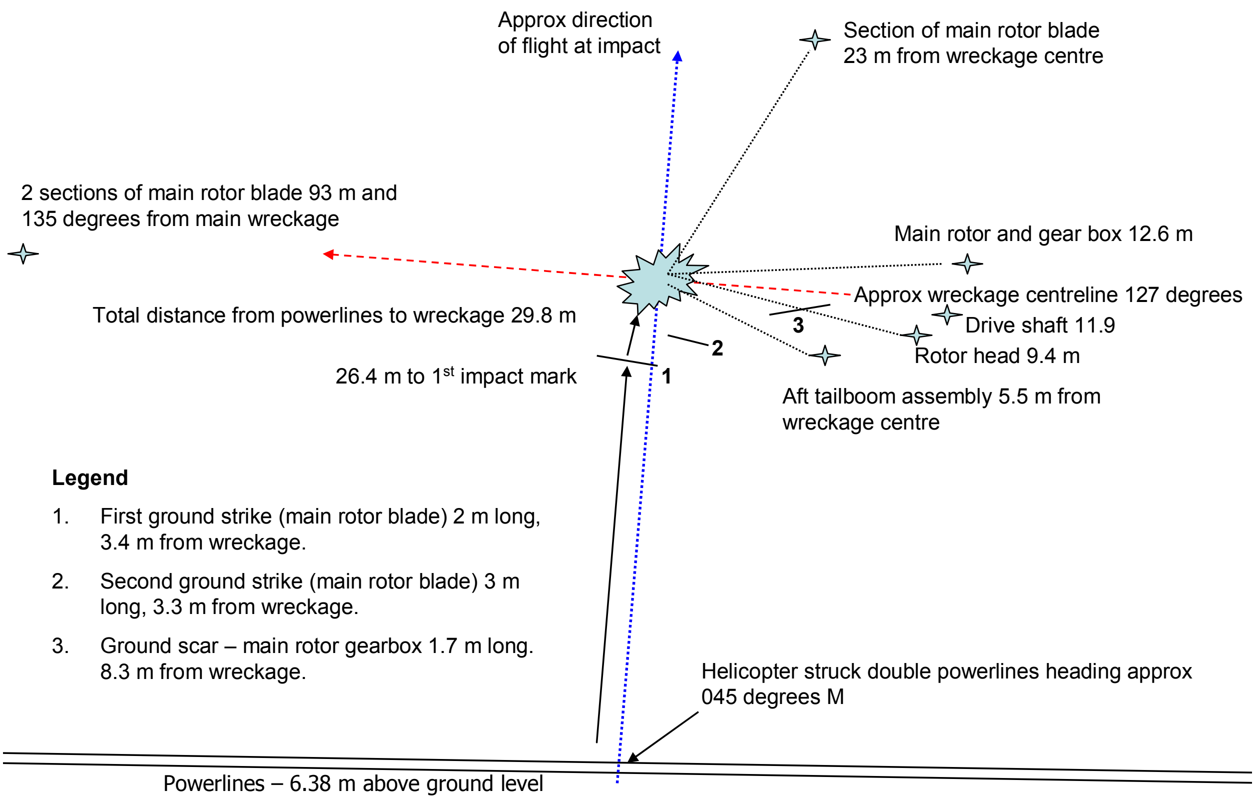
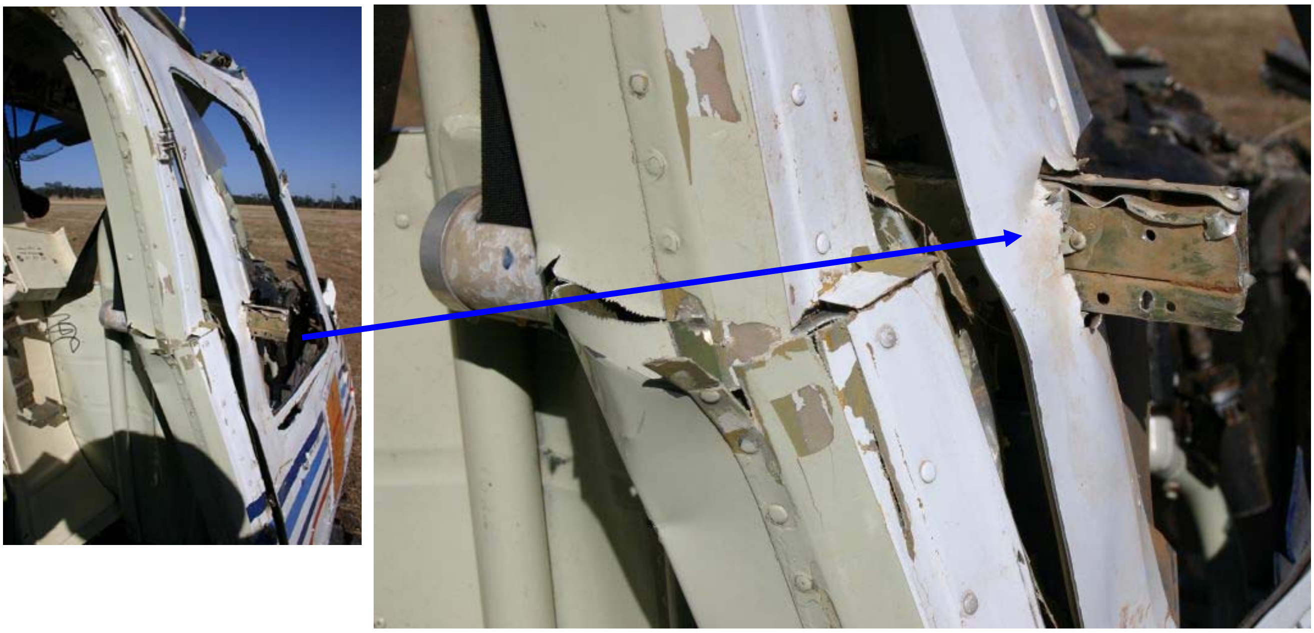


Figure 12: Distortion of fuselage structure

Figure 13: Distortion of fuselage structure

Figure 14: Horizontal beam projecting through the skin of right side cockpit door



During the process to return the helicopter to its skids, a large quantity of fuel drained onto the ground. The amount could not be measured, but was consistent with a quantity sufficient to ensure continued flight (see Figure 15).

Figure 15: Disrupted fuel tank evident as helicopter is righted

Note: Aviation turbine fuel flowing from ruptured fuel tank onto ground.

Examination of the wreckage and ground marks indicated that the engine was operating at the time the helicopter struck the wires. The helicopter had been operating normally prior to the accident, and there was no indication that it was not capable of continued operation.

Flight track data recovered from a hand-held Global Positioning System unit on board the helicopter revealed that the pilot had conducted three flights during the day, including the flight during which the accident occurred. The data indicated a total flight time of about 3.5 hours to the time of the wire strike; about 0.5 from Dubbo airport to a field operating base; about 2.5 hours operating from that base; and about 0.5 from the base to the time of the wire strike. The data indicated that the helicopter was not flying during the periods 1000-1030 and 1300-1400, and showed that the reconnaissance of the property that the pilot conducted during the last flight, included flight along both the main and spur powerlines involved in the accident. The last recorded GPS data indicated that the helicopter was flying at a speed of about 25 kts at the time of the wire strike.

Meteorological information

There was no evidence that prevailing weather conditions contributed to the accident.

Survival aspects

Civil Aviation Order (CAO) 20.11 included a requirement for pilots to orally brief all passengers before each takeoff. The front-seat ranger reported that prior to the flight during which the accident occurred, the pilot gave both rangers a safety briefing, including advice on how to enter and exit the aircraft, safety equipment and switches on board and what to do in the event of an accident. She also advised that the pilot discussed with them wire awareness, including a requirement to draw the pilot’s attention to all wires seen. She indicated that during the flight they used both topographic maps and parish maps for navigation. The topographic maps had wires marked, however the parish maps did not, except where property owners had marked the position of known wires and other hazards prior to the flight.

Each of the two front crew seats was fitted with a four-point harness seat belt, consisting of two shoulder straps and two lap belts that were fastened into a four-point buckle assembly by the seat occupant. The two shoulder straps were joined together into a single strap behind the shoulders of the occupant, which in turn was mounted in an inertia-reel assembly (see Figure 16).

The three seats in the rear cabin of the helicopter were fitted with two-point lap belts that were attached to the airframe at three attachment points on the lower rear bulkhead. The belts had a tongue on one part of the belt that inserted into a lift-to-release buckle on the other part (see Figure 17).

Figure 16: Front crew seat inertia reel assembly and harness buckle correctly secured

Figure 17: Right rear cabin seat belt

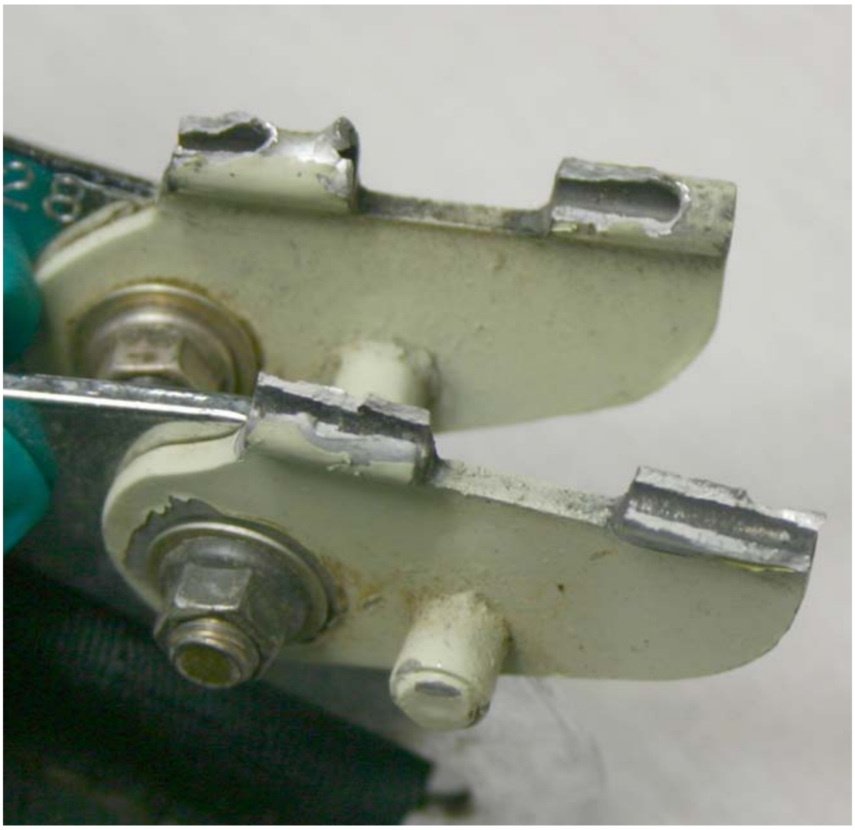
The pilot was wearing a flying helmet at the time of the accident. However, during the accident sequence the helicopter impacted the ground heavily on its right side, in the fuselage area adjacent to where the pilot was seated. The impact severely compromised the survivable space for the pilot and he had been directly subjected to severe and sudden impact forces.

The front left passenger and the rear cabin passenger were both seated on the left side of the helicopter, away from the initial impact with the ground. The helicopter had subsequently rolled onto the left side before coming to a stop. The passenger in the rear of the helicopter survived the impact but succumbed to injuries at the accident scene.

Examination of the pilot’s seat harness revealed that it appeared to have been correctly fastened, and that the attachment points were intact. The front seat passenger’s four-point harness seatbelt assembly was also found intact and correctly fastened for flight. However, both of the ‘piano hinge’ attachments that secured the end of each lap belt to the airframe had failed during the accident sequence. Examination of the fracture surfaces of those attachments indicated that they had failed in overload (see Figures 18 and 19).

Figure 18: Failed seat belt (airframe) attachments for left front crew seat

Figure 19: Failed seat belt attachments for left front crew seat



Both seat belt attachment points, for the passenger who was seated in the left rear cabin, had also failed as a result of the impact. Examination of the fracture surfaces of the rear bulkhead attachment points revealed that they had failed in overload (see Figures 20 and 21). The seat belt had been correctly fastened.

