Australian Government

Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY REPORT
Aviation Occurrence Investigation
AO-2008-084
Final

In-flight breakup PZL M18A Dromader, VH-IGT 58 km SW of Nyngan, NSW 29 December 2008

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CONTENTS

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Prepared By

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Abstract

On 29 December 2008, at about 1145 Eastern Daylight-saving Time, a PZL-M18A Dromader (TPE331) aircraft, registered VH-IGT, took off from a road on a property 58 km south-west of Nyngan, New South Wales to conduct agricultural spraying operations. About 10 minutes later, the aircraft was seen flying back towards the road when a witness saw something fall off the aircraft, and reported that the aircraft then rolled and impacted the ground. The pilot, who was the sole occupant, was fatally injured.

The investigation found that the outboard 1.8 m of the right wing separated from the aircraft resulting in a loss of control and subsequent impact with the terrain. The separation of the right wing section could not be conclusively attributed to any particular factor.

During the course of the investigation, it was determined that a number of operators of the aircraft type were not applying the appropriate service life factors to determine the effective hours flown when their aircraft were operated at take-off weights above 4,700 kg. The effect was to overestimate the remaining service life of those aircraft.

It was also found that operators had an interpretation of the Civil Aviation Safety Authority (CASA) exemptions that, by their understanding, permitted operation at weights in excess of the maximum take-off weight and allowed them to operate at higher take-off weights without the need to account for the additional limitation imposed by the manufacturer for operation at those weights.

As a result of the accident, the following safety action has been taken or proposed:

- The operator undertook a retrospective process of applying the service life factors to its aircraft fleet during operations that had involved take-off weights above 4,700 kg and will apply them to all relevant future flights.
- CASA advised that they had contacted Certificate of Registration holders of M18 Dromader aircraft to verify that they had a procedure for recording and factoring aircraft hours that included overweight operations. Further verification would also occur as part of CASA's routine surveillance program. CASA also advised that they will provide education to operators on the intention of the exemptions and will be revising the exemptions to ensure that the intended interpretation is clear.

THE AUSTRALIAN TRANSPORT SAFETY BUREAU

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

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

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

Purpose of safety investigations

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

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

Developing safety action

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

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

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

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

TERMINOLOGY USED IN THIS REPORT

Occurrence: accident or incident.

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

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

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

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

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

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

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

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

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

FACTUAL INFORMATION

History of the flight

On 29 December 2008, at about 1147 Eastern Daylight-saving Time[1], a PZL M18A Dromader aircraft, registered VH-IGT (IGT), took off from a road on a property 58 km south-west of Nyngan, New South Wales (NSW) to conduct agricultural spraying operations.

About 5½ minutes later, two witnesses who were located at the property homestead saw the aircraft fly over the area towards the north-west. One of the witnesses reported that, after hearing the aircraft fly over the homestead about three times, they went outside to watch. That witness stated that the aircraft 'looked like it had a broken wing', and 'was flapping around swinging side-to-side, waving up and down'. The other witness reported seeing something 'like a little white speck' fall off the aircraft and the aircraft spinning quickly before hitting the ground.

The pilot, who was the sole occupant, was fatally injured and the aircraft sustained serious damage.[2] Subsequently, a 1.8 m section of the aircraft's right wing was located at the beginning of the aircraft wreckage trail, about 100 m from the main wreckage.

Prior to the flight, the pilot had conducted a spraying operation in the aircraft at another location. Based on recorded SATLOC data,[3] the pilot commenced that operation at about 0715 when he departed Trangie Airport, NSW. During that operation, he returned to the airport twice to replenish the aircraft's spray load. At about 1057, the pilot left that application area[4] and flew to the property near Nyngan, landing at about 1125.

After landing at the property near Nyngan, the pilot was met by the loader and the aircraft was loaded with a mix of herbicide chemicals and water. The recorded SATLOC data showed that the aircraft took off from a nearby road at 1147:00 and made a number of passes over the application area (Figure 1).

The recording showed that the aircraft passed roughly along the western boundary of the area and made a left turn before making a pass up the eastern boundary whilst spraying. The pilot then made a 180° procedure turn[5] to the left and flew back along

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1 Eastern Daylight-*saving* Time was Coordinated Universal Time (UTC) + 11 hours.

2 The *Transport Safety Investigation Regulations 2003* definition of 'serious damage' includes the destruction of the transport vehicle.

3 The aircraft was fitted with a satellite-based system to provide guidance for the aerial spraying operation (SATLOC system). The system recorded a range of information that included the aircraft's location, altitude, and spraying information. Refer to the section titled *Satellite navigation/guidance system* (page 13) for more information.

4 An application area is the field where the aerial spraying was to occur.

5 A manoeuvre at the end of a spray run to reverse the direction of flight and align the aircraft for the next spray run in a reciprocal direction.

roughly the eastern boundary, only making a short spray application at the start of the run.

The next run was a spray run along the western boundary, where the pilot set the first two reference points (A and B) that were used by the SATLOC system to define the application area.[6] During that run, the pilot stopped spraying and climbed over a lone tree and then a group of trees that surrounded a dam. At the end of that run, a 180° turn was made, point C entered into the SATLOC system and a spray run made that was parallel to the western boundary. After completing that run, and while conducting a right turn, the track data ended.

The last data point (X) was recorded at 1152:30, an altitude of 973 ft above mean sea level (AMSL) (about 210 ft above ground level) and was about 3.5 km south of the accident site. A three-dimensional representation of the application area and SATLOC track is at Figure 2.

Personnel information

The pilot's qualifications and aeronautical experience is outlined in Table 1.

Table 1: Pilot in command

Type of licence	Commercial Pilot (Aeroplane) Licence Issued 1 November 1990
Aviation Medical Certificate	Class 1, valid until 19 October 2009 (No restrictions)
Ratings	Agricultural Grade 1, issued 2 March 1997
Endorsements	M18 Dromader (TPE331), issued 25 February 2000; Ayres S2R-T Thrush and Air Tractor AT-602, issued 3 March 1997
Flying experience (total hours)	About 6,500[7]
Hours on type	About 3,000[7]
Aeroplane Flight Review	23 August 2008

The pilot was off duty on the 4 days prior to the accident. On the day of the accident, the aircraft loader[8] described the pilot as displaying normal behaviour. A post-mortem medical examination and toxicology report for the pilot did not identify any physiological event or condition that may have contributed to the accident.

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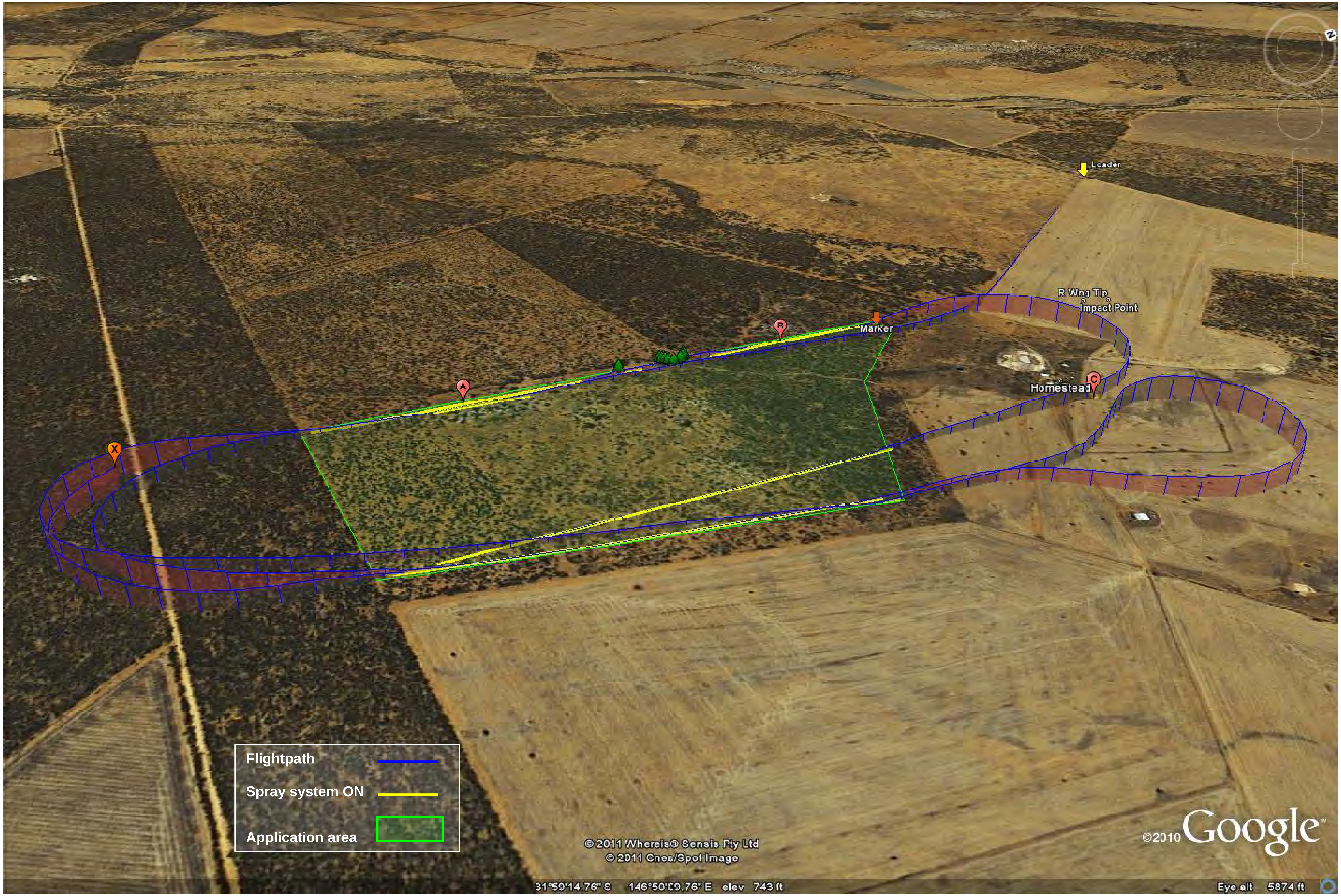
6 The SATLOC system defined a rectangular pattern based upon three points. Points A and B defined the direction of the spray run, and point C defined the width of the area.

7 The last entry recorded in the pilot's logbook was on 3 September 2008.

8 The aircraft loader was responsible for refuelling the aircraft and loading the application product on instruction by the pilot.

Figure 1: Recorded aircraft track with the application area and the last recorded data point (point X) indicated

Figure 2: Recorded aircraft track – 3-dimensional view showing relative heights above the ground



Pilot endorsement on the M18A Dromader (TPE331)

The aircraft operator's pilot training records included a *Single Engine Turbo-Prop Aeroplane Endorsement - Engineering, Data and Performance Questionnaire* for the PZL M18A (TPE331), dated 25 February 2000. The questionnaire was published by the Civil Aviation Safety Authority (CASA) to assist the person conducting the endorsement to determine whether a candidate satisfied the requirements for the issue of a class endorsement[9]. The questionnaire was designed to demonstrate that a candidate had undertaken:

> ...training in the operating limitations, procedures and systems of the type of aeroplane for which the endorsement is sought...

In that questionnaire, the pilot of IGT had correctly answered questions relating to the maximum weights and speed limitations contained in the aircraft's flight manual and applicable flight manual supplements.[10]

Other than as noted below, the pilot's training records did not contain any specific reference to operating the M-18A aircraft at weights greater than the normal maximum take-off weight, nor was there a requirement to do so.

On 11 November 2008, in accordance with the requirements of CASA Exemption EX75/08, and the corresponding Flight Manual Supplement *207/403/FMS, PZL M18, Dromader Restricted Category STC – MTOW Increase*,[11] the pilot was assessed by the chief pilot as being competent to conduct operations in M18A Dromader aircraft at take-off weights above 5,300 kg. The chief pilot was also the aircraft owner and operator.

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9 Civil Aviation Order 40.1.0 sub-section 7 1(a).

10 An aircraft flight manual supplement provides information specific to a modification or particular operation of the aircraft. The supplement provides information that is different or additional to the basic aircraft flight manual.

11 The applicable flight manual supplement at the time of the accident, issued on 3 October 2008.

Aircraft information

A summary of the general aircraft and engine information is at Tables 2 and 3 respectively.

Table 2: General aircraft information

Manufacturer	PZL Mielec
Model	M18A Dromader
Serial number	1Z016-27
Registration	VH-IGT
Year of manufacture	1986
Certificate of airworthiness	Issued 8 November 2005
Certificate of registration	Issued 8 June 2005. Restricted Category[12]
Maintenance release	Airwork Agricultural category issued 12 December 2008. Valid to 6,378.8 hours / 12 December 2009
Total airframe hours	About 6,121[13]
Total wing hours	About 4,214[13]

Table 3: Engine information

Manufacturer	Garrett
Model	TPE331-11U-612G
Serial number	P44723C
Time since overhaul	About1,300[13]
Total time in service	About 13,375[13]

Aircraft description

The M18A Dromader was a single-engine, special purpose aircraft that was used for agricultural operations or aerial fire-fighting (Figure 3). The aircraft was a low-wing, tailwheel-configured, fixed-landing gear design. The fuselage had a welded steel frame structure and the wings and tail assembly were of a stressed-skin aluminium alloy construction.

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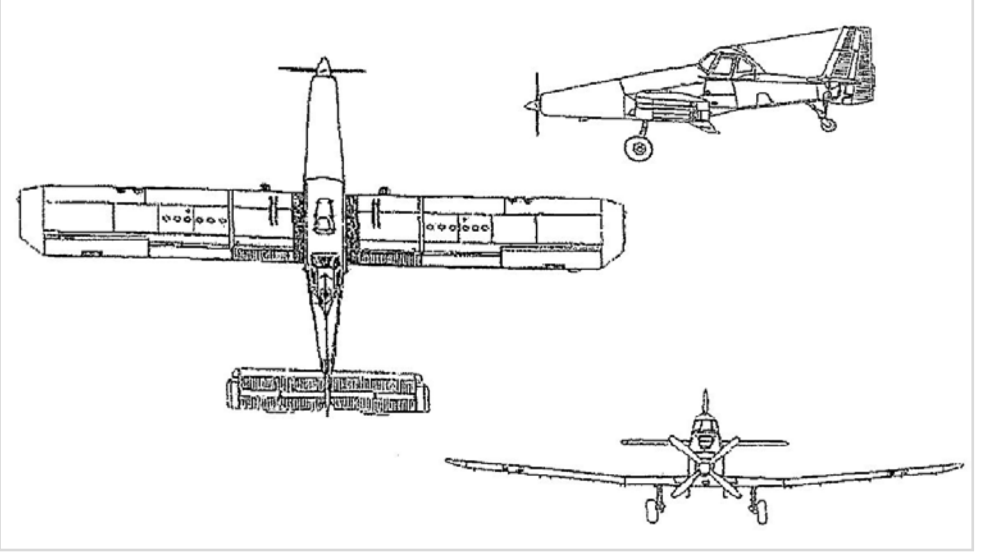
12 For the purpose of agricultural and fire-fighting operations.