Figure 20: Failed seat belt (airframe) attachments for left rear cabin seat

Figure 21: Failed seat belt attachments for left rear cabin seat

No evidence was found to suggest that the seat belts were not in a serviceable condition prior to the accident. All damage noted to the seat belts and attachments was consistent with having resulted from impact forces. The certification basis for the helicopter was contained in the United States (US) Federal Aviation Administration *Type Certificate Data Sheet,* number H2SW. That document stated that the design criteria for the helicopter and restraint system were in accordance with US Civil Air Regulation (CAR), Part 6, dated 20 December 1956. CAR 6 specified that the helicopter and restraint system must be able to sustain a side load of 2 g. The side load experienced by the occupants and the seatbelt assemblies during impact with the ground were calculated to be about 10 g[6]. That load exceeded the design criteria.

[6] That figure could also be increased by the rotation of the cabin and conversion of forward speed into downward speed as it rotated about the powerline.

Previous similar accidents

A number of previous wire strike accidents have been investigated by the ATSB and its predecessor, the Bureau of Air Safety Investigation. In particular, the ATSB conducted investigations into two wire strike accidents that occurred during the plague locust control operation that CSH was involved in (see ATSB Investigation Reports BO/200404285, which is attached at Appendix A, and BO/200404286, which is available at www.atsb.gov.au.)

Occurrence BO/200404285 involved a Bell 206B helicopter, registered VH-JVW, near Forbes on 30 October 2004. That helicopter was of a similar type and conducting a similar task within the plague locust control campaign to CSH. A number of the elements investigated and included in the report are applicable to the accident involving CSH, in particular, organisational elements involving:

- administration of the 2004 plague locust control campaign
- contractual information
- NSW DPI/RLPB *Standard Operating Procedures for Locust Control - Effective 16 July 2004*
- the regulatory framework
- risk management
- mapping and marking of overhead powerlines.

Occurrence BO/200404286 involved a Bell 47 helicopter, registered VH-AHL, near Mudgee on 1 November 2004. That helicopter was not conducting locust control operations at the time that it struck the powerline.

Wire strike protection systems

Wire strike protection systems may be fitted to some helicopter types to reduce the severity of a wire strike. A system which may be fitted to the Bell 206B comprises a number of components including cutter blade assemblies fitted to the top and bottom of the helicopter frontal area, and an abrasive cutting strip built into the windscreen deflector. The system is intended to protect 90% of the frontal area of the helicopter.

The protection provided by such a system varies depending on helicopter operating limitations, customer-specified requirements at the time of the original design application of the system to the helicopter, and the attitude and ground speed of the helicopter at the time of impact with a wire. The degree of protection is substantially reduced when the flight attitude deviates from straight and level. Other factors that can affect protection include forward speed, powerline tension, powerline angle, strike angle, and pilot reaction.

Conduct of aerial locust spotting operations

The front-seat ranger reported that she used standard operating procedures published by the NSW DPI when conducting aerial operations during the plague locust control campaign. She reported that, prior to the flight, she and the other RLPB ranger both briefed the pilot on the nature and location of the operations conducted to date and then briefed about the intended flight, during which the wire strike subsequently occurred. She said that she was aware that the pilot had also been briefed by the helicopter operator on the nature of the operations to be undertaken.

She reported that, during the flight, the rangers' responsibilities included managing the survey task and acting as an observer. She advised that the tasks of the rangers were to primarily look at the ground and the locusts while still looking out for wires, however wire detection and obstacle avoidance was primarily the pilot's task. She recalled that, shortly before the accident, the pilot had broadcast to the spray aircraft to '…fuel-up…' and meet them at the property in order to conduct locust spraying.

Organisational information

The Air Operator's Certificate issued by CASA authorised the helicopter operator to conduct aerial work operations below 500 ft AGL, including aerial spotting. The operator included procedures for the conduct of aerial locust spotting in their Operations Manual.

The requirements for the mapping and marking of powerlines and their supporting structures are published in Australian Standards AS 3891.1, 1991, Part 1, *Permanent marking of overhead cables and their supporting structures*, and AS 3891.2, 1992, Part 2, *Marking of overhead cables for low level flying*. The general requirements of those standards were discussed in ATSB Aviation Safety Investigation Report BO/200404286 and include that, in general, there is no requirement for the marking of powerlines with a height above terrain or obstacles of less than 90 m. The powerline that was struck by the helicopter did not require marking in accordance with either standard.

ANALYSIS

The operator and the pilot were authorised and qualified to conduct aerial locust spotting operations. The two Rural Lands Protection Board rangers were on board the helicopter as part of the plague locust control campaign operating crew, and conducting the operation in accordance with NSW Department of Primary Industry standard operating procedures. Carriage of the property owner for the property reconnaissance prior to the wire strike was also in accordance with those procedures.

An analysis of risk management, relevant to the conduct of aerial operations during the plague locust control campaign, is addressed in ATSB Investigation report BO/200404285 (see Appendix A). Many of the issues discussed in that report are relevant to the accident involving CSH.

A number of options can be applied to mitigate risk during an airborne task, including reducing the consequence and/or likelihood of adverse events, such as an aircraft striking a powerline. Some options having the potential to affect the consequence of a wire strike include, but are not limited to:

- the use of flying helmets and wearing of full-cover protective clothing by aircraft occupants
- fitment of advanced safety harnesses
- installation of wire strike protection systems.

In the accident involving CSH, the pilot was wearing a flying helmet and the occupants were restrained by the restraint harnesses. Examination revealed that the front and rear passenger lap seatbelt anchor points had failed as a consequence of overload, in excess of the design criteria, during the impact sequence.

At the time of the accident the helicopter was not fitted with a wire strike protection system. The front seat ranger and the property owner reported that, just prior to striking the powerlines, the helicopter had been operating at low level and at about 25 kts over the field adjacent to the powerlines. The spur line consisted of two spans of three-strand high-tensile steel wire. The effectiveness of a wire strike protection system is dependent on a large number of variables including, but not limited to, the flight attitude, forward speed, powerline tension, powerline angle, strike angle, and pilot reaction. Consequently, the effect that fitment of a wire strike protection system to the helicopter may have had on the outcome of the accident cannot be quantified.

The conduct of the locust spotting operation required the two rangers to frequently refer to the documentation that they carried. Consequently, the front seat ranger would likely have been able to pay only minimal attention to identification of powerlines. The occupants of the helicopter were generally aware of the presence of the spur line, and were preparing to direct the spray aircraft onto the locusts. Although unable to be quantified, there was the potential that the pilot’s workload and concentration during that stage of the locust spotting operation adversely impacted on his ability to recall the proximity of the spur line. The reason for the pilot flying the helicopter into the spur line was not able to be conclusively determined.

CONCLUSIONS

The investigation concluded that:

- the operator and the pilot were authorised and qualified to conduct low-level aerial locust spotting operations
- the two Rural Lands Protection Board rangers were on board the helicopter as part of the plague locust control campaign operating crew, and were conducting the operation in accordance with NSW Department of Primary Industry standard operating procedures
- the occupants of the helicopter were generally aware of the existence and position of the powerlines
- the helicopter was capable of normal operation prior to striking the spur line

- the helicopter struck the spur line and subsequently impacted the ground.

SAFETY ACTION

As a result of the previous two accidents involving helicopters contracted to the 2004 locust control operation, a number of safety actions were taken by the:

- Helicopter operator
- Civil Aviation Safety Authority
- Aerial Agricultural Association of Australia Limited
- Australian Transport Safety Bureau.

Those actions are addressed at Appendix A. Following the accident involving CSH, a number of additional safety actions were taken or commenced.

NSW Department of Primary Industries

On 25 November 2004, the NSW Department of Primary Industries (NSW DPI) issued advice to aerial operators suspending the use of helicopters for aerial plague locust control, pending a formal risk assessment of their use, which was to be conducted by a contracted independent consultancy.

On 12 December 2004, the NSW DPI issued advice of resumption of helicopter use for locust control operations, but specified a number of conditions regarding their use, including height limitations, crewing and passenger requirements. In addition, the resumption advice specified that operations were to be conducted using:

- *NSWDPI/RLPB Aviation SOPs for Locust Control Version 2.0, 4 December 2004*
- *Supplementary Advice for Aerial Spotting Operations not below 100 ft*
- *Task Profile for Aerial Spotting (not below 100 feet).*

Rural Lands Protection Board

The Dubbo Rural Lands Protection Board provided training to their rangers on operations from helicopters. A phased re-introduction for those staff members was under consideration.

Helicopter operator

The helicopter operator distributed an operational notice to its flight crews suspending locust control operations for 24 hours pending a review of procedures. The operator also called for a meeting amongst interested parties to discuss safety of operations. The meeting was chaired by the NSW DPI and was attended by staff from the aerial operators, DPI, the risk assessment consultant, Aerial Agricultural Association of Australia, Australian Transport Safety Bureau (ATSB) and other parties with an interest.

Civil Aviation Safety Authority

In the March-April 2005, Vol 9, No 2 edition of *Flight Safety Australia,* the Civil Aviation Safety Authority published an article entitled *Wire Worry*, highlighting the hazards posed by powerlines for low flying helicopters.

ATSB

The ATSB commenced two research projects. The first was to examine the potential influence of contractual structure and organisational interaction on the safety of aviation campaign operations such as invertebrate pest management and airborne fire-fighting activities. The examination included the responsibilities for the management of the unique risks inherent to those types of campaign, and sought to highlight risk mitigation options for consideration by future aviation campaign participants. Following completion of the project, the ATSB published Aviation Research Investigation Report B2004/0337, *Risks associated with aerial campaign management: Lesson from a case study of aerial locust control*, in June 2005. A copy of the report is at Appendix B.

The ATSB published an article in the July-August 2005, Volume 9, No 4 issue of *Flight Safety Australia*, entitled *Risks associated with aerial campaign management: Lesson from a case study of aerial locust control.*

The second research project was an analysis of occurrences reported to the ATSB, which were classified as wire strikes in the ATSB database, for the period 1994 to 2004. When complete, the ATSB Aviation Research Investigation Report, *Wire strikes in general aviation - data analysis 1994 to 2004*, will be published on the ATSB website www.atsb.gov.au or be available from the Bureau on request.

Appendix A – ATSB Final Investigation Report BO/200404285

FACTUAL INFORMATION

Sequence of events

At about 1215 eastern summer time on 30 October 2004, the pilot of Bell Helicopter Company 206B, registered VH-JVW, was conducting aerial work in support of the Forbes area Plague Locust Control Campaign (campaign) that was being administered by the NSW Department of Primary Industries (DPI). Also on board the helicopter were the local Rural Lands Protection Board (RLPB) senior ranger, who was seated in the left front seat of the helicopter, and one RLPB and one DPI staff member who were seated in the rear cabin of the helicopter.

The senior ranger requested the pilot to land in a paddock in order to examine a previously unidentified band[7]of locusts. The pilot reported conducting two orbits of the proposed landing area prior to commencing the approach to land in a north-easterly direction. During those orbits, the pilot asked all the occupants of the helicopter to keep a look out for power cables and other potential hazards in or around the landing area. However, one of the rear seat occupants reported the understanding of not being required to call or report power cables unless it was felt that the pilot had not seen a cable. While neither of the rear seat occupants reported the presence of any power cables to the pilot, the pilot and senior ranger saw a north to south running power cable located on the western boundary of the paddock. They also noted a westerly spur line emanating from a power pole located abeam the intended landing point. That power pole was also supporting the north to south power cable. No-one aboard the helicopter identified a second spur line emanating from that same power pole, and tracking to the east and overhead the intended touchdown point.

The pilot reported that, when at ‘low airspeed’ and passing through an estimated 25 ft above ground level (AGL) on the final stages of the approach to land, a previously unidentified power cable became caught between the skids and underbelly of the helicopter. The pilot indicated that he attempted to manoeuvre the helicopter free from the cable, but that the helicopter pitched 90 degrees nose down and impacted the ground heavily on its nose before rolling onto its roof. The helicopter came to rest on its right side, facing back along the direction of approach, and was extensively damaged. There was no fire. The senior ranger suffered minor injuries and the pilot and rear cabin occupants were not injured.

Personnel information

The pilot was appropriately qualified for aerial work operations in the helicopter, and reported being medically fit, feeling well and adequately rested. The pilot was not required to wear or carry any vision correction spectacles, although he reported that he was wearing tinted

[7] A ‘band’ was described by a ranger to indicate the presence of immature, ground-limited locusts. Bands appear as dark, ribbon-like or patchy marks, somewhat like a tide mark or stain.

sunglasses at the time of the accident. He had about 300 hours low flying experience[8] at the time he was nominated by the operator for employment in the plague locust survey task. The pilot indicated that he had:

- most recently been operating in the Kununurra area
- not previously operated in the Forbes area, or with the operator
- no experience in plague locust survey or other operations.

The senior ranger indicated that he had flown in a helicopter once prior to the 2004 campaign. However, he had carried out an estimated 15 to 20 plague locust survey flights in helicopters during the 20 to 25 days preceding the accident. He had attended in-class locust control training courses that were administered by the DPI earlier in the year, but had received no experiential training in accordance with the requirements of DPI Standard Operating Procedure (SOP) for Australian Plague Locust Control in NSW number 15.16. Among other requirements, that SOP required that all DPI and RLPB staff assigned to fly in survey aircraft should have appropriate experience in detecting bands and directing spray aircraft. The senior ranger reported that, during the occurrence flight, his responsibilities included managing the survey task and acting as an observer.

One of the rear seat occupants had been involved in two previous survey flights during the campaign, and reported being responsible for spotting and recording locusts during the flight. That spotter had attended two brief, in-class training courses conducted by the DPI shortly before the campaign, but had been given no experiential training in the detection of bands or direction of spray aircraft.

The second rear seat occupant had been airborne in a helicopter once previously during the campaign and had minimal aviation experience. During the flight, that occupant shared responsibility for spotting and recording locust infestations. That spotter reported having attended a DPI workshop prior to participating in the campaign that examined the identification of plague locusts, but that no experiential training in relation to the detection of bands of direction of spray aircraft had been provided.

Aircraft information

Based on the evidence provided to the investigation, the aircraft was certified, equipped and maintained in accordance with the regulations and approved procedures. The windscreen was reported to have been clean, and there was no damage to the windscreen, or any obstruction that might have adversely affected visibility from the cockpit. The aircraft was not fitted with, and neither was there a regulatory requirement for the installation of a wire-strike protection system[9] (WSPS). The Chief Pilot indicated that he felt WSPS might not have had any effect in this instance because the helicopter struck the power cable at low speed.

One spotter reported an intermittently operating intercom system, requiring communication with the remainder of the helicopter occupants through the second rear seat occupant. The rear seat belts installation included four-point lap and shoulder harness seatbelts for each occupant.

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8 The pilot indicated that his experience included bird control, some powerline work and telecommunication equipment survey and support work in the Kununurra area in the north of WA.

9 Equipment installed on an aircraft to reduce the lethality of an impact with power or other cables.

Meteorological information

No evidence was found to suggest that the weather conditions influenced the circumstances of the occurrence.

Survival aspects

Civil Aviation Order (CAO) 20.11 included the requirement for pilots to orally brief all passengers before each takeoff. The pilot reported that, while he had briefed the passengers in accordance with that requirement, the actions in the event of an emergency and a reliable method for reporting power cables, or other hazards by the senior ranger and spotter were not discussed. For example, …wire right 3 o'clock, 300 m, travelling front to rear (of survey helicopter), etc.

The pilot indicated that he had been wearing a helmet at the time of the occurrence, and that the helmet visor was in the raised position. There was no regulated requirement for the senior ranger or rear seat spotters to be similarly equipped, and no stipulated minimum standard of flying or personal clothing for those persons for airborne operations in accordance with DPI or RLPB requirements. Such requirements might typically include full-cover clothing, safety boots, etc.

Administration of the 2004 plague locust infestation

In NSW, the *Rural Lands Protection Act 1998* (RLPB Act) and *Pest Control Order Number 6* under that Act declared the Australian Plague Locust to be a pest and imposed obligations on the occupiers of controlled land to report locusts on their lands to their local RLPB and to destroy those locusts. Assistance could be provided by the relevant RLPB, DPI or Australian Plague Locust Commission when the destruction of the locusts became beyond the capability of the individual land owner(s). In addition, the RLPB Act established a State Council as a corporate body with responsibility for ensuring implementation by RLPBs of:

- the general policies for the protection of rural lands
- operations in accordance with determinations made from time to time at State Conferences or by postal ballot.

The *State Emergency and Rescue Management Act 1989* (SERM Act) required the DPI to coordinate the response to agricultural or animal emergencies with the support of relevant participating and supporting organisations. The State Agricultural and Animal Services Supporting Plan Memorandum of Understanding (MOU) established the DPI and State Council responsibilities for the preparedness for, and response to agricultural or animal emergencies. That MOU enabled the DPI to approach the State Council in order to seek technical expertise, personnel support and other assistance from RLPBs in agricultural emergencies.

At the time of the accident, there were 48 RLPBs throughout NSW. Each Board was a statutory authority under the RLP Act and was constituted for each rural lands protection district. Legislated RLPB responsibilities included those functions affecting the protection of rural lands, including the surveying and monitoring of plague locust infestations on pastoral lands. Should an infestation be considered to reach a defined density, the relevant RLPB and DPI determined the appropriate control measure. That was the case in 2004, when the locust infestation reached plague proportions in certain regions of NSW.

In response to the expected magnitude of the locust outbreak in the spring of 2004, the DPI requested through the State Emergency Management Committee (SEMC) that the locust outbreaks should be recognised as an emergency under the SERM Act, with DPI as the lead agency in any emergency response. That was supported by the SEMC and allowed the DPI to access relevant emergency management systems and resources. That included a request for assistance from the State Council to RLPBs from throughout NSW.

In response, RLPBs sought volunteers from among their staff who: were willing to be involved; could be released from their own Boards for the agreed period; and had the requisite skills or experience for the necessary tasks. During the campaign, those volunteer personnel were under the control of the relevant Local (locust) Control Centre, while administratively remaining a responsibility of their respective RLPB.

Aerial control of the 2004 locust infestation was coordinated by the Australian Plague Locust Commission, with responsibility for the area west of the Newell Highway and the DPI, east of that highway. The DPI responsibility included:

- monitoring locust populations and levels of infestation
- implementing particular aerial control measures for application in specific areas
- contracting for the provision of aeroplane and helicopter services in response to aerial spraying and survey requirements
- the purchase and supply of chemicals for airborne and ground-based application.

Contractual information

In response to the unpredictable nature of the requirement for aerial support to assist in activities related to the control of Australian plague locust and other species, the DPI sought Expressions of Interest (EOI) from aircraft operators to become ‘prequalified service providers’ of that aerial support. Successfully pre-qualified operators were placed on an approved pre-qualified applicant list, indicating operators’ agreement that their aircraft, pilots and crewmembers would assist with locust control activities on a ‘call when needed’ basis.

The submission of an EOI by an operator indicated the operator’s agreement with the Conditions of Contract as set out in section three of the EOI. Those conditions included that:

- The operator was required to notify the DPI of any variation in respect of aircraft and/or pilot information and obtain DPI approval in writing for that variation.
- The operator and its employees were suitably trained and able to demonstrate current competency. In that regard, an operator’s Chief Pilot was required to certify that each pilot was rated, endorsed and competent to complete plague locust tasking.
- No pilot may undertake any task for the DPI unless approved in writing. That was reflected in the contract clauses, requiring an operator to obtain that written approval before allowing a pilot to undertake aerial support in connection with locust control services.

In respect of the operator’s interaction with the DPI under those conditions:

- In response to a post-accident request by DPI, the operator provided the pilot's information by facsimile on 17 December 2004. There was no measure in place at the Forbes or other local control centres to allow local staff to check variations in pilot information against a DPI master list of approved pilots prior to a pilot commencing locust control work. That was the case with the occurrence pilot.
- The Chief Pilot certified the pilot's ratings, endorsements and competence for employment in the plague locust task on 29 October 2004. That certification was not forwarded to DPI until 17 December 2004.
- There was no control measure in place at local control centres to ensure that written approval was given by the DPI prior to the occurrence, or other pilots undertaking locust survey tasks.

In addition, the EOI allocated responsibility for the training of DPI and RLPB staff, and any other person involved in airborne operations, to the operators of those aircraft. The minimum requirements for applicants for pre-qualification included that 'pilots engaged or to be engaged by the Applicant must have at least 50 hours plague locust spraying and/or survey experience as appropriate' and 'Low Flying approval with at least 500 hours experience'. In the case of aerial spraying of locusts, pilots were required to hold a Grade 1 Agricultural Rating and be Spray Safe-accredited by the Aerial Agricultural Association of Australia (AAAA). In addition to requiring defined flying experience in agricultural operations, that rating included an examination to confirm a pilot's knowledge of the content of the CASA Aerial Agricultural Pilot's Manual, which stressed the importance of an agricultural pilot to carry out his or her own airborne inspection of an area to be sprayed. That was because it was the spray pilot's last critical opportunity to confirm their hazard map and other planning details. In the case of locust survey aircraft:

> …the pilot must have a general permit for low flying ("**Low Flying approval**") in accordance with Regulation 157 of the *Civil Aviation Regulations 1988*.[10]

During the evaluation of the response to the EOI that was submitted by the operator, DPI staff identified that, of the two company pilots initially nominated for the plague locust survey task, one certified having 18 hours locust survey experience and, the second pilot, no locust survey experience. Notwithstanding, the operator was contracted by the DPI as a Pre-Qualified Service Provider, Locust Control on 13 October 2004.

The Chief Pilot reported having an agreement with an operator located in the north of WA for the cross-hire of helicopters between the companies, and short notice cross-employment of pilots. That was to allow for the movement of those resources in response to seasonal up and downturns in each company's workload. The occurrence pilot commenced plague locust survey support work in the Forbes area while remaining an employee of the WA-based operator.

NSW DPI / RLPB Standard Operating Procedures for Locust Control - Effective 16 July 2004

The NSW DPI / RLPB Standard Operating Procedures (SOPs) for Locust Control established the requirements for aircraft operations involved in the 2004 campaign. Knowledge of the content of the SOPs varied amongst those aboard the helicopter. One DPI / RLPB staff

[10] CAR 157 placed a requirement on an operator; it did not directly affect qualifications required to be held by a pilot.

member indicated having read the SOPs, although being unsure of the requirements placed on locust survey aircraft, while another confirmed that there were SOPs, but indicated having not read them comprehensively.

All DPI and RLPB staff assigned to fly in locust survey aircraft were required to '…have SLC [State Locust Controller] approval to fly and appropriate training and experience in detecting bands and directing spray aircraft'. During the investigation a previously unknown error in the SOP was identified by DPI concerning that approval. That error included that approval for DPI and RLPB staff to undertake locust survey flights had always been at the local level. DPI advice was that at the Forbes Control Centre, employees were allocated to locust survey aircraft on a weekly basis, and that allocation was notified to staff on a whiteboard. No written record was available to confirm staff allocation to the occurrence helicopter. Subsequent advice from the DPI included that, due to the nature of the 2004 locust campaign, the SOPs 'were seen as "living" documents which could be changed if required'. In that regard, the change in the approval process for employees to fly in survey helicopters had been conveyed to local control centres verbally, although the text of the SOPs had not been modified.

The SOP included the potential for helicopter survey of widespread and sparsely concentrated young (nymphs) or adult locusts. In the case of nymphs, the initial survey was required to be conducted at about 1,500 feet AGL. The location of significant infestations was marked using Global Positioning System (GPS) equipment and the number and size of the nymphs estimated in order to identify 'blocks' for subsequent aerial control, including aerial spraying of identified infestations to complement the ground spraying campaign.

The SOP included that onboard DPI / RLPB observer(s) 'may require the helicopter to land so that [they can] verify their observations' if the nymphs were not 'banding as normal[11]', or there was extensive ground cover. It was reported that had been the case during the occurrence flight, when the senior ranger had decided that the pilot should land the helicopter in order to prioritise target bands for spraying the following day. The senior ranger indicated that there had been recent discussion between local and other RLPB / DPI staff regarding the need to land a survey helicopter in order to prioritise bands for subsequent spraying. The senior ranger was unable to confirm the outcome of that consideration.