13 The time in service since the last maintenance could not be determined as the maintenance release that was current at the time of the accident was not located in the wreckage.

The original type-certified aircraft had a 9-cylinder, supercharged, radial engine, developing 967 shaft horsepower. In more recent years, modifications have incorporated more powerful turboprop engines. One such modification, which was approved under United States (US) Federal Aviation Administration (FAA) Supplemental Type Certificate (STC) number SA09039SC, used a Garrett model TPE331 turboprop engine. As a result of the engine change, the modification increased the length of the aircraft's forward fuselage. After the incorporation of that modification, the aircraft was designated an M18A Dromader (TPE331).

Figure 3: Aircraft 3-view diagram



Note: IGT was fitted with a 5-bladed propeller.

Aircraft history

The aircraft was manufactured in Poland in 1987. Its history from manufacture until 2004 was unclear, but at some point during that time it was exported to the US. In 2004, it was imported into Australia from the US in a damaged condition. The operator's aircraft maintenance engineer reported that the damage was due to a landing accident and that there was damage to the wings and the tail fin.

The wings were replaced with serviceable wings from another M18A Dromader aircraft that was also imported from the US at about the same time. When installed on IGT, the wings had a total time in service of 3,031.4 hours. The other damage to IGT was repaired and the aircraft was issued with a Certificate of Airworthiness.

The US aircraft maintenance documentation for IGT and the other aircraft, from which the wings were sourced, could not be located. It was therefore not possible to review the maintenance history of the aircraft or the wings prior to them being imported into Australia.

Aircraft modifications

In 2005, significant modifications were made to IGT by the operator. One of those modifications was the replacement of the original radial piston engine and the 4-blade propeller with a Garrett TPE 331-11U-612G turboprop engine and a Hartzell 5-blade constant speed propeller. Those modifications were carried out in accordance with FAA STC SA09039SC, and were completed on 5 November 2005.

Other modifications to the aircraft included increasing the capacity of the hopper from 2,650 L to 3,028 L, the installation of servo tabs[14] to the flight controls, and installation of vortex generators on the wings. The vortex generator manufacturer claimed that the installation resulted in a 7% reduction in the aircraft's aerodynamic stall speed.

All of the modifications were carried out in accordance with FAA STCs and/or Australian Civil Aviation Regulation (CAR) 35-approved engineering orders.

An optional PZL Service Bulletin No E/K/02.158/96, titled *Conversion/Modification of Models M18 and M18A into M18B,* could be applied to an M18A Dromader aircraft to convert it to the M18B variant. That modification included the installation of a '*...Conversion Data Plate on the cockpit rear wall, near the existing Data Plate'*.

Aircraft Fight Manual Supplement number 17, issued by PZL in 1994, described the difference between the M18A and the M18B as:

> Comparing to [sic] the M18A standard airplane, the M18B features some design changes resulting from the enlarged elevator, changed span, dislocation of the elevator trim tab attach joint, the flap travel extended up to 30" and modification of the airplane control system affecting the decrease of forces on the control stick and rudder pedals.

The aircraft's documentation did not include an entry specifying the incorporation of the optional PZL Service Bulletin No E/K/02.158/96 in the aircraft and there was no conversion data plate found in IGT. The operator confirmed that this service bulletin had not been applied to IGT. However, the elevators had been enlarged to match the M18B standard elevators in accordance with an Australian CAR 35-approved engineering order.

Aircraft maintenance

The aircraft was maintained by the operator in accordance with a system of maintenance approved by CASA. A review of IGT's maintenance documentation indicated that all required scheduled maintenance and airworthiness directive requirements had been completed at the time of the accident. The most recent maintenance prior to the accident was a 150-hourly inspection that was conducted on 12 December 2008. No significant modifications or repairs were completed at that time.

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[14] A tab in a primary flight control surface that moves in a direction opposite to the primary surface, generating aerodynamic loads that reduce the required load from the pilot.

The current maintenance release could not be located; however, a copy of the maintenance release that was current at the time of issue (at the completion of the last 150-hourly maintenance inspection) was obtained. That copy did not include any defects that may have been recorded in the time between its issue and the accident.

On 15 January 2001, the aircraft manufacturer issued Service Bulletin No E/02.172/2001, which gave the Dromader series aircraft an extension of the mandatory usable life from 6,000[15] to 10,000 flight hours, at which time the airframe must be retired from service. The extension could only be applied after several detailed structural inspections were completed. After the initial inspections had been completed, further scheduled inspections were required at regular intervals to maintain the 10,000 flight-hour service life extension. Although there was no entry specifically stating that the service bulletin had been complied with, the maintenance records contained entries for all of the individual inspection items contained in the service bulletin.

Previous repair to the right wing

The airframe maintenance records indicated that, on 24 December 2008, birdstrike damage to the leading edge of the right wingtip was repaired. The damage was reported to be located at the very tip of the right wing and was described as a small dent in the leading edge. The repair reportedly consisted of the reshaping the skin from the inside of the leading edge and resecuring the navigation light.

Weight and balance

The aircraft's empty weight was recorded as 2,605.57 kg when last weighed following significant modification. That re-weigh was prior to entering service in Australia on 12 September 2005.

The aircraft documentation noted a maximum fuel weight of 562 kg. Because of the damage from the impact, the fuel quantity on board at the time of the accident could not be conclusively determined; however, the operator's normal procedure was to refuel the aircraft's fuel tanks to between half and full at the beginning of a flight.

According to the operator's Pilot Work Order for the flight,[16] the plan for the flight was to disperse a 6,370 kg mix of herbicide chemicals and water over three separate flights. The work order also stated that for each of those flights, including the accident flight, the aircraft's hopper load was to be 2,123 kg. The aircraft's zero fuel weight[17] with that load was 4,810 kg.

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15 Having previously been increased from 3,000 hours subject to special inspections and the mandatory replacement of some components.

16 A Pilot Work Order was a job sheet that detailed the operation and loading of the aircraft for a specific application area.

17 The total weight of the aircraft, including the pilot and load, without the useable fuel.

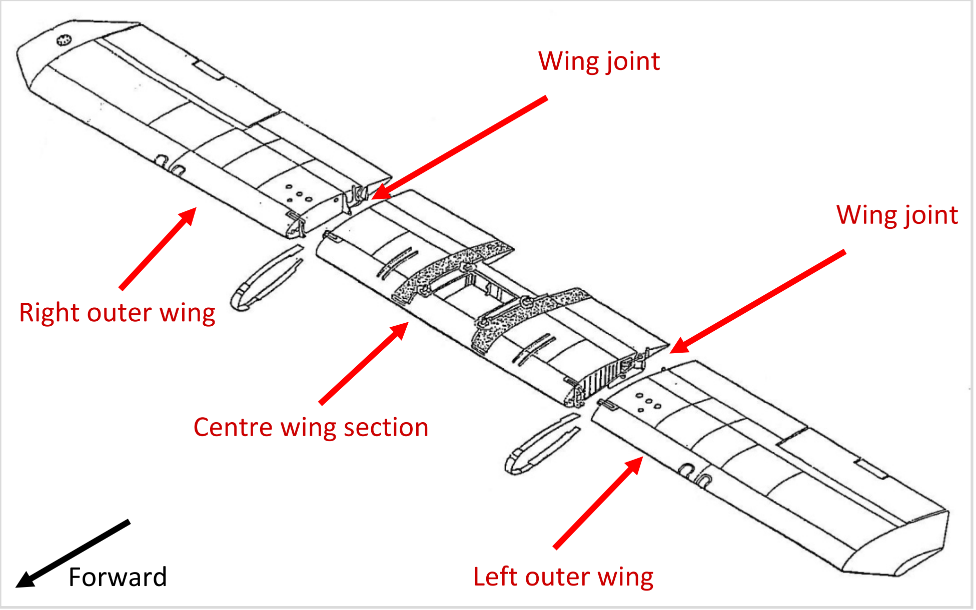
If the pilot had operated the aircraft in accordance with the operator's normal procedures, the aircraft's take-off weight would have been between 5,370 kg and 5,090 kg for a full fuel load and half fuel load respectively.

The M18A Dromader aircraft was originally certified in the normal category with a maximum take-off weight (MTOW) of 4,200 kg; however, approvals for operation at weights in excess of the MTOW (overweight operations) had been granted. See the section titled *Overweight operations* on page 40 for further information.

Aircraft wing

The M18 Dromader had a cantilever wing,[18] with a wingspan of 17.7 m and an area of 40 m^2. The wing consisted of three sections; the central wing section, and the left and right outer wing sections (Figure 4).

Figure 4: Wing section

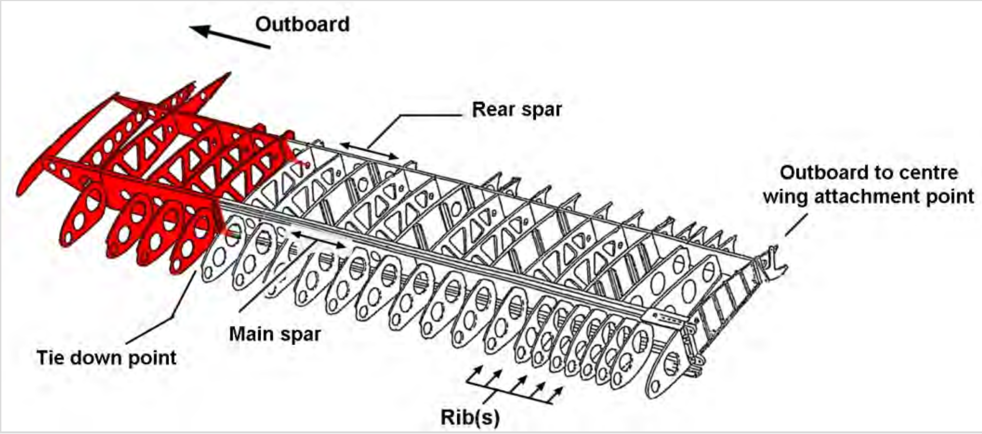


Wing internal structure

Each outer wing section structure consisted of two spars (main and rear) and ribs (Figure 5), which were covered in an aluminium alloy skin.

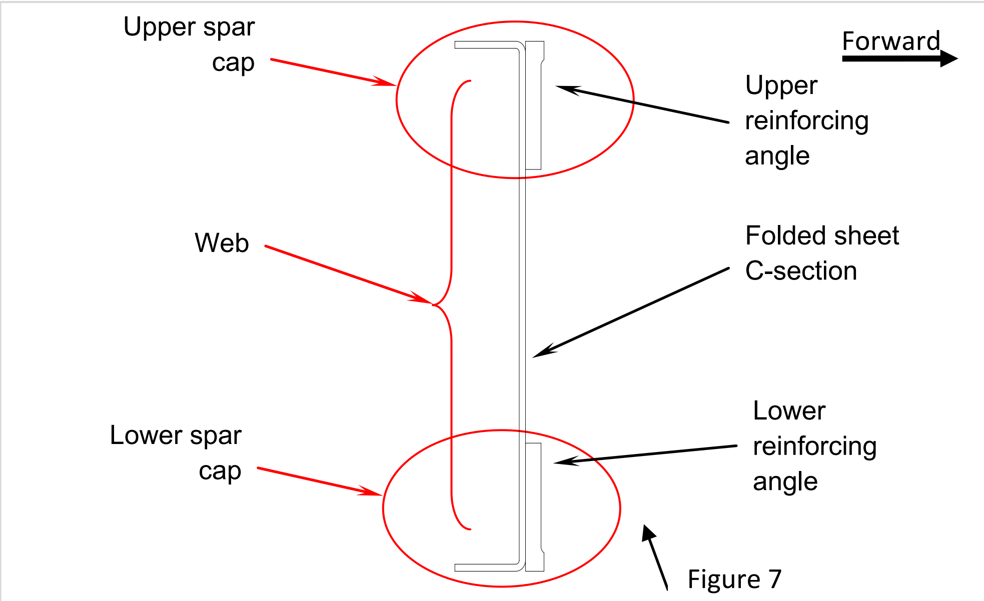
[18] A wing without struts or bracing wires

Figure 5: Internal structure of outer right wing section



The main spar was constructed from aluminium alloy sheet that was folded into a 'C'-section. The section was reinforced with heavy angle sections on the upper and lower face of the spar section (Figure 6). Those reinforcing angles extended from the wing joint out to about 1.8 m from the tip of the wing. The forward flange of the angle was tapered from inboard to outboard such that it was largest at the inboard end. The upper and lower portions of the spar structure are referred to as the spar caps. The vertical section is referred to as the web.

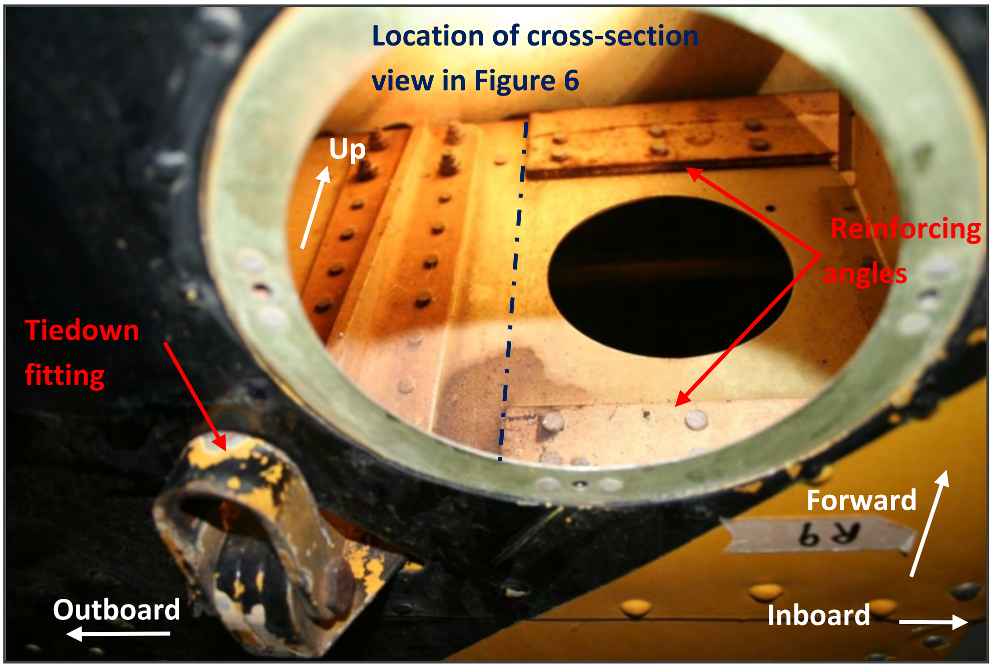
Figure 6: Representative cross-section view of the main spar at the end of the reinforcing angles (looking inboard - right wing)



A tiedown fitting[19] was attached to the main spar about 25 mm outboard of the end of the reinforcing angles (Figure 7).