When conducting searches for adult locusts, and in the expectation that the adult locusts would flush up ahead or around the manoeuvring helicopter, the SOP required pilots to:

> …fly along tree and creek lines and in localised areas of green vegetation approximately 12 ft (3 m) above ground level and at 30 knots (60 km/h).

Once a target group of locusts had been identified for aerial spraying, the SOP required the Local Locust Controller (LLC) or ranger aboard the locust survey aircraft to direct the spray aircraft to the target using GPS coordinates. The LLC or ranger was then required to:

- Relay the boundaries of the target to the pilot of the spray aircraft. That entailed either:
    - the survey pilot flying the boundaries, and the LLC or ranger confirming the spray pilot's understanding of the boundaries via radio communication; or
    - the LLC or ranger verbalising the boundaries via radio communication, then observing the spray pilot flying around those boundaries.

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[11] One of the rear seat occupants indicated that, on a hotter day, the locusts were more active. In that case, the band would be more dispersed and therefore difficult to interpret from the air in terms of density, size, etc.

- Identify and highlight any sensitive areas and hazards to the spray pilot. That included environmental and physical hazards, such as farm dams and powerlines.

The Airfield Controller (controller) was responsible for coordinating aircraft operations at an airfield or landing area, compiling and managing Search and Rescue (SAR) logs, etc. That controller complied with the SOP requirement for the completion of a *SAR – Aircraft Information Sheet* for the occurrence helicopter task. In addition, the SOP required the controller to follow laid down, incremental search procedures should an aircraft fail to make a planned radio broadcast indicating normal aircraft operations or to return to base. The pilot indicated that he had been transmitting scheduled Operations Normal radio broadcasts at regular intervals to indicate normal helicopter operations, and the expected time of the next such transmission by the pilot. The pilot reported that he did not transmit a distress call upon striking the power cable. Notification of the occurrence was via a combination of telephone calls by the pilot and DPI / RLPB staff once clear of the wreckage.

Regulatory framework

In accordance with Civil Aviation Regulations (CAR) 157, flight is authorised below 500 ft when clear of any city, town or populous area and the aircraft is conducting aerial work operations that:

> …require low flying, and the owner or operator of the aircraft has received from CASA either a general permit for all flights or a specific permit for the particular flight to be made at a lower height while engaged in such operations;…

The operator held a Low Level Flying Permit that authorised air work operations below a height of 500 ft AGL. Those operations were specified in the company Operations Manual and included aerial spotting and/or counting of wildlife and other similar tasks on behalf of landowners or Government Departments/Agencies/Instrumentalities. In addition, the company Operations Manual included that pilots in command of company aircraft carrying out low-level aerial spotting operations must:

> (b) hold an appropriate agricultural rating or mustering approval or have satisfactorily completed the dual training specified for the appropriate kind of aircraft in CAO 29.10, Appendix 1;

CAR 206 lists aerial spotting and agricultural operations as operations conducted for aerial work purposes. Agricultural operations are defined as:

> …the broadcasting of chemicals, seeds, fertilizers and other substances from aircraft for agricultural purposes of pest and disease control.

CAO 40.6 defines the requirements of Agricultural Pilot Rating Grades 1 and 2. Those requirements include completion of a period of ground training and a written exam, before carrying out initial and operational flying training. The operational flying training is followed by a period under supervision, before the newly rated agricultural pilot is able to conduct unrestricted agricultural operations. The Grade 1 rating required a helicopter pilot to hold, or have held a Grade 2 rating, and to have logged a minimum of 500 hours experience on helicopter agricultural operations.[12]

Aerial stock mustering is defined in CAO 29.10 as 'the use of aircraft to locate, direct and concentrate livestock whilst flying below 500 feet above ground level'. The aeronautical experience requirements for a pilot to engage in mustering operations include that the pilot must complete 5 hours low flying training[13] and an exam to confirm pilot proficiency, followed by 10 hours operational training. The occurrence pilot completed the low flying training component of that requirement in March 1999.

Pilot induction

The Chief Pilot indicated that the pilot's preparation for the conduct of plague locust survey support included that:

- On 29 October 2004, the pilot signed as having read the company Operations Manual. That indicated the pilot's agreement to operate the helicopter in accordance with that manual
- The Chief Pilot conducted a pre-flight brief followed by a 0.3 hour check flight with the pilot on the morning of the accident. The content and duration of that flight was reported to be based on the pilot's recency with the helicopter type, and the high degree of commonality between the Bell 206B helicopters being operated by the company in support of the locust control campaign, and by the pilot's company in the north of WA. The primary differences between the helicopters included the radio installation and associated switches.

The Chief Pilot reported placing heavy emphasis on identification and avoidance of power cables and other hazards during the pre-flight brief, and stressing the particular dangers associated with operating below the tree tops. That was in recognition of the majority of the pilot's experience being in the Kununurra area, where the Chief Pilot felt there were not as many wires compared with the Forbes area. There was no practical application or review in the check flight of means available to a pilot to identify power cables and their orientation, or to demonstrate the difficulties affecting that identification.

In addition, the Chief Pilot indicated that he preferred steeper landing approaches and departures, because that increased the likelihood that any power cables might be seen during the approach or departure. In order to increase the power margin[14] available for that steeper landing approach and departure technique, the Chief Pilot's preference was to restrict the number of passengers carried to no more than two. Those considerations were developed by the Chief Pilot during the campaign, and were not passed on to the pilot during the pre-flight brief or check flight.

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[12] Experience for the award of an Agricultural Pilot (Aeroplane) Rating Grade 1 included 1,000 hours agricultural flight time, of which 250 hours experience was required on spraying operations.

[13] Including: avoidance of obstacles; aerial reconnaissance and operational planning; and the effect of obstacles on operational procedures.

[14] The surplus of power between that produced by the helicopter engine compared to the power required by the helicopter and its systems during the approach in the ambient conditions.

Risk management

Australian/New Zealand Standard AS/NZS 4360:2004 *Risk Management* (the Standard) defined risk as:

> the chance of something happening that will have an impact upon objectives.
> NOTE 1: A risk is often specified in terms of an event or circumstance and the consequences that may flow from it.
> NOTE 2: Risk is measured in terms of a combination of the consequences of an event … and their likelihood…
> NOTE 3: Risk may have a positive or negative impact.

The Standard described risk management as 'the culture, processes and structures that are directed towards realizing potential opportunities whilst managing adverse [or negative] effects'. Residual risk is that 'risk remaining after implementation of risk treatment'. Options for modifying or treating identified risks with negative outcomes included:

- influencing the likelihood of a risk, in order to reduce the probability of a negative outcome
- changing the consequence(s) of an event to minimise the extent of any losses.

RLPBs were required to satisfy themselves that adequate arrangements were in place to manage risks associated with aerial survey operations before allowing their employees to undertake work-related tasks in support of the locust control campaign. There was no evidence of any guidance, such as the Standard having been provided to RLPBs to allow their confirmation of the adequacy of those arrangements. The State Council indicated that, while low-level survey by any aircraft was a high risk activity, the adoption of appropriate risk control measures had the potential to reduce the probability of an adverse incident to acceptable levels. However, the Council recognised that, even with such risk controls in place, there remained the residual risk of a serious incident or accident.

Wire density and the requirement to mark overhead power cables

The pilot stated that there were virtually no power cables in the Kununurra area when compared with his locust survey support experience in the Forbes area. The investigation determined that the density of the known power cables within a 100 km radius of Kununurra, excluding in the townships of Kununurra and Wyndham was one known power cable per 10,476 square kilometres. That represented three power cables that tracked between the two towns, and from Kununurra to the Ord River Dam and on to the site of the Argyle Diamond Mine.

In the Forbes area, that wire density, excluding in any townships was estimated to approach one known power cable per 10 square kilometres. The pilot indicated that the cable struck by the helicopter had not been marked on the World Aeronautical Chart used to navigate to the nominated survey area. He felt that the power cable had been difficult to see because of the extended spacing between the poles supporting that cable when compared with the spacing of the poles supporting the north to south power cable that was identified on the western boundary of the intended landing area.

The requirements for the mapping and marking of power cables and their supporting structures are published in Australian Standards AS 3891.1 1991 Part 1: Permanent marking of overhead cables and their supporting structures, and AS 3891.2 – 1992 Part 2: Marking of overhead cables for low level flying. The general requirements of those standards were discussed in ATSB investigation report BO/200404286[15] and include that, in general, there is no requirement for the marking of power cables with a height above terrain or obstacles of less than 90 m. The power cable that was struck by the helicopter did not require marking in accordance with either standard.

Technical committees are formed by Standards Australia to develop and review relevant standards, and comprise a balance of interested and affected parties that are nominated by generally national organisations. The aim is that the standards should include consideration of the views of large, common interest groups. Organisations that consider they represent a valid, previously unrepresented interest group are able to nominate for consideration for inclusion in a committee. A number of aviation industry associations and other bodies were involved in the development of the Australian Standards affecting the marking of overhead power cables and their supporting structures. That did not include some of the groups and associations normally associated with a number of agricultural and other low-level operations.

ANALYSIS

Risk management options for application during an airborne task include reducing the consequence and/or likelihood of adverse events, such as an aircraft striking a power cable. Those options having the potential to affect the consequence of a wire strike include:

- the use of helmets and wearing of full-cover clothing by aircraft occupants
- installation of wire-strike protection systems
- inclusion of advanced safety harnesses
- appropriate flight following and search and rescue procedures.

However, in terms of risk, the consequence of an aircraft striking a power cable can generally be expected to be severe to catastrophic. As a result, a large investment is generally made by involved parties in order to decrease the likelihood, and therefore risk of a wire strike. That was the case during the 2004 Plague Locust Control Campaign.

The regulatory requirements affecting aircraft operations below 500 ft above ground level, including in the plague locust aerial support task, were an attempt to reduce the likelihood of an adverse event affecting a pilot during those operations. In addition, the Expression of Interest (EOI) mandated requirements affecting the acceptability of nominated pilots for employment in the locust survey task, indicated an attempt by the NSW Department of Primary Industries (DPI) to further reduce the likelihood of an adverse event during the locust control campaign. Also, the establishment by the operator of specific pilot low-level operations competency requirements defined an additional risk mitigation strategy that was based on the reduction of the likelihood of an adverse event in that environment. Both the DPI and the operator's requirements were in excess of the Civil Aviation Safety Authority regulatory requirements, and were valid risk management options for application in the locust survey task.

It was likely that Rural Lands Protection Boards (RLPBs) relied on the pilot's competence and experiential requirements of the EOI when considering the risks affecting their employees

[15] Available at www.atsb.gov.au

during aerial survey operations. The lack of any local control measure that would have allowed the Forbes or other control centre staffs to ensure that the occurrence and other pilots complied with those requirements meant that the Forbes, and possibly other RLPBs unknowingly placed its employees in a potentially higher risk environment than intended. Similarly, the residual risk inherent in the locust control campaign, including that of a wire strike could have been higher than initially accepted by the State Council in order for the campaign to commence.

The emergency nature of the 2004 locust control infestation resulted in the involvement of DPI and RLPB staff volunteers from throughout NSW in the locust control campaign. In addition, operators and pilots from many backgrounds and experience bases were also involved in that campaign. Those circumstances, together with the 'living' nature of the Standard Operating Procedures (SOP) and, in some instances verbal amendment process minimised the likelihood of the standardisation of airborne techniques and procedures among those operators, pilots and DPI / RLPB staff. That was confirmed in this instance by the recent consideration of whether a survey helicopter needed to land to examine the bands of locusts and the variation in knowledge of the content and application of the SOPs among the DPI / RLPB staff aboard the helicopter.

It was probable that the pilot was unaware of the rear seat occupants' perceived lack of involvement in the identification of power cables or other hazards, or communication equipment difficulties affecting that process. That meant that the identification of any power cables and other hazards effectively rested with the pilot and senior ranger. It was likely that, having drawn the pilot's attention to the wires to the west of the landing area, the senior ranger applied his concentration to the locust band in the paddock once the pilot commenced the final stages of the approach to land. In that case, the identification of the west to east spur line fell to the pilot. Although unable to be quantified, there was the potential that the pilot's workload during the approach to land in the unfamiliar environment adversely impacted on his ability to detect the west to east spur line. The result was that no-one onboard the helicopter detected that spur line.