[19] A fitting to which the aircraft can be secured to the ground to prevent the aircraft moving when not in use.

Figure 7: Detail of the end of the spar straps on a right wingtip

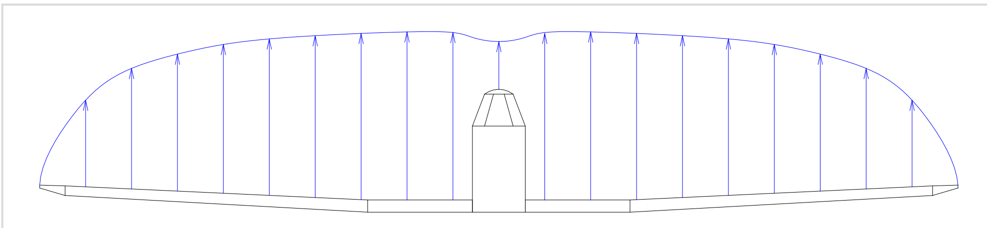


Note - This photograph is of an exemplar aircraft and was taken through an access panel on the bottom of the leading edge.

Wing aerodynamic loading

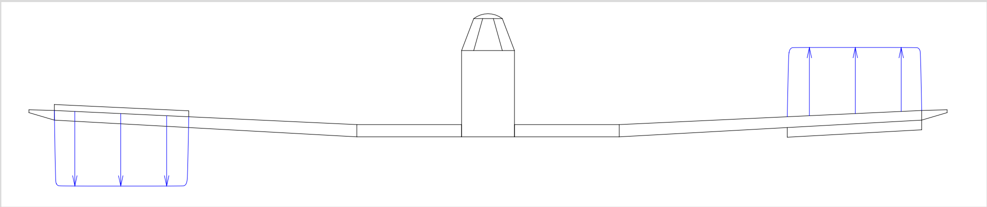
In steady level flight, an aircraft's wings produce lift that produces an upward force equal to the weight of the aircraft. That lift is not distributed evenly along the wingspan, but is distributed in the manner as shown Figure 8. This distribution is symmetric about the fuselage centreline. The shape of the lift distribution is determined from a number of factors, including the shape of the wing.

Figure 8: Spanwise lift distribution – symmetric



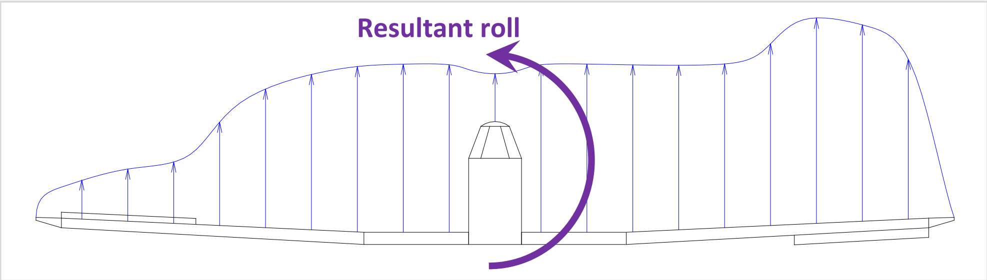
Ailerons are movable surfaces at the trailing edge of the outboard wing that move in opposite directions (that is, when the left aileron is moved down, the right aileron moves up, and vice versa). The ailerons change the lift distribution by locally altering the shape of the wing. A deflection of the ailerons can be thought of as making an incremental change to the lift distribution as shown in Figure 9.

Figure 9: Spanwise lift distribution – aileron increment



This increment reduces the lift on one side and increases it on the other, resulting in a lift distribution as represented in Figure 10. This asymmetric distribution is not balanced and results in a roll about the aircraft's longitudinal axis.

Figure 10: Spanwise lift distribution – asymmetric loading



As can be seen from the above figures, the lift is distributed along the wing, which is supported only at the fuselage. Thus, the lift distribution results in a bending of the wing. Both the lift force and the bending are supported along the wings by the wing spars, primarily the main spar. The spars are designed to have sufficient strength and stiffness when operated within the specified limitations.

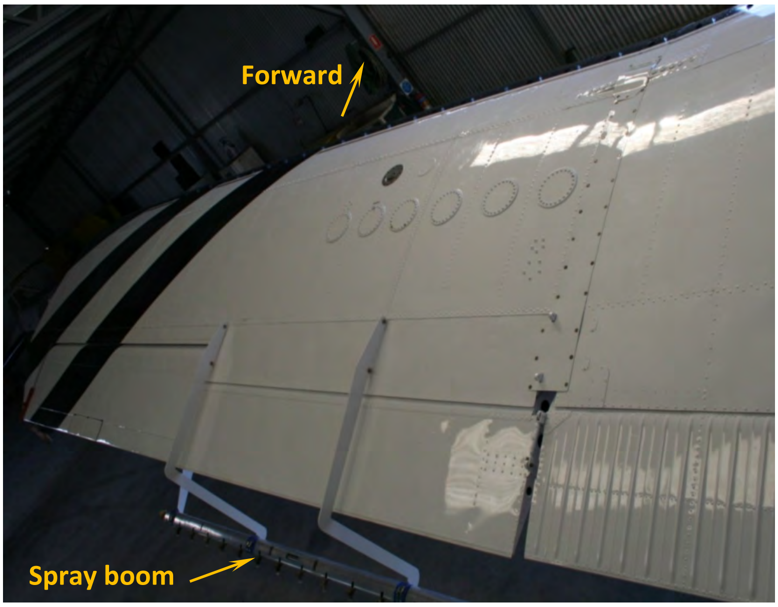
Aircraft role equipment

Aerial spraying equipment

The M18A Dromader could be configured with different equipment for spraying, spreading or fire-fighting roles. At the time of the accident, IGT was configured for spraying, with a spray boom located below and behind the wing. The most outboard attachment for the spray boom was located on the underside of the wing, inboard of the tiedown fitting (Figure 11). The three inboard spray boom attachment points were secured to the upper surface of the wing. The spray boom, and associated spray nozzles were visible from the cockpit (Figure 12).

Figure 11: Exemplar M18A Dromader (TPE 331) in the spraying configuration

Figure 12: View of the spray boom from the cockpit (looking left)



Note - This photograph is of an exemplar aircraft.

Satellite navigation/guidance system

The aircraft was equipped with a satellite-based Global Positioning System (GPS) SATLOC AirStar system (SATLOC) to provide guidance for aerial spraying operations. The system also recorded position and spray information, termed 'logging' by the manufacturer.

The system consisted of a:

- GPS receiver
- central processing unit (containing a removable memory card)
- keypad
- display screen
- lightbar.

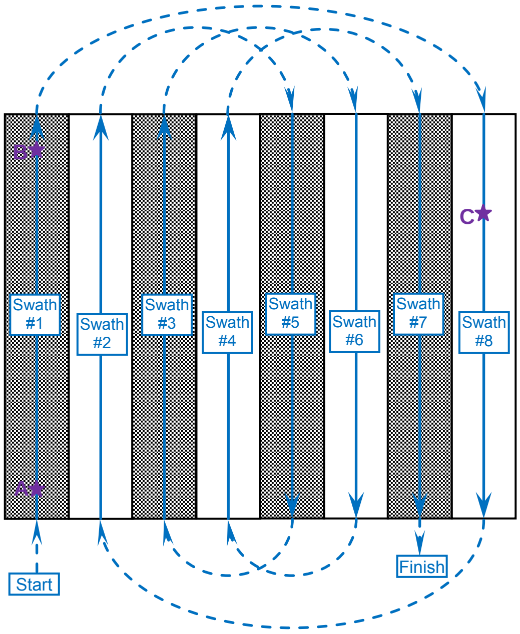
The display and keypad were located inside the cockpit within view and reach of the pilot at the lower right side of the instrument panel. The lightbar was located outside the cockpit, immediately forward of the windscreen and was within the pilot's view when looking forward (Figure 13). The lightbar displayed track guidance to the pilot to facilitate accurate spray runs (swaths).

Figure 13: Lightbar

Note - This photograph is of an exemplar aircraft and may contain slight variations to IGT.

The SATLOC system can provide guidance for a number of spray patterns (the order in which the swaths are made). For all patterns, the system requires a reference line that is defined by points A and B (Figure 1). All swaths are flown parallel to the reference line. A number of patterns also require an additional point C to define the width of the spray area. The 'racetrack' pattern selected by the pilot of IGT required a point C (Figure 14).

Figure 14: 'Racetrack' spray pattern (right hand)



Note – The above pattern is an example only and does not represent the number of swaths required on the accident flight. A left-hand racetrack pattern is a mirror of the right-hand pattern, mirrored along the A|B line.

Based on a measurement of a representation on a Google Earth™ image of the distance between the reference line A|B and point C for the flight, and a swath width of 22m, the pattern being carried out on the accident flight would have required about 39 swaths. The subsequent swath pattern would have been:

Swath # 1, 39, 2, 21, 3, 22, 4, 23, 5, 24, ...,37, 20, 38

The SATLOC also included a function that allowed the pilot to mark a point during the operation that would allow for the interruption of the operation to refuel and/or load more application chemical. The pilot could then resume the operation from that point. The system would also automatically record a mark at the end of each spray run (when the spray button was released).

<u>Recorded SATLOC data</u>

The SATLOC recorded a number of files to the removable memory card during flight. That included a:

- log of the flight, which included the aircraft's GPS location, altitude, groundspeed and spraying information every 1.5 seconds
- job file, which included information on the planned spray job (including the pattern and the coordinates of the A, B and C points)
- list of the marks recorded, which included the GPS position of the mark, current swath number, heading, area sprayed and information on the spray pattern already sprayed.

The log file was not continually recorded during the flight and was last recorded on the memory card at 11:52:58. The system continually buffered the data in internal memory, before recording it to the removable memory card at 60-second intervals. The removable memory card was ejected from the SATLOC during the impact and was found at the accident site. The information contained on the memory card was downloaded by the Australian Transport Safety Bureau (ATSB).

The last track point in the log file was time stamped at 11:52:30.

The log file was converted using two pieces of proprietary software from the SATLOC manufacturer to produce two ASCII[20] files. One file contained the recorded track points at 1.5-second intervals, basic spray information (including when the spray switch was depressed by the pilot), and GPS accuracy information. This file was used to produce the flight path presented in Figure 1. It showed a total of 7 spray applications by the pilot before the track ended and that the GPS had adequate satellites to provide accurate position calculations. After each spray application, the system automatically calculated and recorded the accumulated spray area. The last recorded spray area was 11.06 ha.

A second file summarised the spray information for the flight. That file showed that the last swath recorded in the log file was swath # 39. That correlated with the estimated number of swaths, and confirmed the recording of seven spray applications.

Two job files were recorded to the removable memory card, one at 11:52:08 (at the southern end of the swath that included point C) and the other at 11:53:06. Examination of the job file showed that the pattern was a right-hand racetrack. The A, B and C points were as shown in Figure 1, and the swath width was set at 22 m.

The file containing the mark information was recorded whenever a mark was made, either manually or automatically. The marks file was recorded onto the removable memory card at 11:53:06 and contained seven marks. All but one of the marks were from previous jobs; however, the last mark in the file was from the accident flight. The numbering of that mark was not in the range that the system permitted the pilot to select, indicating that the mark was automatically recorded by the SATLOC, rather than input by the pilot.

The last-recorded mark (‘marker’ in Figure 1) was located at the northern end of the application area (about 960 m from the impact point) and was about 22 m to the east of the A|B line. The mark related to swath #2 and the total area sprayed was 15.0995 ha at that time. This was 4.0395 ha greater than the accumulated area in the log file and, for a swath width of 22 m, equated to a further 1,836 m of spraying. The swath information indicated that the final swath consisted of two spray applications.

Examination of recorded data

An examination of the SATLOC data allowed an understanding of the operation of the aircraft during the application. In addition, the GPS data was converted from groundspeed and heading data to indicated airspeed and bank angle (Figure 15). The resulting data indicated that the aircraft was flown during the spray runs at indicated airspeeds of around 126 kts and that the turns were consistently made at

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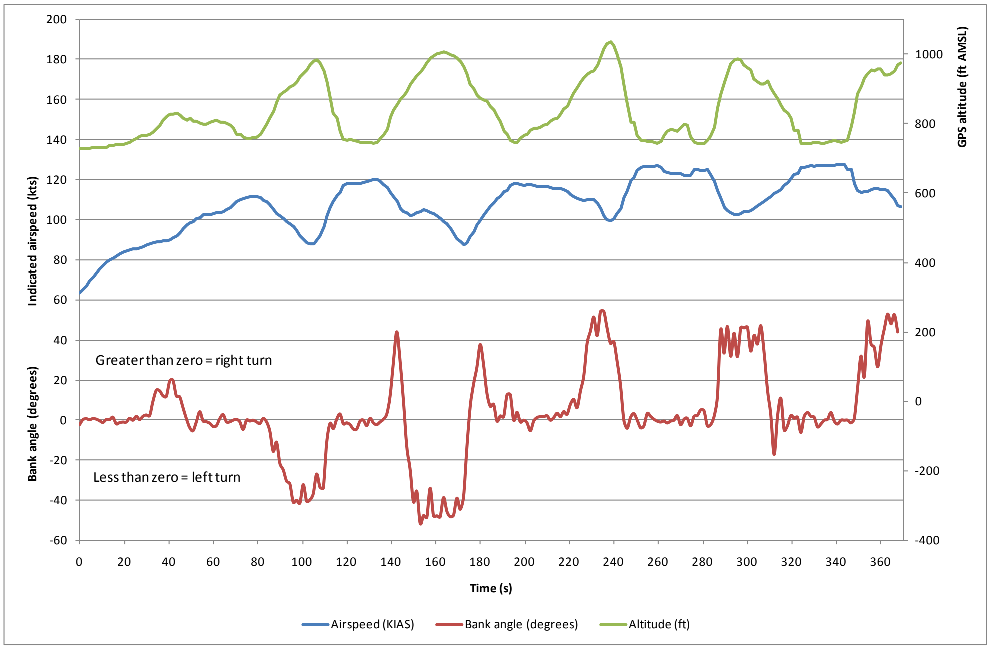
20 A standard code used in computers to represent English character text.

bank angles of about 40°. Further detail on the calculation methodology is provided in *Appendix A: Recorded data*.