The abbreviated nature of the pilot's induction meant that the pilot had to integrate relevant aspects of his low flying training and previous experience to the specifics of the locust survey task while carrying out that task. In contrast to the pilot's likely intimate knowledge of the few power cables in the Kununurra area, the density of the power cables in the Forbes area, and the differing environmental and other cues indicating the presence of those cables, suggested that the pilot would have benefited from a practical consolidation of elements of the Chief Pilot's brief. The lack of that practical consolidation had the potential to reduce the reliability of the operator's low-level rating/approval/training requirement as a risk management tool.

Depending on respective pilots' ratings and endorsements, there was a potential difference between survey and spray pilots' knowledge and skills bases affecting the low-level locust control operations. Adherence to the DPI SOP meant that, in the event that a survey pilot did not have an agricultural rating, the pilot may not be able to contribute effectively to the identification and communication of low-level hazards and sensitive areas by an on board ranger or spotter. That could result in the ranger or spotter unwittingly omitting information that was potentially critical to the safe application of relevant chemicals by a spray pilot. Although a spray pilot retained ultimate responsibility for the safety of that application, the investigation concluded that the SOP compounded the risk of an unsafe or environmentally unsound application by a spray pilot.

The SOP requirement for locust survey pilots to fly along creek and tree lines in order to flush up adult locusts could be perceived to represent a form of mustering manoeuvre. Unless included as an individual operator requirement, or an individual pilot held a mustering approval or had completed low-level training, the SOP required pilots to conduct those mustering-like manoeuvres without the benefit of the competency-based mustering risk controls inherent in the requirements of Civil Aviation Order 29.10. In addition, that procedure placed pilots in an environment identified by the Chief Pilot as being particularly dangerous with regard to power cables and other hazards. There was the potential that the SOP manoeuvre requirement could combine with those environmental dangers to increase the likelihood, and therefore risk that a pilot might strike a power cable or other hazard to unacceptable levels.

This investigation identified the potential for the application of relevant risk management strategies to reduce the residual risk affecting a low-level aircraft operation to a level considered acceptable by that operation's stakeholders. The majority of the investment in risk management in that environment was found to be in the reduction of the likelihood of an adverse event. In this occurrence, the lack of a robust application of existing risk controls to the locust survey task resulted in the level of residual risk, including that of a wire strike, being above that intended by the State Council, and considered by respective RLPBs when approving the employment of their staff in airborne operations. The investigation was unable to quantify the contribution of that elevated residual risk to the development of the accident.

SIGNIFICANT FACTOR

1. No-one aboard the helicopter identified the spur line overhead the intended touchdown point in sufficient time to allow the pilot to avoid impacting the wire.

SAFETY ACTION

Operator

The Chief Pilot has amended the company procedures to include the requirement for pilots to restrict the number of persons carried during locust survey operations to two. That was in order to increase the anticipated helicopter power margin, which would decrease the incidence of pilots being constrained to the conduct of heavy, shallow arrivals and departures to/from landing areas.

Civil Aviation Safety Authority

On 31 January 2005, the Civil Aviation Safety Authority (CASA) convened a round table discussion to consider potential safety activities relating to the conduct of aerial work in proximity to power cables. The participants in that discussion included representatives from relevant industry associations and other bodies and affected Government departments and agencies.

CASA has commenced planning to facilitate a conference in September 2005 involving relevant industry associations and other bodies and affected Government departments and agencies to further progress those safety issues confronting aerial work operations that were identified during the 31 January 2005 round table discussions.

Aerial Agricultural Association of Australia Limited

The Aerial Agricultural Association of Australia Limited has nominated to be included in the Standards Australia committee responsible for the development of the standards affecting the mapping and marking of power cables and their supporting structures.
The NSW Department of Primary Industries

The NSW DPI has commenced an iterative approach to the review and amendment of the NSW DPI / RLPB SOP for Locust Control. That has included:

- involving an operator having extensive experience in the conduct of plague locust campaigns in the re-development of the SOP
- deleting the requirement for low-level flight along tree lines in order to flush adult locusts up and ahead of the helicopter
- developing standard Task Profiles for the aerial survey and spotting tasks that include the following operating height limitations:
    - locust survey, not below 500 ft AGL
    - locust spotting, not below 100 ft AGL
- promulgating minimum personal protective equipment requirements for the conduct of locust survey and spotting tasks
- promulgating a minimum crew composition for locust survey and spotting tasks of one pilot and one aviation trained observer. That observer is to be provided by the aircraft operator, be appropriately trained and have a minimum of 50 hours aviation experience. The aviation trained observer is responsible for assisting the pilot with:
    - the operation of the aircraft
    - identification of hazards and their avoidance
    - mapping identified locust infestations
- establishing an observer position, which can include carriage of either RLPB / DPI staff or local farmers in the rear of the survey aircraft. If carried, that observer has responsibility for assisting the pilot with:
    - local knowledge, including property boundaries and owners and environmentally sensitive areas
    - identification and mapping of locusts infestations
- other than approved observers, prohibiting the carriage of back seat passengers
- prohibiting flight by RLPB / DPI employees below 100 feet AGL
- amending the flight following and search and rescue procedures.

RLPB and DPI staff members likely to be involved in locust control helicopter operations have completed the National Parks and Wildlife aircraft operations awareness course.

ATSB

The Australian Transport Safety Bureau has commenced a research project that is examining the potential influence of contractual structure and organisational interaction on the safety of aviation campaign operations such as invertebrate pest management and airborne fire-fighting activities. That examination includes the responsibilities for the management of the unique risks inherent to those types of campaign, and seeks to highlight risk mitigation options for consideration by future aviation campaign participants.

When complete, the research project report will be published on the ATSB website www.atsb.gov.au or be available from the Bureau on request.

Appendix B – ATSB Aviation Research Investigation Report B2004/0337, *Risks associated with aerial campaign management: Lesson from a case study of aerial locust control*

Australian Government

Australian Transport Safety Bureau

AVIATION RESEARCH INVESTIGATION REPORT
B2004/0337

Risks associated with aerial campaign management:

Lessons from a case study of aerial locust control

June
2005

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ABBREVIATIONS

AGL	Above Ground Level
APLC	Australian Plague Locust Commission
ATSB	Australian Transport Safety Bureau
CASA	Civil Aviation Safety Authority
CFIT	Controlled Flight into Terrain
DPI	New South Wales Department of Primary Industries
DPI Victoria	Department of Primary Industries, Victoria
HROs	High Reliability Organisations
NRM	Queensland Department of Natural Resources and Mines
RLPB	Rural Lands Protection Board
SARDI	South Australian Research and Development Institute

EXECUTIVE SUMMARY

In 2004, there were two wirestrike accidents in New South Wales involving helicopters undertaking locust control operations. The first accident occurred in October 2004 near Forbes and resulted in minor injuries to one occupant and extensive damage to the helicopter. The second accident occurred in November 2004 near Dunedoo and resulted in the death of two occupants. A third occupant was seriously injured and there was extensive damage to the helicopter. A third accident, near Mudgee in November 2004, involved a helicopter that was being used for locust control, although the helicopter was not involved in locust control activities at the time of the accident.

The Australian Transport Safety Bureau (ATSB) began formal investigations into all three accidents and a research investigation into the practices used by Government organisations to contract aerial operators for locust control in order to identify issues that may enhance future aviation safety.

Locust control operations are presented as a case study, but it is intended that organisations managing other aerial operations with similarities to locust control, such as aerial fire control, other pest management operations, and emergency service operations, may also find the concepts presented in this analysis useful. These types of operations, collectively referred to in the report as 'aerial campaigns', are characterised by:

- a significant community need for the operation, possibly urgent;
- requiring the coordination of significant numbers of resources and organisations;
- a degree of irregularity or unpredictability as to when the operation will be required and the size the operation;
- requiring aerial operations with a relatively high hazard level; and
- a regularly changing operational environment throughout the course of the campaign.

These characteristics potentially increase risk to the organisation and its staff. Locust control organisations are closely involved in aerial operations and can therefore influence the level of risk of the operations.

Many complex organisations operating in a hazardous environment, such as major public air transport companies, recognise the influence they have on safety. While they may subcontract many safety-critical aspects of their operations, these organisations still maintain an interest in the safety of these operations and proactively manage safety beyond what is required by regulation. Similar methods can be effective for mitigating risk in aerial campaigns.

Locust control organisations and other organisations involved in aerial operations with similar characteristics may benefit from developing some of the characteristics identified in High Reliability Organisations (HROs). HROs work in complex high-hazard environments but with relatively low numbers of accidents and incidents. These organisations have been identified as having an 'organisational mindfulness' which is defined by:

- an attitude that recognises failures, no matter how small, are symptoms of a problem in a system and that failures provide learning opportunities for the organisation;
- encouraging diverse views and approaches to operations to assist to identify a diverse range of risks and solutions;
- ensuring there are people within the organisation who have a clear understanding of the ‘big picture’ at all times;
- a commitment to resilience, in that the organisation can cope with unexpected dangers by being able to organise itself appropriately at times of increased risk;
- a deference to expertise at times of increased risk, rather than relying on traditional management structures.

After the two helicopters accidents involved in locust control in NSW in October and November 2004, the organisation overseeing these operations has advised the ATSB that it has taken considerable steps towards safer operations by developing more comprehensive safety management systems. The organisation has consulted widely with aviation industry bodies, aerial operators and other government departments and has developed risk controls based on a risk management approach to the entire locust control campaign.

INTRODUCTION

In 2004, there were two wirestrike accidents in New South Wales involving helicopters undertaking locust control operations. The first accident occurred in October 2004 near Forbes and resulted in minor injuries to one occupant and extensive damage to the helicopter. The second accident occurred in November 2004 near Dunedoo and resulted in the death of two occupants. A third occupant was seriously injured and there was extensive damage to the helicopter. A third accident, near Mudgee in November 2004, involved a helicopter that was being used for locust control, although the helicopter was not involved in locust control activities at the time of the accident[16].

The Australian Transport Safety Bureau (ATSB) began formal investigations into all three accidents and a research investigation into the practices used by Government organisations to contract aerial operators for locust control in order to identify issues that may enhance future aviation safety.

This report analyses how organisations that contract aerial operators for locust control can potentially influence the safety of these operations. Further information regarding the specific accidents associated with locust control operations in October and November 2004 is available in the ATSB *Accident and Incident reports* 200404285, 200404286 and 200404590[17].

[16] Appendix 1 contains summaries of these three accidents and four other accidents the ATSB has on record as involving locust control.

[17] This accident is still under investigation at the time of publication of this report. Some preliminary information is available.

METHODLOGY

Scope of the analysis

The focus of the report is on the management of aerial operators by Government organisations that contract aerial operators for locust control. While there are numerous hazards associated with locust control operations, including those associated with chemical application and ground control, the primary concern of this analysis is aviation safety.

Information sources

The information for this report comes from two ATSB investigation reports into helicopter accidents which occurred during the NSW 2004/2005 locust campaign[18], and extensive interviews with locust control organisations throughout Australia and aerial operators involved in locust control.

Application of the analysis

Locust control operations have been presented as a case study, but it is intended that organisations managing other aerial operations with similarities to locust control, such as aerial fire control, other pest management operations, and emergency service operations, may also find the concepts presented in this analysis useful. These kinds of operations, collectively referred to in this report as 'aerial campaigns', are characterised by:

- a significant community need for the operation;
- a requirement for the coordination of significant numbers of resources and organisations;
- a degree of irregularity or unpredictability as to when the operation will be required and the size the operation;
- a requirement for aerial operations with a relatively high hazard level; and
- a regularly changing operational environment throughout the course of the campaign.

[18] *Accident and Incident reports* BO/200404285 and BO/200404286.

AERIAL LOCUST CONTROL IN AUSTRALIA

Locust plagues are a significant problem for agriculture in Australia. Crop damage from locusts can be significant[19]. Aerial control is a significant component of locust control programmes once locust populations reach a high enough level.