Figure 15: Derived indicated airspeed and bank angle



Note: GPS altitude was recorded directly by the SATLOC and is referenced to mean sea level.

Meteorological information

Bureau of Meteorology reports for the Nyngan area indicated fine conditions, winds from the south-west at 12 kts and that the recorded temperature was about 29 ºC at the time of the accident.

Witnesses on the property reported that the weather conditions on the day of the accident were fine, with south-westerly winds and willy-willies[21] occurring throughout the day.

Communications

The aircraft was equipped with a Very High Frequency (VHF) and an Ultra High Frequency (UHF) radio. The UHF radio was used for communications with the operator and the aircraft loader, who was at the property for the duration of the flight. The aircraft loader reported that there were no radio communications from the pilot during the flight.

[21] Willy-willies (also known as dust devils or dust whirls) are revolving masses of air resulting from local atmospheric instability, such as that caused by intense heating of the air mass adjacent to the ground by the sun on a hot day.

Accident site and wreckage information

Property and accident site overview

The aircraft wreckage was located in a field about 900 m from the property homestead and about 950 m from the edge of the application area. The terrain in the area was flat, at an elevation of about 225 m (740 ft).

The application area was surrounded by trees (Figure 16). The height of the tree canopy was about 15 m (50 ft). The areas of trees on the northern, southern and western sides of the field had a number of dead branches extending 3 to 6 m (10 to 20 ft) above the canopy. Those dead branches were devoid of any foliage and varied in colour from dull grey to dull light brown. An extensive search of the trees along the northern, western and southern boundaries, which included along the flightpath where the SATLOC recording stopped, and where the trees surrounded the dam, did not find any evidence of an impact from the aircraft such as fresh breaks, paint transfer or aircraft wreckage debris.

Although there were small pieces of timber distributed around the main wreckage site, those pieces were weathered and had an appearance of having been on the ground in that location for a number of years. They were consistent in appearance with other pieces of timber that were in the same field, but remote from the accident site, and no piece of timber was found that contained evidence of having been struck by the aircraft.

The landowner reported that, in the days after the accident, there was no evidence of any 'die off' in the vegetation along the swath runs made in the application area, as he had expected to find following the spraying. The aircraft operator suggested that this could indicate that there had been a problem with the spraying equipment. There was also no evidence of a concentrated die-off that would result if the pilot had jettisoned[22] the herbicide in the application area or in the area between the application area and the accident site. Evidence of a significant amount of fuel and herbicide was spread across the accident site.

The residential buildings on the property had a number of tall aerials. The flightpath recorded by the SATLOC system and described by the witnesses did not place IGT near those aerials. There were no marks visible on those aerials consistent with an aircraft striking them.

There were no powerlines in the vicinity of the application area, but there was a domestic powerline traversing across the area of the accident site. There were no contact marks on either the powerline or power poles that could indicate a strike by an aircraft. Also, the detached section of right wing was located on the application area side of the powerline, indicating that it had separated from the aircraft before the aircraft had travelled to the powerline (Figure 16).

A number of large birds, such as eagles, were observed by the investigation team in the vicinity of the property on the days after the accident.

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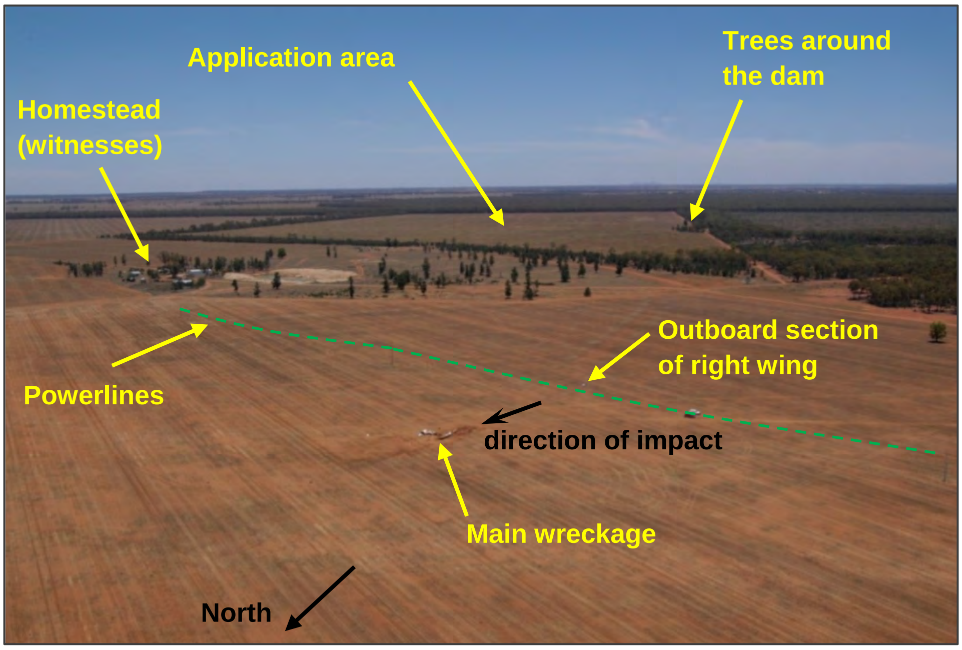
22 Pilots of agricultural aircraft can jettison hopper contents in an emergency.

Figure 16: Aircraft accident site and property (looking south)

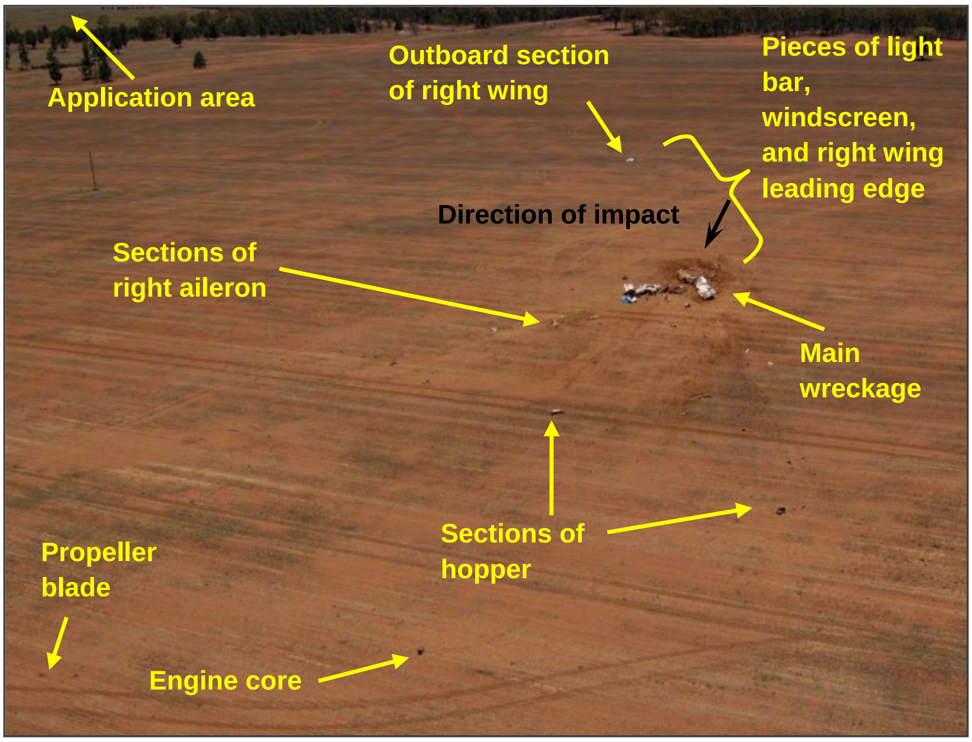


Wreckage distribution

The wreckage trail extended for about 330 m in a north-easterly direction; starting with a group of items that included perspex from the cockpit, the lightbar and the outboard section of the right wing. The last item beyond the main wreckage was a propeller blade (Figure 17 and 18).

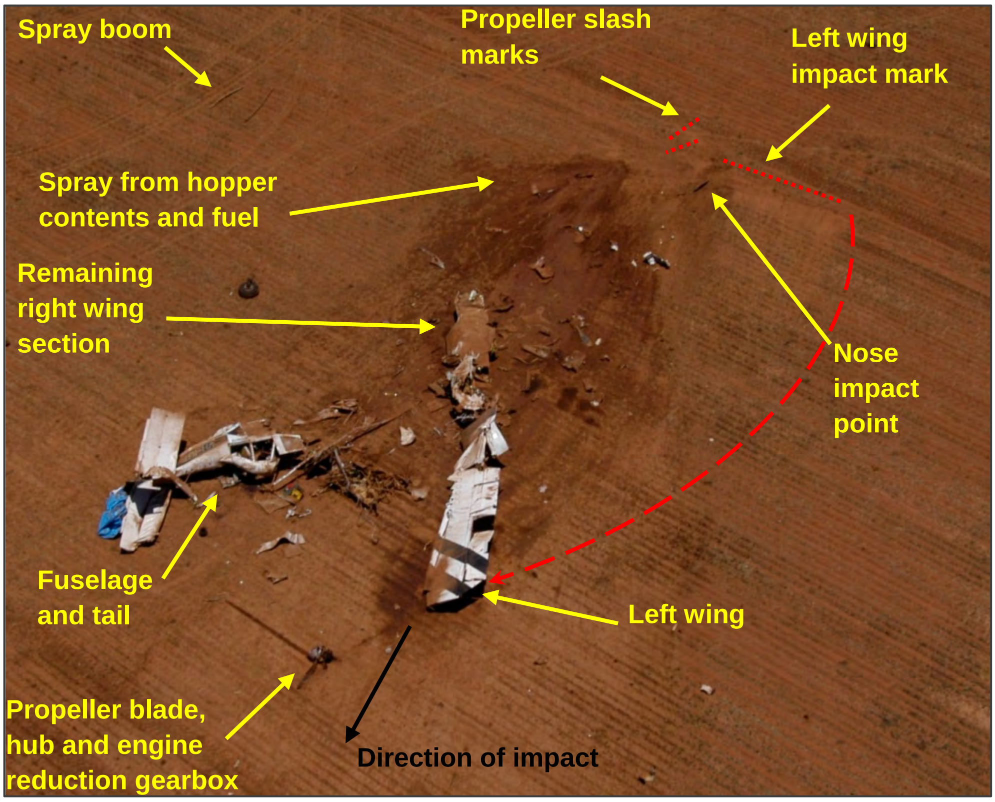
Figure 17: Wreckage distribution

Figure 18: Wreckage distribution (aerial view looking south-west)



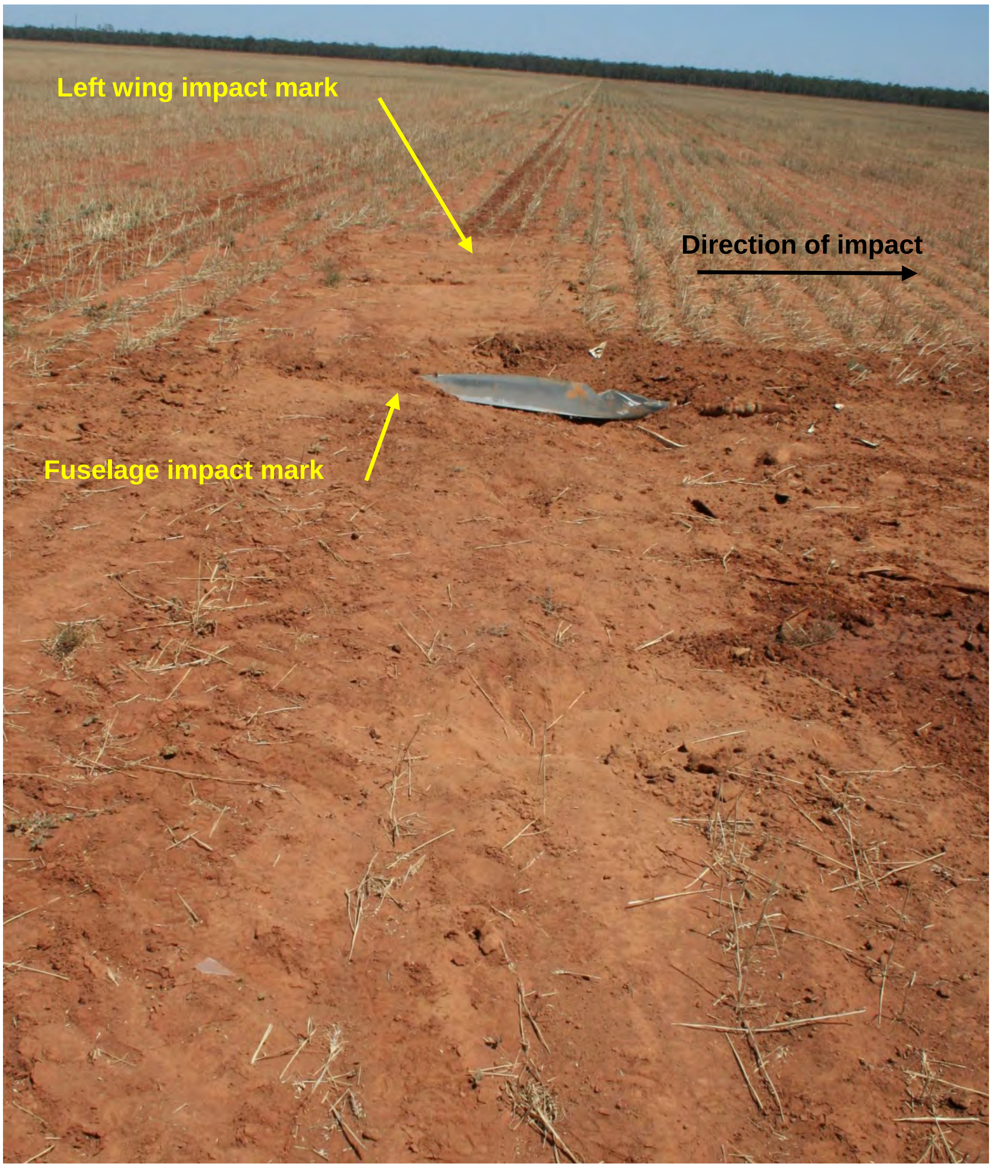
The main wreckage was located about 100 m from the outboard section of the right wing. The immediate area around the main wreckage contained most of the remaining aircraft parts (Figure 19), with the exception of sections of the hopper, the engine core and two propeller blades.