Locusts are insects belonging to the same order as grasshoppers and crickets (the Orthoptera). There are a number of species of pest locusts in Australia which occur in different areas and have different behaviour (Australian Plague Locust Commission, 2005a).

All locust species develop in three stages: egg, nymph and adult. The time at which they develop into each stage is dependent on the species. Locust eggs are laid by adult locusts in soil. Locust nymphs hatch from the eggs wingless, but they are able to move along the ground eating vegetation. When the nymph population is high enough, certain plague locust species aggregate into large bands. These bands may extend over several kilometres and can move significant distances each day consuming large numbers of crops and damaging pastures (Australian Plague Locust Commission, 2005a).

The nymph locust develops wings over successive shedding of the skin until it reaches the final adult stage. If the population is large enough, adult locusts form large mobile swarms. A single swarm can extend over a considerable area of land (up to 50 km^2) depending on the environmental and ecological conditions (Australian Plague Locust Commission, 2005a). Swarms usually only move short distances (10 to 15 km) during the day and generally swarm fly at about 10 to 25 metres above ground level. However, adult locusts are capable of migrating long distances overnight with recorded displacements of 500 to 600 kilometres not uncommon. It is this ability to band, swarm and travel large distances which allows locusts to consume large amounts of crops and pasture, and makes them a significant pest for agriculture when the populations are large.

The development of locusts into plague-size populations is dependent on sufficient amounts of rainfall in inland Australia over successive seasons which allows the locust to breed rapidly (Australian Plague Locust Commission, 2005b).

Organisations conducting aerial locust control in Australia

A number of government-funded organisations are involved in locust control activity in Australia.

The Australian Plague Locust Commission (APLC) is tasked to manage locust populations which are considered a significant interstate threat, to assist the States to manage locust outbreaks in their area of responsibility and to seek to improve the effectiveness and safety of locust field operations (Australian Plague Locust Commission, 2005c). The APLC is funded by funds administered by the Australian, New South Wales, Victorian, South Australian and Queensland governments.

[19] A plague in 1984 has been estimated to have cost $5 million with the control measures in place. Without the control measures, the costs would have been $103 million. See Australian Plague Locust Commission (2005) for more information.

Locust control in NSW is undertaken by the New South Wales Department of Primary Industries (DPI), the Rural Lands Protection Boards (RLPBs), APLC and landholders. The DPI is responsible for coordinating ground control state-wide and coordinating aerial control in its area of responsibility (East of the Newell Highway). The APLC is responsible for coordinating aerial control generally west of the Newell Highway. The RLPB's responsibilities for locust control include monitoring and reporting locust outbreaks, organising landholder control of locusts and assisting DPI and APLC with aerial control activities.

Aerial locust control in Queensland is conducted by the APLC and the Queensland Department of Natural Resources and Mines (NRM). The majority of locust control conducted by the NRM is carried out within the boundaries of the Central Highlands. The NRM conducts aerial locust control, but not every year.

Aerial Locust control in South Australia is conducted by the APLC and the South Australian Research and Development Institute (SARDI). SARDI conducts aerial locust control, but not every year, and it is generally limited to between two and four aircraft.

Aerial locust control in Western Australia is conducted by Department of Agriculture; however, locust plagues in Western Australia are relatively infrequent (Australian Plague Locust Commission, 2005a).

Locust control in Victoria is conducted by the APLC and Department of Primary Industries, Victoria (DPI Victoria). DPI Victoria does not conduct aerial mitigation.
Certain locusts species do exist in the Northern Territory; however, the Northern Territory Government do not undertake State-wide aerial control programmes. The APLC is not funded by the Northern Territory Government.

For the purpose of this report, these organisations will be referred to collectively as locust control organisations, although the majority of them have responsibilities in other areas relating to agriculture and natural resources. Locust control – and more particularly, aerial locust control – is only a small component of their business. The exception to this is the APLC, which only works on locust management.

Landholders may apply chemicals on the ground or use privately contracted aerial operators. However, aerial control of locusts by landholders is not considered in this paper.

Aerial control of locusts

The requirement for aerial locust control is determined by the locust control organisations based on criteria such as the population level of the locusts and the potential impact on agriculture. The APLC is the only locust control organisation which normally conducts aerial locust control on an annual basis.
There are two types of aerial operations carried out around Australia as part of locust control programmes: surveying and spraying. Each of these aerial operation types can be conducted using fixed-wing or rotary-wing aircraft or a combination of the types.
Surveying is conducted to establish the numbers of locusts in the area, to identify suitable target areas for spraying, to delimit target boundaries and to identify known hazards for the spray pilot within the target area.

Surveying using fixed-wing or rotary wing aircraft is conducted by most government agencies responsible for locust control in Australia. The aircraft is flown systematically over an altitude generally in the order of 1,500 feet above ground level (AGL) while a dedicated locust spotter in the aircraft searches for locust bands and locust crop and pasture damage. The location of locust bands and damage are recorded for control using spray aircraft and/or for further surveying.

Adult locusts are unlikely to be detected from such altitudes. The procedure followed by many locust control organisations is to fly at lower altitudes, sometimes as low as 10 feet AGL. Helicopters are the more appropriate aircraft for this kind of work. In order to gauge the density of a locust swarm or band and to delimit the infestation boundaries, the survey helicopter may be flown so that the locusts are forced upwards by the downwash from the helicopter rotor, so that they can be seen.

Survey helicopters may be required to land on properties to gain the land owner's permission to spray and to request additional information regarding chemical and aviation hazards. This may include information regarding the location of areas sensitive to spray (eg housing or dams), utility wires (such as power or telecommunications) and other hazards to low-flying aircraft.

When it is determined by the occupants of the survey aircraft that an area requires spraying, a spray aircraft will be called in. The survey aircraft is responsible for providing the spray pilots with the location of the spray area. This information is generally relayed to the spray pilot via radio communications. The survey aircraft may conduct a flight around the perimeter of the spray area to visually indicate the target area boundaries and any hazards to the pilot of the spray aircraft. The spray aircraft may conduct a flight around the perimeter of the spray area while the survey pilot observes to ensure the spray pilot has understood the instructions.

Spraying is generally conducted using fixed-wing aircraft, although rotary-wing aircraft have been employed in NSW by the DPI, and experimentally by the APLC.
Hazard identification is undertaken by the survey aircraft and relayed to the spray pilot by radio. It was unclear from interviews that the ATSB conducted with the locust control organisations and the aerial operators as to whether spray pilots routinely conduct their own independent hazard assessment, although the spray pilot retains responsibility for the safe application of the spray chemicals.

POTENTIAL RISKS ASSOCIATED WITH AERIAL CAMPAIGNS

The current Australian/New Zealand Standard on risk management, AS/NZS 4360:2004 (page 4), defines risk as:

> 'the chance of something happening that will have an impact on objectives.'

Risk is composed of hazards, events, consequences and conditions which cause the presence of the hazard, moderate the likelihood of an event occurring or moderate the consequences of the event.

Risk is measured in terms of the consequences of an event and its likelihood. In terms of the safety of aerial locust control and other aerial campaigns, risk may be measured in terms of the likelihood of an accident occurring and the consequences which result from an accident for people and property.

A hazard is a source of risk (Standards Australia, 2004). Hazards will always exist in any activity involving aircraft; however, with appropriate controls, a high-hazard environment can be managed to be a low-risk environment. Utility wires such as power and telecommunication wires are a major hazard for aerial agricultural operations and other operations involving low-level operations, including aerial locust control. A search of the ATSB aviation accident database returned seven accidents involving locust control activity since 1985[20], six of which were accidents involving a helicopter striking a wire[21].

The characteristics of aerial campaigns, such as aerial locust control, have the potential to increase the risk to aerial operations.

A significant community need for the operation

There is considerable public pressure on government agencies to control locusts due to the potential for damage to crops and pastures. The costs of locust damage are a significant concern for farming communities. This pressure can intensify during certain months when locusts are in their highest numbers.

Significant community pressure on organisations to conduct operations may have the potential to increase risk as organisations focus their energy and resources on completing the tasks without appropriate planning or resources allocated to controlling the hazards.

[20] Appendix 1 contains a summary of these accidents. The appendix includes an accident near Mudgee in which a pilot was repositioning a helicopter in preparation for locust control activities but was not involved in locust control activities at the time of the accident.

[21] These six accidents include the three helicopter accidents that occurred in NSW in 2004 already referred to in the text.

The coordination of resources and organisations

Organisational complexity

The organisational complexity of aerial campaigns and the subsequent coordination effort required may lead to a diffusion of responsibility among the parties involved. The ATSB has in the past identified a diffusion of responsibility among parties involved in similarly complex operations, such as the manufacture of aviation fuel[22] and the management of helicopter emergency medical service operations[23]. The complexity is further increased when staff from different organisations are working together towards a joint outcome.

In a large locust control operation, the spraying of one infested area may involve the locust control organisation, a rotary-wing aerial operator, a fixed-wing aerial operator, the property owner, and other government organisations (rangers and other agricultural organisations frequently provide staff and other assistance in the event of a large locust infestation). The process is normally cooperative and effective, however the lines of management and responsibility for ensuring that the work is being done satisfactorily are often complex. The responsibility for safety may become diffuse and elements of safety management may be lost as no single organisation is cognisant of the whole operation.

Regulatory complexity

The regulation and contractual arrangements involved in campaigns and locust control are relatively complex and may also lead to a diffusion of responsibility for safety.
CASA's task as the aviation regulator is to set and maintain a minimum standard for commercial aviation operations. It can regulate organisations that conduct commercial aviation activities; however, it cannot influence the customer and contractual relationships that may affect the behaviour of an aviation operator. CASA's role can be seen as but one part of a cooperative safety management system for aviation operations.

Under State, Territory and Federal Occupational Health and Safety (OHS) legislation, contracting organisations have 'duty of care' responsibilities to their employees working with contractors. Contracting organisations also have a duty of care to the contractor's employees working within the contracting organisation's workplaces. This duty of care requires these organisations to do everything reasonably practicable to remove or minimise any possible causes of injury and illness to their employees. Similarly, the operator has a duty of care to its employees and the staff of the contracting organisation, and all employees have a similar duty of care to cooperate and participate in safety-related activities.

[22] In January 2000, a large number of piston-engine aircraft were grounded as a consequence of contaminated aviation gasoline. The ATSB investigation revealed that one of the factors which allowed the contamination to occur was that there was a diffusion of responsibility among the various regulatory bodies that oversee the manufacture, quality assurance, supply and use of aviation fuel. It was possible for each one of these bodies to influence the quality of the fuel, but there was no clear delineation of roles and responsibility of the respective regulatory organisations. For further information see (ATSB, 2001).

[23] On 17 October 2003, a Bell 407 helicopter crashed into the sea near Mackay, Queensland while en-route to pick up a patient at Hamilton Island. There were a number of organisations involved in the provision of the emergency medical helicopter service. The investigation found there was a diffusion of responsibility for ensuring safe operations of the emergency medical service helicopter among these organisations. For further information see (ATSB, 2005).

Under State, Territory and Federal regulation, organisations cannot contract out their duty of care. Compliance with the regulatory requirements of CASA by itself does not meet all the requirements associated with Australian OHS legislation.

Irregularity of operations

There is some degree of irregularity in aerial campaigns. The control organisation may be aware that the operation may be required soon, but the exact time of this requirement may not be known.

In the case of locust control operations, the size of the locust population in a season is dependent on a number of environmental factors such as sufficient rainfall in successive seasons (Australian Plague Locust Commission, 2005b). Locust plagues are relatively uncommon. There have been 12 locusts plagues and five major outbreaks of locusts in eastern Australia since 1933 (Australian Plague Locust Commission, 2005b). There may be a significant period between even small-scale aerial operations and they are rarely conducted on such a large scale as the campaign that was conducted in NSW during 2004 and 2005. While the locust population can be forecast, there are time limitations on these forecasts. The irregular nature of campaigns has a number of potential influences on the risks associated with the operation. It reduces the amount of time available for organisations to plan and coordinate control activities.

The opportunities for staff and aerial operators to be involved in these kinds of campaigns are limited. This in turn limits the experience of staff within the control organisations and the aerial operators.