Figure 19: Main wreckage



Ground impact marks and damage to the wreckage indicated that the aircraft was rotating about its longitudinal (rolling) and vertical axis (yawing) just prior to ground impact (Figure 20), which was consistent with the witness reports. When the aircraft impacted the ground, the left wing, remaining section of right wing, engine, propeller, hopper, right aileron and flap separated from the aircraft due to impact forces. The fuselage and tail rotated over the top of the wings and came to rest facing in a westerly direction.

Figure 20: Impact point



Engine and propeller

The engine core, minus the reduction gearbox, was located about 125 m beyond (to the north-east of) the main wreckage. All of the damage to the engine was consistent with having occurred during the ground impact.

Four of the five propeller blades were liberated from the propeller hub during the impact. Two of the propeller blades were located about 200 m from the main wreckage impact point.

Torsional deformation of the engine case, and the location and deformation of the propeller blades, was consistent with the engine delivering significant power to the propeller at the time of the accident.

Flight controls

All flight control surfaces were found at the accident site. All of the flight control systems were inspected and no pre-accident damage was identified.

The right flap was wrapped around the vertical stabiliser. The right flap had chordwise compressive buckling on the inboard end and other damage that was consistent with the ground impact sequence.

The right aileron had broken into two sections and was connected to a section of the rear spar. Those items were located near, but beyond the main wreckage (Figures 21 and 22). The aileron and rear spar were covered in soil that was consistent with the wetted soil that had been sprayed out by the fuel and hopper contents upon impact. The overall deformation was consistent with upward bending with the fracture slightly inboard of the fracture of the right wing. The aileron sections and control system did not exhibit any of the damage characteristics associated with aeroelastic oscillation or control surface flutter, such as the liberation of mass balances, trim tab separation, control surface over-travel in both directions, or reverse bending or twisting of the immediate structure.

Figure 21: Location of right aileron pieces and section of right rear spar

Figure 22: Right aileron pieces and section of the rear right spar

Right wing damage examination

An initial examination of the right wing sections was carried out on site. The outboard right wing section was later examined in detail at the ATSB's facilities in

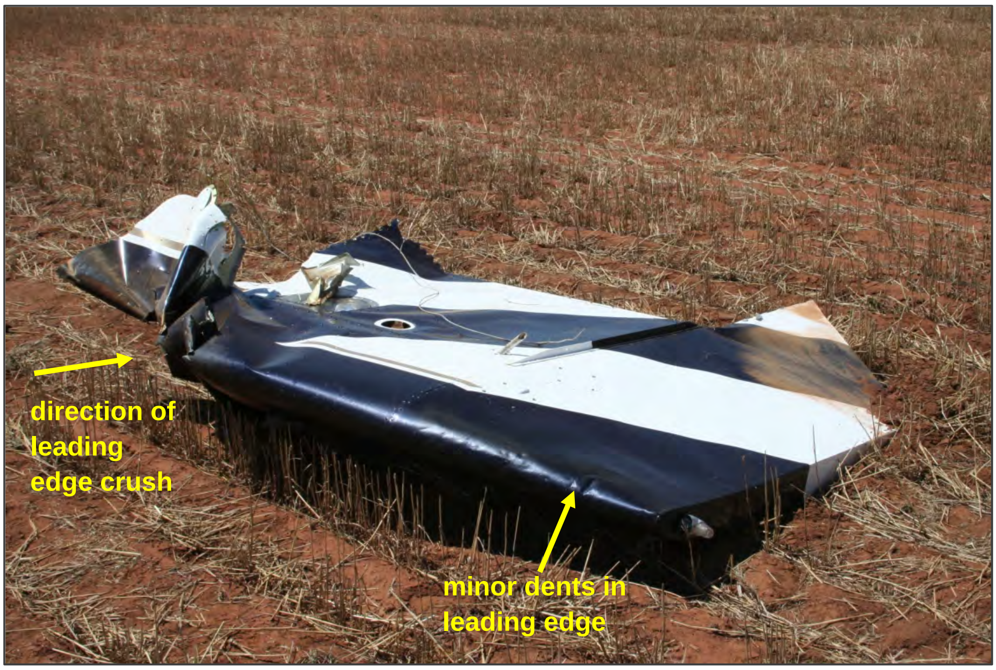
Canberra.[23] A full report of the results of that technical examination is at Appendix B.

All fractures were consistent with overstress of the structures. There were no foreign objects, or material, found within the accident site or wreckage; such as foliage, bark, sap, or fibres. The right wingtip contained a small feather under a rivet head that had an aged/weathered, appearance. There was no local deformation, or other bird remnants, associated with a birdstrike.

On-site examination of the outboard section of the right wing

The outboard section of the right wing separated about 1.8 m inboard of the tip. Approximately 0.6 m of additional (inboard) leading edge skin was attached to the separated section. The separated section of the right wing first impacted the ground on the inboard leading edge corner; crushing and tearing the additional 0.6 m of leading edge skin. This crushing was directed along the leading edge towards the wingtip (Figure 23). There were minor dents in the leading edge very near the tip. Examination of those indentations indicated that they were present before the flight, and that they were not of sufficient size or in a location with the potential to have degraded the strength of the wing.

Figure 23: Outboard section of the right wing (bottom surface showing)



There was an impact mark and a cut in the upper skin surface that were consistent with having contacted the lightbar, windshield and/or windscreen wiper (Figure 24).

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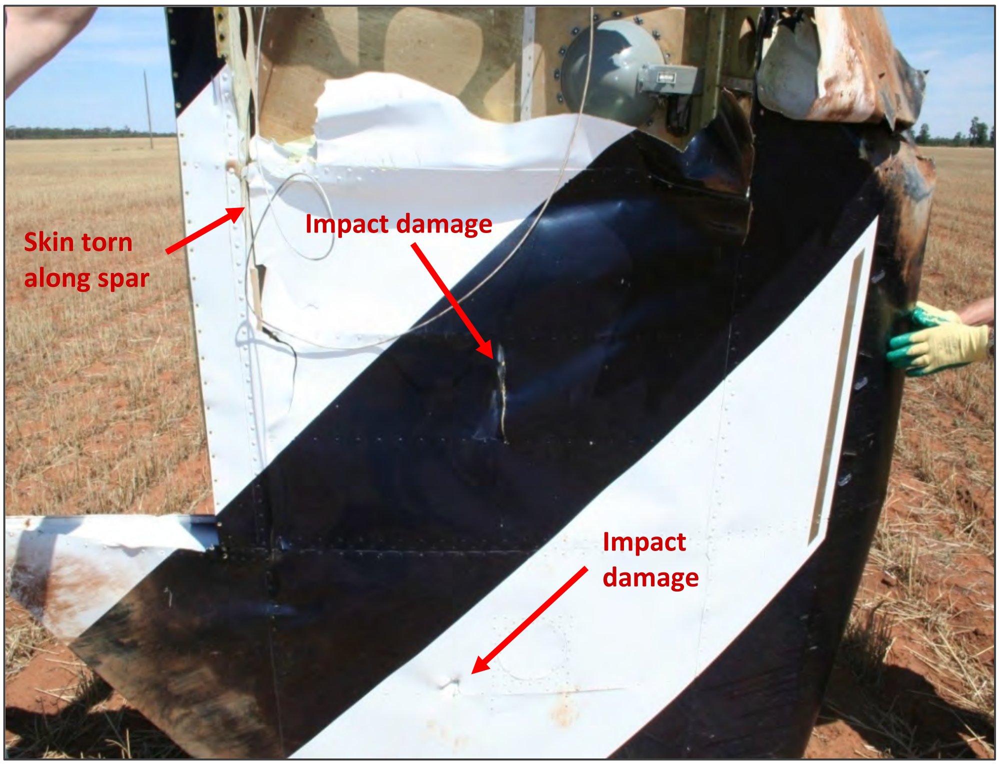
[23] The outboard right wing section was not under ATSB control for a period of time between the on-site examination and the technical examination at the ATSB's Canberra facilities. However, a comparison of that wing section on its receipt at Canberra with photographic evidence of its condition on site identified that the only differences since that time were removal of the landing light and some additional marks from its transportation to Canberra.

All of those items were located early in the wreckage trail and near the right wing section, indicating that contact between the right wing section and the fuselage occurred in-flight during the accident sequence.

The upper skin was torn away from the forward and rear spars in several locations. That tearing was consistent with a vertical load applied to the upper skin that pressed it downwards. The upper skin was also indented between the ribs, which was consistent with a spanwise compression load.

Figure 24: Top of outboard section of right wing



Another two sections of the right wing leading edge skin that had separated from the aircraft were located in the wreckage trail between the outboard section of the right wing and the main impact point and wreckage. Reassembly of the sections of right wing on-site indicated that those sections were the upper and lower portions of a small section located between the section on the outboard wing piece and the portion that remained with the inboard wing; hence, there were no missing sections of wing skin (Figure 25).

The reassembled sections suggested that the outboard region had been 'squashed' downward before being torn into two pieces (Figure 26). Some of the vortex generators in that region had been folded over, consistent with a vertical force. The upper skin had been torn along the upper spar by a downward force and the lower skin had been pulled away from the spar, tearing between the rivets that secured it to the spar. There was no rearward deformation that would have been consistent with impacting the ground, or another object, at flying speed. Along with the location of the sections, this indicated that the section of leading edge separated with the outboard section of wing.

Figure 25: Leading edge sections

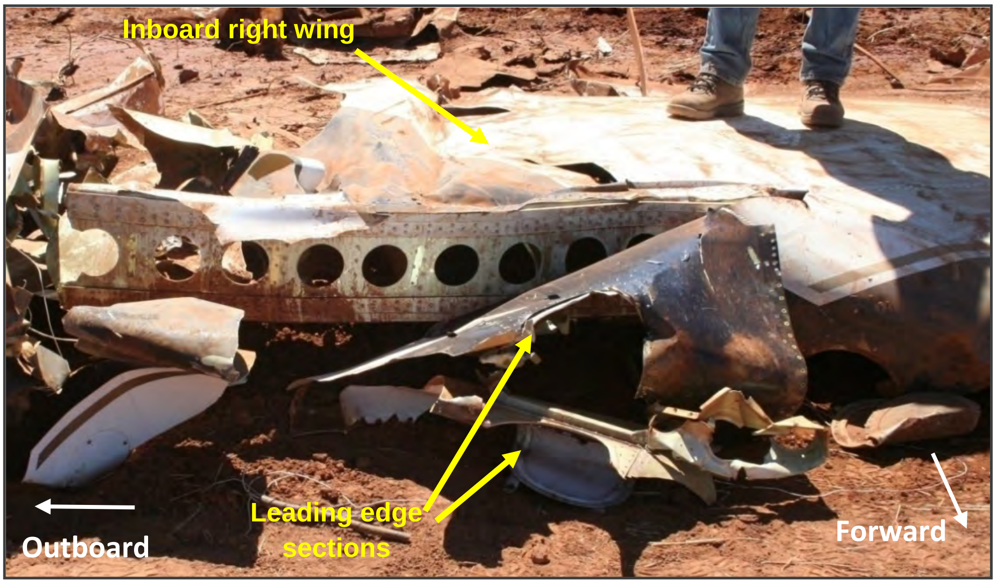


Figure 26: Leading edge deformation

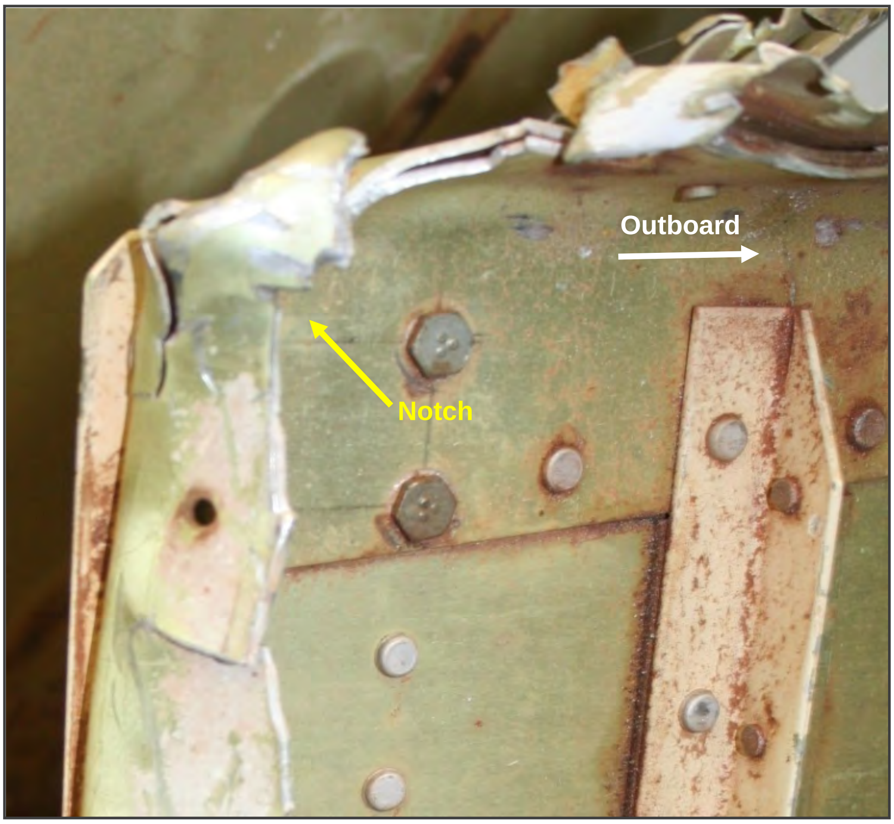
Right wing main spar examination

The right wing spar was in two sections: one section was contained in the outboard section that had separated from the aircraft; the other was in the inboard section of wing at the main wreckage site. The main spar had fractured in the C-section between the end of the heavy spar caps and the tiedown fitting.

The outboard section was subjected to a detailed analysis in the ATSB laboratory that found that the spar had failed in upward bending overstress (Appendix B).

There was no evidence of any pre-existing cracking, mechanical or corrosion damage that could have compromised the overall strength of the wing. Wrinkles were identified at several locations along the upper spar cap that were consistent with a compression loading 'buckling' the cap material. The web material was folded rearwards, such that it was almost bent back on itself, and there was a square notch out of the material in the upper cap that was consistent in size and shape with the outboard end of the heavy angle on the upper cap (Figure 27).

Figure 27: Upper spar cap of right wing outboard section



The inboard section of main spar was exposed where the leading edge had separated. The upper spar cap was permanently deformed such that the exposed length had an 'S' shape (Figure 28). This shape was formed by the upper cap bending rearwards at two points. The lower spar cap did not have the same rearwards bending at the inboard point, instead presenting a slight upward bending deformation (Figure 29).

Figure 28: Right wing main spar (top view) with separated section shown placed in close proximity

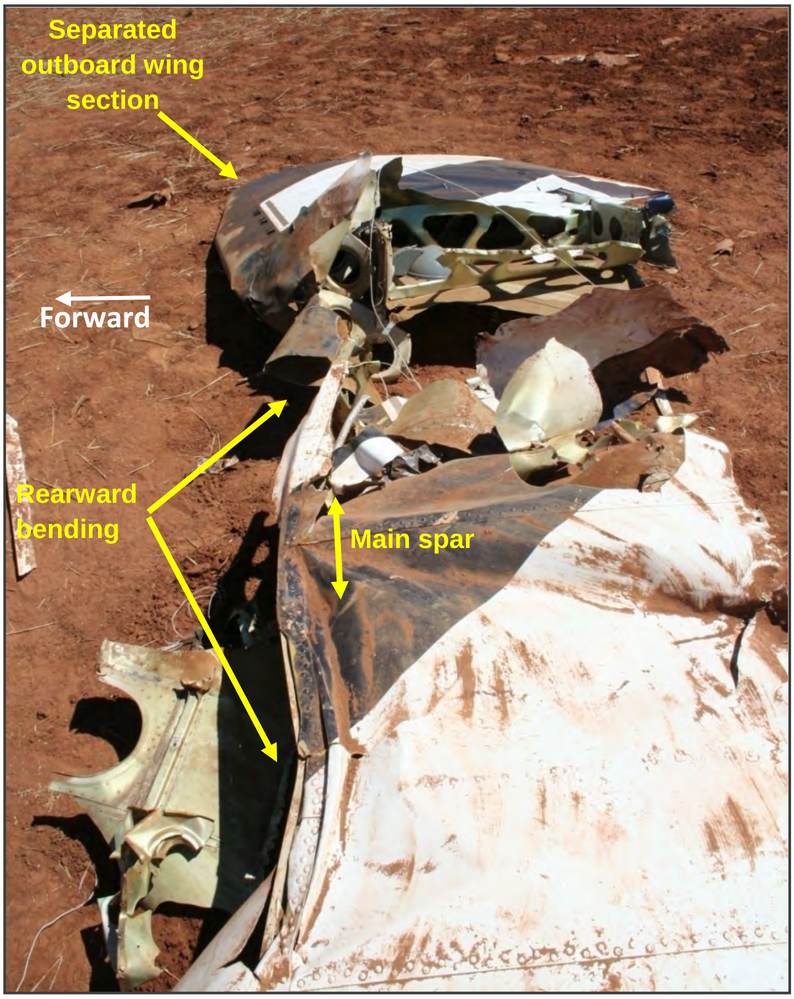
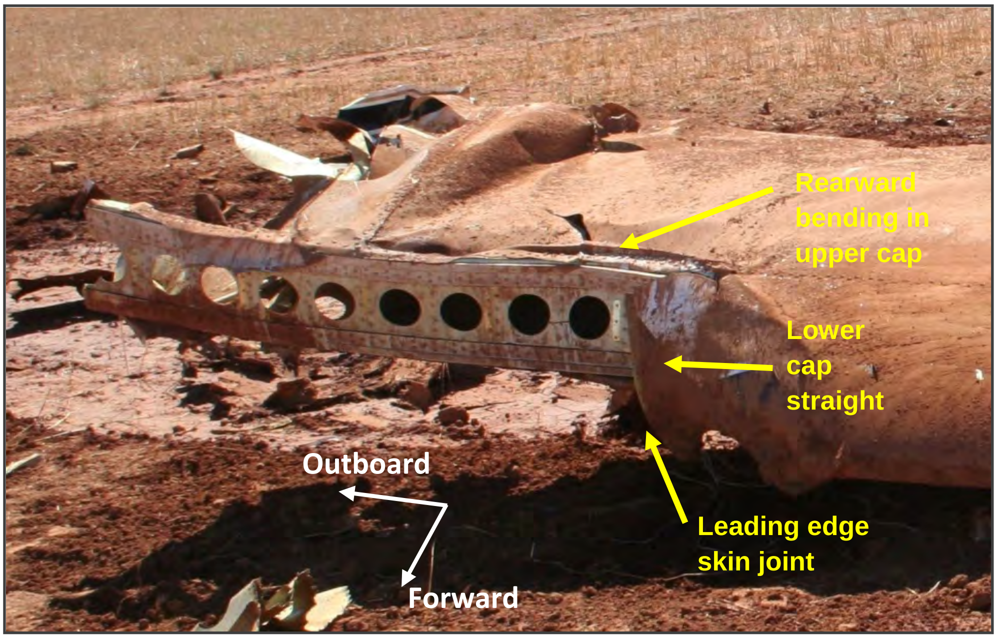


Figure 29: Right wing main spar (inboard section)



All fracture surfaces were examined on-site and appeared to have been freshly created during the accident sequence, with no evidence of pre-existing fatigue or obvious corrosion damage. The fractured sections of the right wing main spar had deformation that was consistent with the deformation on the outboard section (Figure 30). However, whereas the web of the outboard section was bent rearwards, the web of the inboard section was bent forward around the ends of the heavy spar cap angles. Score marks were visible on the inboard section of the main spar that were consistent with an arc transcribed about the fracture on the lower spar cap (Figure 31).

Figure 30: Right wing outboard and inboard main spar fracture (looking forward)

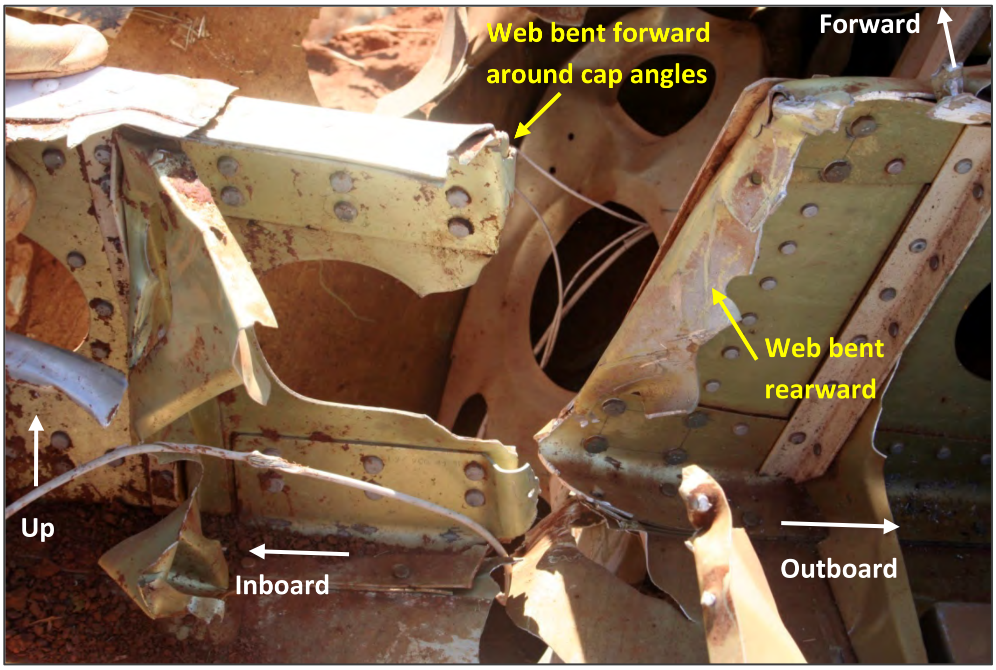
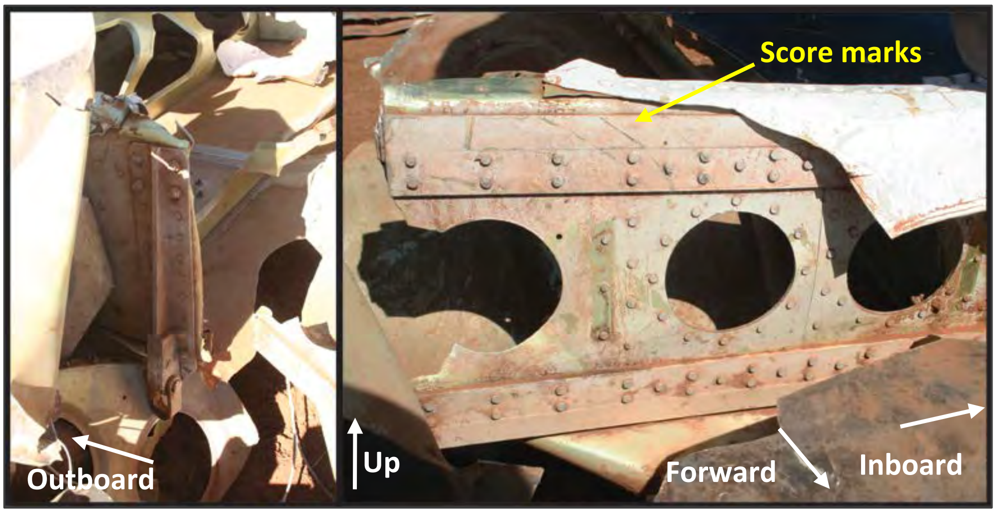


Figure 31: Right wing outboard and inboard main spar fracture (looking rearward)



Right wing rear spar examination

The section of rear spar attached to the aileron was examined on site. The rear spar fractured in two locations, directly behind the main spar fracture and near the inboard aileron attachment point. The section was straight and did not contain any damage that would indicate a point load (Figure 32). The spar section also contained a portion of the aileron control system. The outboard fracture surface was consistent with an upward bending overstress and was approximately in line with the main spar fracture (Figure 33). The inboard fracture contained damage that was of a mixed mode, but showed predominantly upward bending (Figure 34).

Figure 32: Rear spar section looking along its length from the inboard fracture

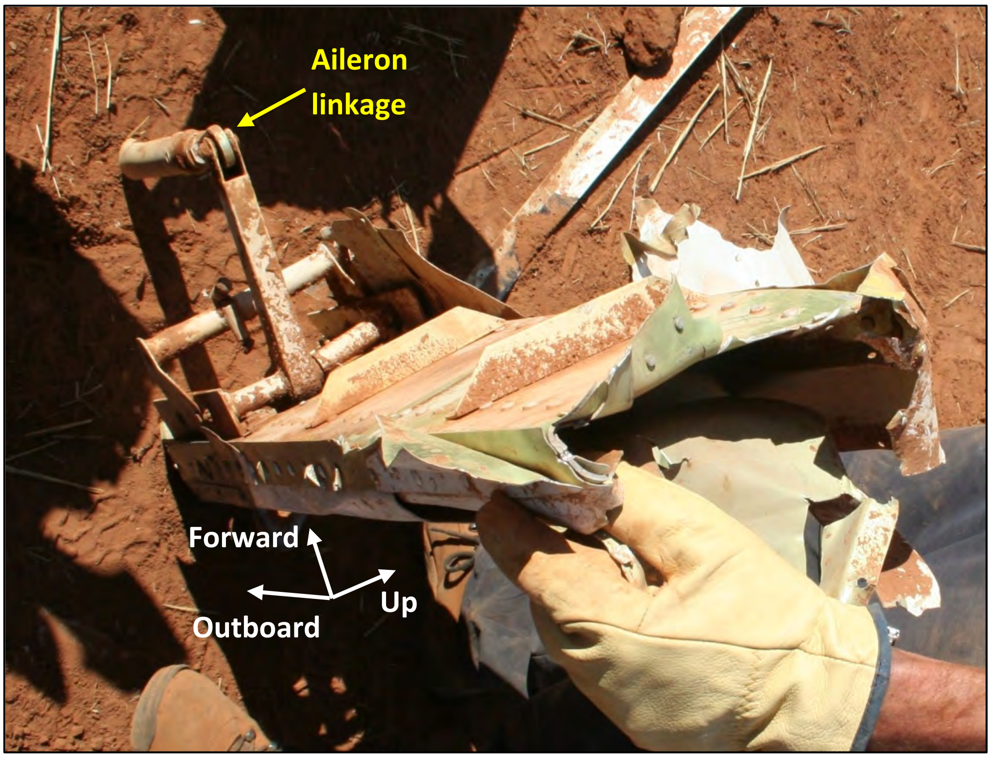


Figure 33: Rear spar looking rearward at the outboard fracture point

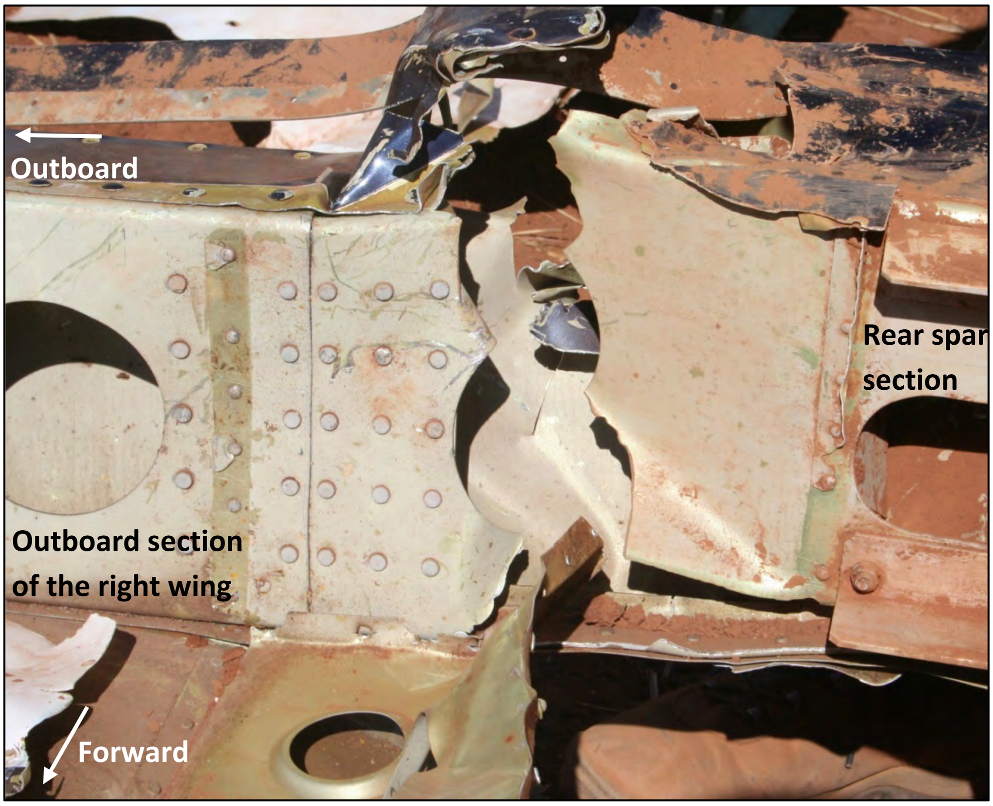


Figure 34: Rear spar inboard fracture

Right wing underside examination

The underside of the right wing was examined on site. All of the skin was present and the outboard skin fracture corresponded to the skin fracture on the detached wingtip section. The damage to the lower wing skin that was just inboard of the primary wing fracture was consistent with the outboard spray boom support structure being forced upward and outboard during the ground impact (Figure 35).