If there is a significant locust population in a season, considerable resources may be required to control the problem. Aerial operators and pilots may be called in from other unaffected areas of Australia, and these operators and pilots will be required to conduct operations outside their immediate area of familiarity. Pilots working in unfamiliar areas have a higher workload, as they need to pay more attention to navigation, the terrain and infrastructure such as utility wires.

Aerial operations with a relatively high hazard level

Aerial campaigns usually require relatively hazardous aerial operations often involving low-level flying. Locust spotting has routinely involved low-level flying in order to see the locust swarms and to record their location and density. In circumstances where the spotters believe there are adult locusts in vegetation, helicopter rotor wash may be used to ‘flush’ the locusts into the air to provide some indication of density. Low-level operations are inherently more hazardous than higher-level flying as:

- there are a greater number of obstacles, including vegetation, the terrain, utility wires, and other man made structures, for the helicopter to avoid;
- in the event of an emergency situation, such as loss of aircraft control, the pilot has significantly less time to regain control of the situation before contacting the ground; and
- pilots have a higher workload at low levels, as they must negotiate the hazardous environment in addition to their normal workload.

Low-level flying is normally prohibited by regulation except for times when it is necessary, such as take-off and landing[24]. Where there is an operational need for low-level flying, operators may apply to CASA for an exception from the regulations, and alternative risk controls are required to decrease risk. The controls include formal pilot training in the extra skills required to operate safely at low level, and extra procedures required to identify and avoid the hazards.

Rotary-wing survey aircraft are required to land on agricultural properties on unsurveyed landing sites to obtain the permission of the land holder to spray the locusts and to discuss any aviation or chemical hazards on the property. Although helicopters can land at unprepared sites, there are potentially a greater number of hazards to avoid than at a designated landing site, and regular operations of this nature increase the risk of collision without appropriate mitigating procedures.

Changing environment

Aerial campaigns are characterised by an environment that can change rapidly. Unlike airline operations with set operations conducted on a regular basis and planned well in advance, each flight in a campaign operation is likely to be unique as the problem changes in magnitude or position. Pilots and control organisation staff face novel situations on a regular basis. These kinds of operations reduce the time available for pre-flight planning and in-flight hazard assessment and reduce the effectiveness of generic risk management systems.

The ability of locusts to increase in population rapidly and travel large distances may result in a constantly changing campaign environment. Control activities must be carried out in a number of environments with varying terrain and human population as locusts move through different areas. An area with higher human population levels will tend to have more infrastructure and subsequently a greater number of wires in the flying area, while terrain with a greater variation in elevation increases the risk of controlled flight into terrain (CFIT) accidents.

[24] Civil Aviation Regulations 1988, Regulation 157.

ORGANISATIONAL INFLUENCES ON AVIATION SAFETY

Modern theories of accident causation recognise that accidents have many causes involving people at different levels within an organisation (Reason, 1990) (Reason, 1997). James Reason's model of organisational accidents[25] proposes that this accident type has its origins in the strategic decisions and organisational processes of the organisation, such as budgeting, auditing, planning, scheduling and managing[26]. These processes, combined with a natural tendency for human error and human violations to be committed by individuals at the operational end of an organisation, may result in an accident (Reason, 1997).

Organisations are protected from hazards by a series of controls or defences. Defences reduce risk in a number of different ways, including by containing or limiting hazards, by providing alarms and warnings of imminent danger, by providing guidance on how to operate safely and by creating and understanding an awareness of the local hazards (Reason, 1990, 1997). Defences exist at multiple levels in complex systems within an organisation (Reason, 1990, 1997). They reduce the risk that an error by one or two people may result in the failure of a system, as other system defences capture the error before it creates an unacceptable situation. The effectiveness of defences in preventing hazards from being realised is influenced by organisational factors.

There are numerous examples of investigations into accidents or incidents in aviation and other industries which have led to identification of systemic problems within an organisation that may have contributed to the incident or accident[27].

It is likely that the immediate precursor to many wirestrike accidents involving low-level operations has been that the pilot did not see the utility wire, or had seen the wire but had forgotten about it. The pilot provides one level of defence against wirestrike accidents. However, it is unrealistic to expect a single pilot to see every wire or keep every wire in their memory at all times while at the same time control an aircraft at low-level, and conduct other tasks associated with the operation. Other defences may be provided by the organisations supporting the pilot such as:

- the pilot's employer, providing operating procedures, training, equipment;
- the contracting organisation, providing task allocation based on risk assessments by suitably knowledgeable staff;
- CASA, providing appropriate regulatory requirements for low level aircraft operations; and
- and the landowner, providing information about the local area and hazards.

[25] More information on Reason's model of organisational accidents is contained in (Reason, 1990, 1997).
[26] While organisations themselves are influenced by other organisations, regulation and society in general, for practicability, Reason's model is confined to the boundaries of the organisation.
[27] Appendix 2 contains examples of accidents identified by the ATSB as involving organisational elements.

How can an organisation contracting an aerial operator potentially influence the safety of aerial operations?

Locust control organisations:

- are responsible for selecting and obtaining the services of the aerial operator;
- are responsible for tasking the operator;
- are responsible for briefing the pilot and operator at the beginning of the day and throughout the operation;
- are responsible for components of ground support; and
- may often have staff on board the contracting aircraft.

Locust control organisations are involved in the management of significant parts of the aerial campaign. Decisions made in the management processes therefore have the capacity to influence the campaign's safety. If safety is to be maintained, that capacity must be monitored and managed: leaving responsibility for safety to another party that is not managing the overall campaign will not be effective.

Contract selection and management

Tendering documentation and contract specification

The criteria for the selection of operators have the potential to influence aviation safety by defining:

- flight crew and operator experience;
- the nature of the performance measures that will drive the contract;
- the nature and quality of any safety management system or occupational health and safety systems required of the contractor; and
- the types of equipment used.

The effective development of appropriate selection criteria may be difficult if there is limited aviation knowledge within an organisation. The aviation industry is relatively complex in that it is has components that are highly regulated and highly technical. In addition, aerial agriculture and rotary-wing aircraft industries have a relatively large range of operators, ranging from small businesses to large organisations. All these businesses have different areas of expertise and use different safety management systems and aircraft, making it difficult for the controlling organisation to compare them.

If an organisation uses the same selection criteria when contracting aerial operators for different task types, such as fire fighting or mammal pest management, then there is a risk that the criteria may be inappropriate for the task.

Evaluation of the selection criteria

Risk can be introduced if the selection criteria are not checked throughout the campaign. As the campaign progresses, possibly with increasing intensity, new operators and pilots may be brought in. In the case of an accident involving a locust spotting helicopter striking a wire near Forbes in October 2004, the pilot provided by the operator did not have the experience required by the contractor in the original tendering documentation. The locust control organisation did not ensure the pilot complied with the requirements of the original tendering document. There were no formal audits of contracted aerial operators conducted by the locust control organisation prior to the accident. While the investigation could not determine the direct influence of this factor on the accident, it did result in the placing of employees in potentially higher-risk environments. Without proper evaluation and audit of the aerial operators against the criteria specified in the tendering and contract documentation, the criteria are not effectively mitigating any risk.
Selection criteria need to be set to balance the needs for suitably competent staff with the need to be able to employ sufficient pilots and to enable pilots to become additional risk controls must be considered to mitigate the increased risk.

The management of operations throughout the campaign period

Briefing and tasking

The controlling organisation is involved in briefing and tasking of the aerial operators and is therefore directly involved in placing the aircraft in a particular work environment. This is a potential area of risk as the contracting organisation has an element of financial control over the operator. However, locust control organisations did state that the final decision for conducting an operation was always the pilot's. This was generally written into locust control organisation operating procedures, and many operators stated there was no undue pressure placed on them by the contracting organisation to complete a task.

Pre-flight planning and general briefing is an opportunity for pilots and staff to set the objectives of a flight, share ideas on how the operation is going, identify any problems, plan operations and discuss any common hazards.

Operating procedures

The absence, deficiency or inappropriateness of operating procedures for operators may increase the risk to aviation safety.

The absence of standardised procedures means there may be considerable differences in the techniques used by different operators and contracting organisation staff to conduct tasks. Processes that are used to accomplish a particular task will evolve through a process of experience and passing on this information, often by word of mouth. There will be inconsistencies in how the task is accomplished, as different staff and operators will have differing levels of competence and experience, and different solutions to the same problem will have naturally evolved. The organisation that is managing the operation in such an uncontrolled environment will not be in full control or fully aware of how its tasks are being accomplished and therefore will have less control over the safety of the operation.

On the other hand, while operating procedures encourage consistency and control of a process, this does not guarantee that they reflect the safest way to conduct that activity. For example, in the recent NSW locust management campaign, the procedures used by aerial operators with limited experience of locust management operations were provided by the contracting locust control organisation. One helicopter company manager informed the ATSB that the company's pilots learnt the technique of flushing the locusts directly from locust control staff and the contracting organisation's operating procedures. The text contained in the operating procedures read:

> 'When looking for adults, the helicopter should fly along tree and creek lines and in localised areas of green vegetation approximately 12 ft (3 m) above ground level and at 30 knots (60 km/h). Locusts adults will flush-up ahead, to the side or behind the helicopter. If the weather is cool or very windy, adult locusts will be difficult to see. Warm, sunny days with wind of less than 3 m/s are ideal for survey work.'

There was no mention in the operating procedures for planning the task, for assessing risk, for assigning tasks among crew to minimise risk or of operational limitations to manage the risks associated with this task. This text has since been removed from the operating procedures and the locust control organisation no longer uses this procedure.

Procedures can also introduce risk by being inappropriate for the task at hand. Overly restrictive procedures may prevent the task being completed and are more likely to result in the rules being broken.

Procedures that are not constantly reviewed and re-evaluated by their controlling organisation may not prove to be an effective risk control in a dynamic operating environment. In the case described above, the locust control organisation did conduct a substantial evaluation and modification of their risk mitigation strategies.

The contracting organisation staff

Management staff

Management staff are responsible for making the high level decisions which set the context of the operation. If management prioritise safety and ensure this is reflected in the processes of the organisation, then this will influence staff throughout the organisation as well as contractors and staff of other involved organisations.

Operational staff

Operational contracting organisation staff can influence the safety of an aerial operation as they are normally directly involved. In the case of locust control, operational locust control staff are responsible for tasking the operators, providing ground support and often fly in the survey aircraft for spotting purposes.

The risk to aviation safety may be increased by inappropriate management of staff who fly on aircraft. Exposing greater numbers of staff to aerial hazards increases the risk to the organisation; therefore risk may be reduced by only allowing essential staff on the helicopters. Some operators suggested to the ATSB that during the recent NSW locust control programme, the excitement of working in a helicopter, in addition to a financial incentive, caused many staff in the locust control organisations to be eager to be involved in helicopter work. There were four locust control staff on board the helicopter which crashed near Forbes in 2004. According to the locust control organisations standard operating procedures, all staff were required to have written approval and appropriate training and experience in detecting bands and directing spray aircraft. In the case of the Forbes accident, no written records were produced to indicate that this was the case. There was no indication of a consistent risk-based procedure for determining flight crew tasking.

There was an inconsistent perception by the helicopter operators of the roles of the occupants in the Forbes NSW helicopter crash in November 2004. Prior to the accident, the pilot had requested all occupants of the helicopter (a ranger in the front and two locust spotters in the back) to look out for power cables and other potential hazards around the landing site. One spotter reported understanding that a cable should not be reported unless it was felt the pilot had not seen the cable. It is not clear what the understanding of the other spotter was with regard to hazard spotting. Neither spotter reported the presence of any power cables. One spotter had some limited experience in survey flights and some brief training courses, but no on-the-job or practical training. The other spotter had been in a helicopter on one occasion prior to the accident flight and had no training in regard to the campaign or helicopter operations. The potentially different perceptions of roles by individuals in the helicopter increased the risk that a pilot might not be made aware of a wire threat by another crew member.

Management staff within most locust control organisations appeared to be aware of an informal hazard spotting role among their spotters; however, the extent of this role varied. This could lead to an inconsistent understanding among spotters and pilots regarding the spotters' role. Operators were also unclear about the extent to which locust control organisation staff had a locust spotting role. Many stated they had variable experiences with spotting staff and most stated their pilots would not rely on the spotters for hazard spotting.