Figure 35: Underside of the inboard wing section at the primary fracture

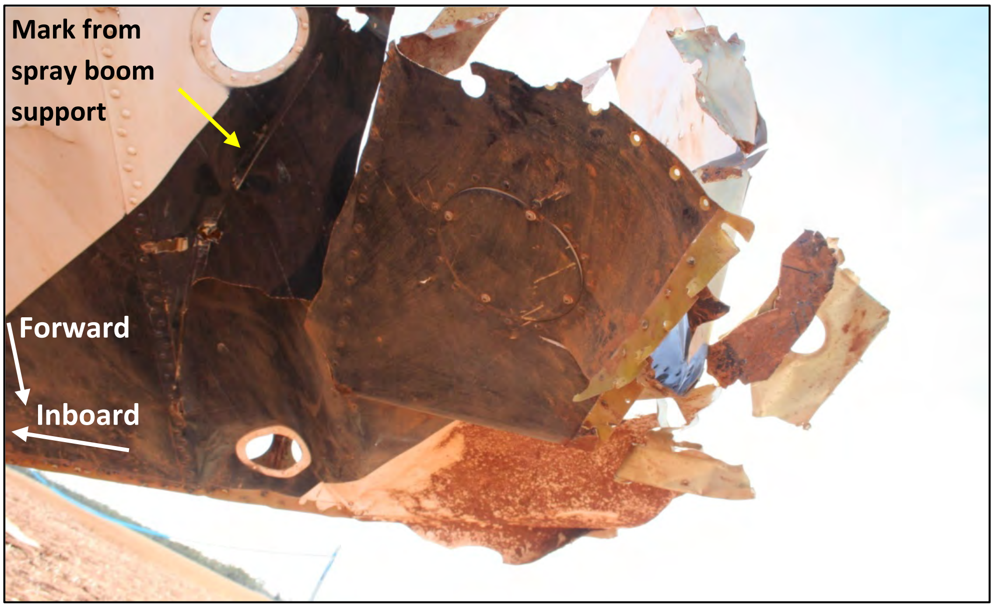
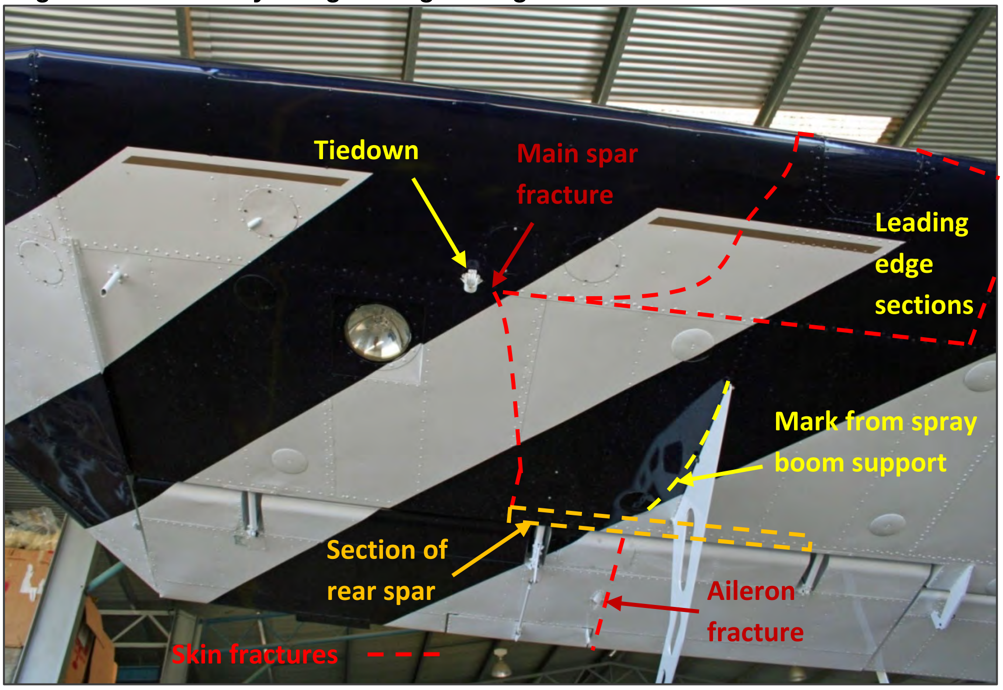


Figure 36 summarises the damage to the outboard section of the right wing, showing the approximate lines of damage in the lower side of the wing.

Figure 36: Summary of right wing damage



Note: This exemplar aircraft has a slightly different paint scheme to IGT

Left wing

The left wing leading edge crush damage indicated that it impacted the ground at greater than 40º nose-down (Figure 37). Red glass fragments from the left wingtip navigation light were located at the initial impact point. The wing was intact and all of the damage sustained by the wing was consistent with the impact with the ground.

Figure 37: Left wing

Spray boom

The spray boom was broken into three sections. One was located at the main wreckage site, between the left wing and fuselage, and was a complete side from the inboard junction to the tip. The other two sections were located close to the right of the impact point, and comprised two sections of another complete side. The spray boom had a general bending in a vertical plane (Figure 38). All of the damage to the boom was consistent with the ground impact with no evidence of a concentrated (point) contact.

Figure 38: Spray boom

Tests and research

Previous Dromader accidents

The ATSB contacted a number of international aviation investigation agencies and did not find any similar wing failures in the M18 Dromader aircraft type. In addition, the aircraft manufacturer advised that it was not aware of a similar wing failure in the type. There were no service bulletins, service letters or airworthiness directives applicable to the aircraft's structure at the location of the wing failure.

There had been a number of wing separation failures that had occurred at the outer wing-to-centre section joint as a result of corrosion-induced fatigue of the bolts and fittings (Figure 4). That area was subject to inspections under an airworthiness directive.

The US National Transportation Safety Board (NTSB) database contained several M18 Dromader accidents that included a collision with a foreign object, but the collision was not necessarily the primary factor. A summary of important descriptions of the damage in a number of those accidents follows.

NTSB ID: FTW98LA034

On 27 October 1997, an M-18A agricultural aircraft, registered N149RA, was substantially damaged during a forced landing following a loss of engine power in Louisiana. During the landing roll, the left wing contacted a tree that turned the aircraft left into a ditch, where it nosed down and came to a stop. The wreckage description included that:

> ...the leading edge of the left wing was crushed back to the spar at the point where the outer wing mated to the wing center section.

NTSB ID: CHI00FA139

On 20 May 2000, an M-18A, registered N178RA, was destroyed when it impacted a wooded area in Michigan. A witness observed the aircraft diving through the trees before it crashed to the ground. The wreckage description included:

> Also preceding the airplane's main wreckage were the airplane's outboard wing sections, portions of the left and right ailerons... Both wings were broken aft.
>
> The right wing tip and outboard 18 inches [0.5 m] of the right wing was broken longitudinally aft and outward and crushed inward along the leading edge. The right aileron was broken out at the hinges ... The left wing tip was broken aft along the rivet line. The left aileron was broken out at the hinges and was broken aft longitudinally.

NTSB ID: FTW01LA211

On 28 September 2001, an M18B agricultural aircraft, registered N203MC, impacted terrain after striking a standpipe while manoeuvring in Texas. After striking the pipe, the pilot continued west for about 4 miles (6.4 km). The pilot then reported that ‘he could not hold it anymore’, and subsequently, the aircraft impacted the terrain. The wreckage description included:

> The 30-foot [9 m] tall standpipe ... displayed an impact mark approximately 4 feet [1.2 m] from the top. The outer 4 1/2 feet [1.37 m] of the left wing, outer 1 foot [0.3 m] of the left aileron, and red glass, consistent with the left navigation light lens, were found in a 300-foot [91 m] long debris field northwest of the standpipe.

NTSB ID: ATL05LA052

On 23 February 2005, an M-18A, registered N2296Y, collided with trees during a forced landing in South Carolina. The damage description included that the aircraft:

> ...collided with and rested in trees tops about 400 feet [122 m] short of the runway. The pilot was able to egress and climb down the tree without injury.
>
> The post-accident examination of the airplane revealed the left and right wings were separated from the fuselage, both wings exhibited circular crush damage.

In-flight break-up of Piper Arrow

The UK Air Accidents Investigation Branch (AAIB) investigated an in-flight structural failure of a Piper PA-28R-200-2 Cherokee Arrow II, registration G-BKCB, in December 2000.[24] That investigation determined that the first event in the breakup sequence was a bending overstress failure of the outer section of the left wing. The failure occurred in the folded C-section spar immediately outboard of the end of the spar reinforcement where, like IGT’s wing, there was an abrupt change in the stiffness of the spar. The failure of the spar was determined to have commenced as a localised buckling in the cap.

As part of its investigation, the AAIB conducted a substantial amount of computational analysis and simulations of the wing structure, the wing’s behaviour under load, the aircraft’s control response, and the aerodynamic loading, in order to determine the mode of failure. Significantly, the AAIB’s analysis found that it was possible to generate loads on the wing that were capable of producing a compressive overstress in the main spar structure, immediately outboard of the reinforcing, by a particular combination of flight control inputs, even at speeds below the maximum permitted speeds.

Tree impact damage

Other accidents in which aircraft were known to have flown into trees were reviewed for typical tree impact signatures. The damage to wings from tree impacts could be grouped into two basic groups: partial penetration and full penetration.

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24 See http://www.aaib.gov.uk/cms_resources.cfm?file=/dft_avsafety_pdf_025533.pdf for further details.

Partial penetration impact damage typically had a rounded indentation with ‘concertina’ crushing behind the indentation and normally contained some material from the tree either caught in the damage, or pressed onto the metal. An example of partial penetration tree impact damage is in Figure 39.

Figure 39: Partial penetration tree impact damage

Image from accident involving Fairchild SA227-DC VH-TFU, Lockhart River 7 May 2005 (ATSB Occurrence 200501977)

Full penetration impact damage has crushing damage similar to a partial penetration impact, but because it penetrates the full width of the wing, it is similar to one side of a partial penetration impact. In such cases, the impacted tree has also passed through significant aircraft structure, such as spars. As such, the heavy structures exhibit significant rearward deformation at the fracture.

Willy-willies

Willy-willies (also known as ‘dust devils’) occur as a result of hot air at ground level expanding, becoming less dense, and rising rapidly. Sideways movement (such as a light wind) in the initial upward surge of the air, establishes a vortex and a twisting, rising column is formed. Willy-willies are only seen by the naked eye when dust or debris is picked up within the vortex. As a result, not all willy-willies are visible.

Willy-willies are capable of vertical development in excess of 1,000 feet above ground level, with reports of grass lifted in willy-willies being observed at 8,000 feet in western Queensland. The air within willy-willies is very unstable with rapid rising thermals and downdrafts created.

A 1990 Bureau of Meteorology Research Centre report[25] observed horizontal wind gusts in willy-willies of up to 19.5 m/s (38 kts). The report also found that they mainly occur between 1100 and 1500 local time.

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25 Spillane, K.T. and Hess, G.D., A Survey of Australian Dust Devils in *BMRC Research Report No. 20* Bureau of Meteorology Research Centre, Melbourne, June 1990.

The ATSB has investigated several accidents where willy-willies were thought to have influenced an accident. Examples include a Cessna 172 that crashed at Mount Vernon Station, in Western Australia (WA), and a Cessna 172 that crashed at Uaroo Station, also in WA. Summaries of those accident reports follow. Both are available in full at www.atsb.gov.au

Cessna 172L, VH-RIL, 1 September 2006, Mt Vernon Station WA[26]

The investigation summary included the following:

> The pilot and female passenger reported that the aircraft had entered severe turbulence during the descent to land, which resulted in a near-vertical nose down attitude of the aircraft approximately 300 to 350 feet above the terrain.
>
> The investigation determined that the pilot had most likely flown through a strong willy-willy and was unable to recover from the in-flight upset.

Cessna 172M, VH-TCS, 16 November 2007, Uaroo Station, WA[27]

The investigation summary included the following:

> There is evidence to indicate the possibility of adverse meteorological phenomena such as strong wind gusts and willy-willies in the area on the days before, during and subsequent to the accident. The willy-willies were reported to be difficult to see, form and dissipate rapidly, and travel in the same direction as the prevailing wind.
>
> While the reason that the aircraft impacted terrain could not be conclusively determined, it is probable that the aircraft encountered adverse meteorological phenomena such as strong wind gusts and willy-willies, after takeoff from runway 27.

A review of aviation literature on the hazards posed to aviation by willy-willies found many references were made to risks of an in-flight disturbance from such encounters, but that there was no reference to the risks of an associated in-flight breakup.

Overweight operations

Operating in excess of the originally-certified weight limits

Aircraft are not permitted to take off at weights greater than the certified MTOW as stipulated in CASA CAR 235(4):

> The pilot in command of an aircraft must not allow the aircraft to take off if its gross weight exceeds its maximum take-off weight or, if a lesser weight determined in accordance with a direction under sub-regulation (2) is applicable to the take-off, that lesser weight.

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[26] ATSB investigation 200605133.

[27] ATSB investigation AO-2007-060.

However, agricultural aircraft have regularly been exempted from this requirement and operated in excess of their originally-certified MTOW. In Australia, exemptions to allow increases to the MTOW of agricultural aircraft resulted in those aircraft being certified in the restricted category.

Restricted category certification by CASA allowed the conduct of special purpose operations as defined by CASA. In October 1998, CASA issued Advisory Circular AC 21.6(0) *Restricted category aircraft - certification* that addressed overweight operations. The circular advised that aircraft structural load, airframe fatigue and flight handling studies, including flight tests, would normally be necessary before any approval for overweight operations would be granted. Any such approval would require the relevant operating conditions to be shown in a certificate of airworthiness (COA) annex and in an amendment to the approved flight manual.

CASA issued a restricted category certificate of airworthiness for IGT for the purposes of agricultural and fire-fighting operations. That was because it had not been shown to fully comply with the normal category requirements at weights higher than the originally-certified MTOW. Accordingly, specific aircraft operating limitations were prescribed and restrictions on its intended use were imposed. Those limitations prohibited the aircraft being flown over densely populated areas, required a capability to jettison the excess load, and prohibited the carriage of persons other than the operating crew.