CONCEPTS FOR ENHANCING THE SAFETY OF CAMPAIGNS

There are a number of safety management concepts that have been developed from accident investigations and from studying high reliability organisations (HROs)[28] that may assist agencies involved in aerial campaigns to further reduce the risk to the organisation and their staff.

Integrated and flexible risk management practices

Major aviation accident and incident investigations in Australia have frequently identified organisational deficiencies in the aviation system surrounding an accident. These deficiencies are usually incorporated during a change, often years before the accident and are difficult to identify (Reason, 1997). Examples of these kinds of accidents and incidents can be found in Appendix 2.

Many aviation organisations use documented procedures as a tool to manage risk. Documented procedures can reduce risk by making operations more consistent, thereby reducing the opportunity for unplanned changes in the procedures associated with an activity. However, aerial campaigns are more dynamic than many other types of aerial operations. Reliance on a standard set of risk controls is likely to incorporate irrelevant requirements which are likely to be ignored or subverted, or unnecessarily reduce the effectiveness of the operation. They may also give an inappropriate sense of security to those involved and lead to a false perception of safety. Campaign risks may be better managed by a system that actively seeks and manages risk throughout all design, management and implementation processes. A risk management system that is integrated into all processes also signals to operators and staff involved in the campaign that there is an ongoing commitment to safety by the contracting organisation.

An important component of the risk management process is to monitor and review the process on an ongoing basis[29]. The organisational culture necessary to maintain a high degree of reliability in complex technical and organisational operations was described in the ATSB investigation report BS/20010005, which examined the management of maintenance at Ansett Airlines leading up to the grounding of its Boeing 767 fleet. It describes the need for an organisation to constantly review how its activities are measuring up against the achievement of its objectives.

Clearly defined responsibilities for safety

Aerial campaigns are potentially high risk, and technically and organisationally complex. A significant potential exists for the requirements of one aspect of the operation to adversely affect another aspect of the operation. Each part of the operation (such as aircraft operation, chemical management and ground support for obtaining permission to spray) can manage its own tasks. For example, in the case of aerial operations, a safety management system is required by the Civil Aviation Safety Authority (CASA) for the aircraft operator. However,

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[28] High Reliability Organisations operate in difficult environments with relatively few accidents (Weick & Sutcliffe, 2001).

[29] The *Australian/New Zealand Standard Risk Management* AS/NZS 4360:2004 and the corresponding guidelines (HB 436:2004) provide an overview of the risk management process.

this system only encompasses the operation of the aircraft by that operator and does not include other elements that have the potential to affect the safety of the operation such as the tasking of the operator. An effective overall management system can ensure that no one aspect of the operation compromises another aspect.

The relative infrequency of some campaigns and the occasional requirement for large numbers of operators means that operational experience of the campaign will normally reside within the contracting organisations. The effectiveness of this process will be enhanced by good information sharing among operators and the locust control organisations. Campaign control organisations are in the best position to facilitate this by seeking external expertise, by monitoring the effectiveness of procedures and modifying them if necessary, by encouraging information sharing through regular operator briefings and by encouraging and formalising feedback processes from operators and their staff on the operations.

Confidence in the safety of the entire operation can be enhanced by a system which manages all the influences that can affect the outcome of the operation and this function can normally be best accomplished by the organisation that is responsible for initiating the operation.

Organisational mindfulness

Organisational mindfulness is a concept proposed by Weick and Sutcliffe (Weick & Sutcliffe, 2001) to help understand the success of HROs. HROs rarely fail to achieve their objectives despite encountering numerous unexpected events. These organisations 'organise themselves in such a way they are better able to notice the unexpected in the making and halt its development.' (Weick & Sutcliffe, 2001). Weick, Sutcliffe, and Obstfeld (1999) outline five processes that characterise organisational mindfulness[30]:

- 'a preoccupation with failure';
- reluctance to simplify interpretations;
- sensitivity to operations;
- commitment to resilience; and
- deference to expertise.

'A preoccupation with failure' describes a mindset in which an organisation recognises that failures, no matter how minor, provide the opportunity to learn about potential disasters. The organisation treats every failure as a symptom of something wrong with the system. It requires an organisation to encourage the reporting of safety-related incidents, consider their potential impact and modify procedures accordingly.

HROs are reluctant to simplify interpretations in that they use complex systems to manage a complex environment and encourage diverse views and approaches to operations. An application of this is to encourage the sharing of information among all involved, from managers to operational staff, and involve these parties in the risk management processes. This may assist in developing a diverse range of opinions and in identifying potential risks that may not be identified by only one area of an organisation.

[30] A similar concept to organizational mindfulness has been described as 'chronic unease' (Reason, 1997).

HROs are sensitive to operations in that they ensure that someone in the organisation has a clear understanding of the 'big picture' of operations at all times. For example, organisations that are sensitive to operations will have managers who have a clear understanding of the functioning of line operations at all times. Managers may gain greater sensitivity to operations by encouraging operational staff to report to management on the progress of the operations towards meeting their objectives.

HROs have resilience in that they recognise that no system is perfect and are committed to ensuring that the organisation can cope with unexpected dangers. These organisations are not derailed by errors and are able to organise themselves in ways that enable them to deal with errors (Hopkins, 2005). In particular, HROs do not rely on hierarchical structures, particularly in problem solving, when experience and expertise become more important than rank in the management hierarchy. At critical times these organisations consult widely and hunt out the required expert. This type of approach requires open communication among all staff and operators involved in an operation.

CONCLUSIONS

Aerial campaigns such as aerial locust control operations are conducted in relatively hazardous environments that also have the potential to be high-risk environments. Campaign control organisations are directly involved in numerous aspects of the aerial component of these campaigns and can increase or decrease the risk of these operations.

While the aerial component of the operation is provided by an aerial contractor, the campaign control organisation is in a central position to understand the big picture. The adoption of good systems for managing risk by the contracting organisation can provide an effective additional layer of defences over and above that provided by each operator to protect against an incident or accident.

Many complex organisations operating in a hazardous environment, such as major public air transport companies, recognise the influence they have on safety. While they may subcontract many safety-critical aspects of their operations these organisations still maintain an interest in the safety of these operations and proactively manage safety beyond what is required by regulation. Similar methods can be effective for mitigating risk in aerial campaigns.

The focus of this paper is on aviation safety, but it is recognised that there are hazards in other components of a campaign. For example, in the case of locust, there are hazards associated with ground vehicles and chemical application. However, risk management processes can guide the organisation towards the lowest risk solution to a problem if they are integrated into all aspects of an operation.

After the two helicopters accidents involved in locust control in NSW in October and November 2004, the organisation overseeing these operations has advised the ATSB that it has taken considerable steps towards safer operations by developing more comprehensive safety management systems. The organisation has consulted widely with aviation industry bodies, aerial operators and other government departments and has developed risk controls based on a risk management approach to the entire locust control campaign.
At the time of publication of this research paper, the ATSB has released investigation reports for the Mudgee (BO/200404285) and Forbes (BO/200404286) accidents. The fatal accident in Dunedoo (BO/200404590) is still under investigation. The ATSB is also conducting further research into wire strike accidents. The results of this research will be released in the second half of 2005.

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APPENDIX 1- ACCIDENTS INVOLVING LOCUST CONTROL

The following accidents have been recorded by the ATSB as involving locust control activity.

ATSB Occurrence number: 198700756
Date of incident: 10/12/1987
Location: Near JAMESTOWN, SA
Accident summary: A helicopter crashed after striking a wire while engaged in low level locust survey operation. Two occupants were fatally injured.

ATSB Occurrence number: 199300124
Date of incident: 27/01/1993
Location: 5km E Menindee, NSW
Accident summary: A helicopter crashed after engine power loss due to fuel exhaustion while engaged in a locust survey operation. The accident did not result in any injuries.

ATSB Occurrence number: 199703877
Date of incident: 27/11/1997
Location: 7.5km SW Orroroo, SA
Accident summary: A helicopter crashed after striking a wire while engaged in locust control operations. The two occupants were fatally injured.

ATSB Occurrence number: 200005357
Date of incident: 16/11/2000
Location: Jerramungup, WA
Summary: A helicopter crashed after striking a wire while engaged in locust control operations. The pilot was fatally injured.

ATSB Occurrence number: 200404285
Date of incident: 30/10/2004
Location: Forbes, NSW
Summary: A helicopter crashed after striking a wire while engaged in locust control operations. One occupant sustained minor injuries.

ATSB Occurrence number: 200404286
Date of incident: 1/11/2004
Location: Mudgee, Aerodrome, NSW
Summary: A helicopter crashed after striking a wire while re-positioning in preparation for locust control operations. The helicopter was not engaged in locust control activities at the time. The pilot sustained minor injuries.

ATSB Occurrence number: 200404590
Date of incident: 22/11/2004
Location: 12km SW Dunedoo, NSW
Summary: A helicopter crashed after striking a wire while engaged in locust survey operations. The pilot and one passenger were fatally injured and one passenger sustained serious injuries. The investigation is continuing at the time of publication of this report.

APPENDIX 2- AUSTRALIAN ACCIDENTS AND INCIDENTS INVOLVING ORGANISATIONAL FACTORS

Examples of Australian accidents and incidents involving organisational factors investigated by the ATSB include:

Report number: BO/199403038
Boeing 747 landing with nose wheel not locked down, Sydney, NSW.
On 19 October 1994, Boeing 747 VH-INH landed at Sydney without its nose landing gear locked down. The operating company had recently introduced this aircraft type. While the processes for training staff and developing operating procedures had been conducted, the actual process had been rushed, and delays had been absorbed by compressing the change programme. Workarounds were used when parts of the process were not working properly, so that although all the induction and change procedures had been completed, no one was reviewing the whole change procedure to ensure that it was achieving its desired objective. The organisation was not monitoring the change process to ensure that it was effectively achieving all the necessary tasks to ensure consistent and safe operations when the aircraft type was introduced to service.

Report number: B98/166
G airspace demonstration implementation.
In October 1998, a trial of a new airspace structure was developed in one area of Australia. A Bureau of Air Safety Investigation (BASI) report found that the purpose of the airspace change was not clearly defined, so there was no common understanding against which the effectiveness of the change could be measured. There were inadequate established processes for managing such a complex change, and the change agent did not have appropriate resources to monitor and control its activities during the change process. The review mechanisms that were incorporated into the change process were not appropriate to the review needs during the design and implementation of the airspace changes, and the review mechanisms were not independent from the process they were reviewing.

Report number: Not available
Aviation Gasoline contamination
Just before Christmas 1999, the supply of aviation gasoline (Avgas) from a major refinery was inadvertently contaminated with a chemical that made aircraft engines unreliable. The change to the use of this chemical in the refining process was initiated some eight years earlier to increase the efficiency of the process. The undesired outcomes from an inadvertent contamination with this chemical were not investigated, nor were the circumstances when a contamination would be likely. The change process examined the desired outcomes thoroughly, but missed the risks associated with some of the undesired outcomes.

Report number: BO/199904538
Boeing 747 over ran the end of a runway, Bangkok, Thailand.
On 23 September 1999, a Boeing 747 overran the end of the runway at Bangkok International Airport at some speed. A number of factors combined to increase the probability of the overrun event. One factor was a change to the normal landing configuration for this aircraft type that had been implemented in 1996. The change increased the efficiency of the operation in a number of ways, and reduced the cost of the operation. A proper risk assessment of the new procedure was not undertaken. There were also significant deficiencies in the manner in which the company implemented and evaluated the new procedures associated with this change in landing configuration.

Report number: BS/20010005
Ansett's maintenance of continuing airworthiness in Class A aircraft
In December 2000 and April 2001, Ansett Australia elected to ground its fleet of Boeing 767 aircraft, because it was not confident that it knew that all necessary maintenance had been done. It had lost control of the information systems necessary to ensure that all necessary maintenance was being done at the right time. The organisation had become very complex with many different aircraft types, and frequent partial changes of ownership changing the commercial focus of the airline. The information management support that was necessary to control the information needed to design the maintenance systems was not changed to reflect the needs associated with the increasing complexity. In this case the supporting infrastructure was not given the same budgetary priorities as the visible front of the organisational changes. The organisation finally became aware that it did not know what it did not know, and therefore lost confidence in its own system