Aircraft manufacturer-approved overweight operation

As previously mentioned, the M18 Dromader aircraft type was certified in the normal category with a MTOW of 4,200 kg. In 1980, the aircraft manufacturer issued Aircraft Flight Manual (AFM) Supplement No 1.[28] That supplement was not a mandatory inclusion in the flight manual and permitted an increase in the MTOW for aircraft that were being operated in the restricted category, and increased the MTOW to 4,700 kg. That supplement also required the inclusion of a placard in the cockpit noting the increase in the maximum take-off weight to 4,700 kg.

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[28] AFM Supplement No. 1 – *Manufacturers recommendations concerning the operation of the M18 "Dromader" airplane in overload version at the takeoff weight of 10,340 lbs / 4,700 kg.*

In 1993, the aircraft manufacturer issued non-mandatory Service Bulletin E/K/02.148/93 admitting the aircraft to the firefighting overload version with a maximum take-off weight of 5,300 kg. That service bulletin required the modification of the hopper to include an anti-slosh baffle and the inclusion of AFM Supplement 16[29] into the aircraft flight manual. Supplement 16 provided operational information, including limitations, for an increase in the MTOW in the restricted category for firefighting roles up to 5,300 kg. The logbooks for IGT did not contain reference to the completion of this service bulletin and the flight manual did not contain supplement 16.

The supplement specified minimum pilot experience levels as follows:

> - total flown time - 2000 hours;
> - authorization to conduct agricultural operations;
> - 1000 flown hours in agricultural and fire-fighting operations, including 200 hrs on the PZL M18A;
> - authority to perform fire-fighting missions. ...
>
> The instructor-pilots granting other pilots the authorization to conduct fire-fighting missions must undergo training under supervision of instructor-test pilots at the WSK PZL MIELEC manufacturer's facility.

AFM Supplement No 16 included the following in Section 4 *Normal Procedures*:

> 4.10. Level Flight
>
> The aircraft shows dynamic longitudinal instability with free control stick /after about 20 seconds and two vibration cycles, the aircraft shows tendency to reaching the stall speed or exceeding the allowable maximum flight speed/.
>
> 4.18 Aerial Operations
>
> The aircraft with the weight of 11700 Lbs (5300 kg) is not permitted for agricultural missions.

In 1994, the aircraft manufacturer issued AFM Supplement No 17.[30] That supplement was only applicable to the M18B variant and allowed operations with a MTOW of up to 5,300 kg for aerial spraying and firefighting. Aerial spreading[31] had a MTOW increase to 4,800 kg.

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[29] AFM Supplement No. 16 – *Operation of the M18, M18A, M18AS (working variant) "Dromader" aircraft in fire-fighting overload version with takeoff weight of 11,700 lbs (5,300 kg).*

[30] AFM Supplement No 17 – *M18B, Airplane operation.*

[31] Aerial spreading is the application of solids.

In comparison to AFM Supplement No 16, Supplement No 17 included the following in Section 4 *Normal Procedures*:

> 4.10. Level Flight
>
> No change.
>
> 4.18 Aerial Operations
>
> No change.

The aircraft manufacturer advised that:

> Aircraft M18 and M18A in overload version (take-off weight between 4700-5300 kg) is [sic] allowed to use only in fire-fighting version according to conditions described in **supplement 16**.
>
> Aircraft M18 B can be operated in complete range in accordance with conditions described in **supplement 17**. ...
>
> Aircraft in version M18 B has constructional changes in comparison with aircraft M18 A, which allows for operation in different range.

Operational limitations in overweight operations

For operation under AFM Supplement No 1 with a MTOW of 4,700 kg, or AFM Supplement No 16 with a MTOW of 5,300 kg, specific additional limitations were imposed. Under Supplement No 1, those limitations included a reduction in the never exceed and maximum structural cruise speeds, and a reduction in the manoeuvring flight load factors. Supplement No 16 included a maximum permissible bank angle of 15º, an increased minimum speed and a further reduction in the manoeuvring flight load factor. Those operating limitations are detailed in Table 4.

Table 4: Comparison of operating limitations

	Basic PZL AFM	**PZL AFM Supp. No 1**	**PZL AFM Supp. No 16#**
MTOW (kg)	4,200	4,700	5,300
Never exceed speed, V_{NE} (KIAS[32])	148	121	121
Maximum manoeuvring speed, V_A (KIAS)	120	120	120
Maximum structural cruising speed, V_{NO} (KIAS)	121	104	104
Minimum speed in operational flight (KIAS)	≈ 82 [$1.2V_{S1}$ at 4,200kg]	Not listed	89
Maximum bank angle in turn	60º	60º	15+5º

Limited to firefighting operations only

32 KIAS is kts indicated airspeed.

The European Aviation Safety Agency (EASA) Type Certificate Data Sheet for the M-18A[33] included the operational limitations listed in Table 5. (Note, the figures in brackets were calculated from the values listed.)

Table 5: Type Certificate Data Sheet-listed operating limitations

	Normal Category	Restricted Category Versions	
		Overload	Firefighting overload
MTOW (kg)	4,200	4,700	5,300
V_{NE} (km/h)[34]	280 (148 KIAS)	230 (121 KIAS)	230 (121 KIAS)
V_A (km/h)	228 (120 KIAS)	228 (120 KIAS)	228 (120 KIAS)
V_{NO} (km/h)	230 (121 KIAS)	200 (104 KIAS)	200 (104 KIAS)
Load factor[35]	+3.4 -1.4	+3.0 -1.2	+2.8 -1.1
Maximum hopper load (kg)	1,500	2,000	2,200

Aircraft flight manual

The aircraft flight manual (AFM) for IGT was not located in the aircraft wreckage and was later obtained from the operator. The AFM did not contain any of the aircraft manufacturer's three flight manual supplements that related to overweight operations (Supplement Nos 1, 16 or 17), nor were they required to be as they were non-mandatory supplements.[36] However, the AFM did contain a copy of CASA Exemption EX75/08, allowing overweight operations up to 6,600 kg MTOW, and a copy of the associated flight manual supplement.

Training for overweight operations

Although there was no regulatory requirement for specialised overweight training, the Chief Pilot reported that, as the operator, he had imposed additional experience requirements on type before pilots were permitted to operate at higher weights or with a hopper load greater than 2,000 L. It was the individual pilot's responsibility to read and understand the operating limitations at the higher take-off weights.

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33 The EASA Type Certificate (TCDS A.056) for the PZL M18 aircraft was first issued on 24 October 2004. That type certificate replaced the previous Polish CAO Type Certificate number BB-120/1.

34 Speeds listed in the Type Certificate Data Sheet were in calibrated airspeed. The figure in brackets was corrected using the 'Airspeed Correction' chart in section 5 of the flight manual and then converted to knots.

35 The vertical acceleration relative to gravity, often referred to in terms of 'g'. For example, a load factor of 3, or 3g, is three times the acceleration due to gravity. In that case, a mass effectively weighs three times its normal weight.

36 The operator reported that when a flight manual for the aircraft was purchased from the manufacturer, it did not contain any of the supplements.

CASA general weight exemptions

Sub-regulation 137.190(1) of the Civil Aviation Safety Regulations 1998 (CASR 1998) required that an aircraft's gross weight did not exceed any of the following:

(a) the maximum gross weight shown in the aeroplane's flight manual; or

(b) any maximum gross weight that:

(i) has been established for that type of aeroplane by a flight test supervised by CASA; and

(ii) is shown on a placard, approved by CASA and displayed in the aeroplane's cockpit; or

(c) the maximum gross weight shown on the type certificate, or type certificate data sheet, that is issued for the aeroplane by the NAA of the State of Design (within the meaning given in Annex 8 to the Chicago Convention) of the aeroplane.

In contrast, CASA exemption EX56/07 required that an aircraft's gross weight was not to exceed the **highest** of those three possible weights. In addition, the exemption stipulated that it was necessary to be able to jettison the load in the aircraft's hopper. For IGT, EX56/07 permitted the highest of the following operating weight limits:

(a) **The aeroplane's flight manual:** MTOW in the basic AFM was 4,200 kg.

(b) **Placard**: there was no gross weight placard in the cockpit.

(c) **Type certificate**: The EASA Type Certificate Data Sheet (TCDS) stated that the MTOW was 4,200 kg in the normal category. In the restricted category, the MTOW was 4,700 kg for overload and 5,300 kg for firefighting overload versions.[37]

A second CASA exemption, EX09/07[38], exempted pilots operating agricultural or restricted category aircraft from the requirements of CASA Regulation 138 of CAR (1988) to the extent that they did not have to comply with the MTOW as published in a flight manual or a placard or another document. The explanatory information accompanying that exemption advised that the exemption applied only to the aircraft's MTOW and required pilots to comply with all other limitations in the flight manual.

CASA reported their interpretation of the exemptions that any limitations, including the type of operation associated with the higher weights listed on the Type Certificate Data Sheet, and in their associated flight manual supplements, have equal application and were to be observed during the operation.

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[37] EASA TCDS A.056 noted that the certification basis for restricted category versions of the aircraft was Civil Aeronautics Manual 8, second edition.

[38] This exemption expired at the end of March 2009, but in that month CASA issued exemption number EX30/09 that in effect further extended the exemption to the end of March 2011.

CASA exemption EX75/08 overweight operations

In August 2007, an application was made to CASA for an STC to allow M18 and M18A Dromader (TPE331) aircraft to operate to an increased MTOW of 6,600 kg. On 12 November 2008, the intention of which was to allow the aircraft to be utilised for firefighting operations during the 2008/09 bushfire season (prior to the issue of the STC), CASA issued exemption EX75/08. That exemption allowed flight up to a MTOW of 6,600 kg for both agricultural and firefighting operations. The exemption was applicable only to specific M18 and M18A aircraft that were identified by registration, which included IGT, and listed a number of conditions. The operator reported that they did not operate IGT to the higher weights permitted under that exemption.

Service life factors applicable to overweight operations

AFM Supplement No 16 and the *Aircraft Structural Repair Manual – Airframe Service Life in Overload Version* included a requirement to apply a service life factor to operations carried out at take-off weights above 4,700 kg. The aircraft structural repair manual stated:

> The service life is established for the airplane takeoff weight of 10,340 lbs (4700 kg).
>
> Increase in T-O [take-off] weight up to 11,700 lbs (5300 kg) causes higher fatigue wear and drop of service life by 1.35 times.
>
> Thus, the recorded flown time with the weight ranged from 10,340 lbs (4,700 kg) to 11,700 lbs (5,300kg) shall be multiplied by 1.35 coefficient [factor] and the obtained result is to be regarded as the basis for calculating the service life of the airplane.

The aircraft manufacturer provided further clarification to CASA, stating that the factor was to be applied to the entire flight when the aircraft took off at a weight greater than 4,700 kg, not just the portion of the flight when the aircraft weight exceeded 4,700 kg.

CASA exemption EX75/08 required pilots to comply with the operational limitations and procedures for operations above 5,300 kg that were published in the Flight Manual Supplement titled *PZL M18, M18A Dromader Restricted Category STC-MTOW Increase*. Section 2.11 of that supplement stipulated the service life limitations for the aircraft and referred pilots to section 2.4 of the approved STC Maintenance Manual Supplement. That supplement contained a chart of the service life penalty for a range of weights from 4,700 kg up to 6,600 kg.

The aircraft operator had no structural fatigue management system in place to manage the service life limits in M18 Dromader aircraft at take-off weights greater than 4,700 kg. The operator reported being unaware that application of a service life factor was required because they were operating the aircraft under the CASA exemptions which, in their interpretation, did not require them to refer to flight manual supplement 16.

The operator did not require the pilots to record the take-off weight for each flight. Thus, the investigation could not determine what flights had been made a weights above 4,700 kg.

Recorded service life factors

There was no record of the application of a service life factor in IGT's aircraft logbooks or maintenance documents.

An hour meter was fitted to IGT when it was first placed into service in Australia. The corrected aircraft hours should have been placed in the maintenance release after any service life reduction calculations had been completed.

A comparison of the actual recorded aircraft total time in service hours and the hour meter readings was made by reviewing all of the expired maintenance releases for IGT. One maintenance release had a difference between aircraft total time in service and the hour meter reading of 150 hours. The aircraft maintenance engineer was asked about the discrepancy and stated that, when a new maintenance release was issued, 150 hours was required to be added to the maintenance release to show when the next service was due. He indicated that the figure was most likely inadvertently placed in the incorrect position in the maintenance release.

A comparison of the maintenance release information with the hour meter reading showed that the aircraft total time in service hours and hour meter reading matched with the exception of that discrepancy.

A review of the factored service life of the aircraft was carried out based on information provided by the operator. The calculations shown in Table 6 are a conservative estimate of that service life based on the assumption that the aircraft was operated at the maximum permitted weight for all hours in that period.

Table 6: Conservative factored service life calculations for IGT

	Total hours at entry into service	Hours of operation under EX09/07# at 5,300 kg Factor = 1.35	Hours of operation under EX75/08 at 6,600 kg[39] Factor = 2.10*	Total
Airframe – unfactored	4,938	1,110	72.6	6,121
Airframe – factored	4,938	1,498	152.5	6,588.5
Wing – unfactored	3,031.4	1,110	72.6	4,214
Wing - factored	3,031.4	1,498	152.5	4,681.9

estimate supplied by operator
* the operator reported that IGT had a maximum possible take-off weight of 6,200 kg as it did not have the large fuel tanks. The service life factor in the STC Maintenance Manual Supplement for 6,200 kg was 2.1

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[39] The flight manual supplement required by CASA Exemption EX75/08 included a service life factor based upon the take-off weight. At 6,600 kg, that factor was 2.59.

Thus, both the airframe and wing were within the total permitted service life at the time of the accident.

Recording of service life factors in other M-18A Dromader aircraft

The investigation examined the maintenance records for another two M-18A Dromader aircraft that were also involved in accidents. It was found that service life factors had not been applied to those aircraft's total time in service either. Those aircraft were operated by different operators to IGT but in similar roles, where the CASA overweight exemptions applied.

ANALYSIS

Introduction

The accident involving the M18A Dromader, registered VH-IGT, was the result of the in-flight separation of the outboard 1.8 m of the right wing, leading to a loss of control and collision with terrain.

No pre-existing damage was identified during the investigation that would have precluded normal operation of the aircraft. Damage to the engine and propeller assembly indicated that the engine was supplying significant power to the propeller at the time the aircraft impacted the ground.

Separation of the outboard section of the right wing

The location of the outboard section of the right wing early in the wreckage trail prior to the main wreckage impact point, along with the witness reports, indicated that the section had separated from the aircraft in flight. The location of pieces of hopper, light bar, windscreen and windscreen wiper in the area around the outboard section of right wing indicated that, when the outboard section of right wing separated, it impacted the fuselage just forward of the cockpit. That was most likely because of the rapid roll from left to right, induced by the sudden and significant loss of lift from the damaged right wing.

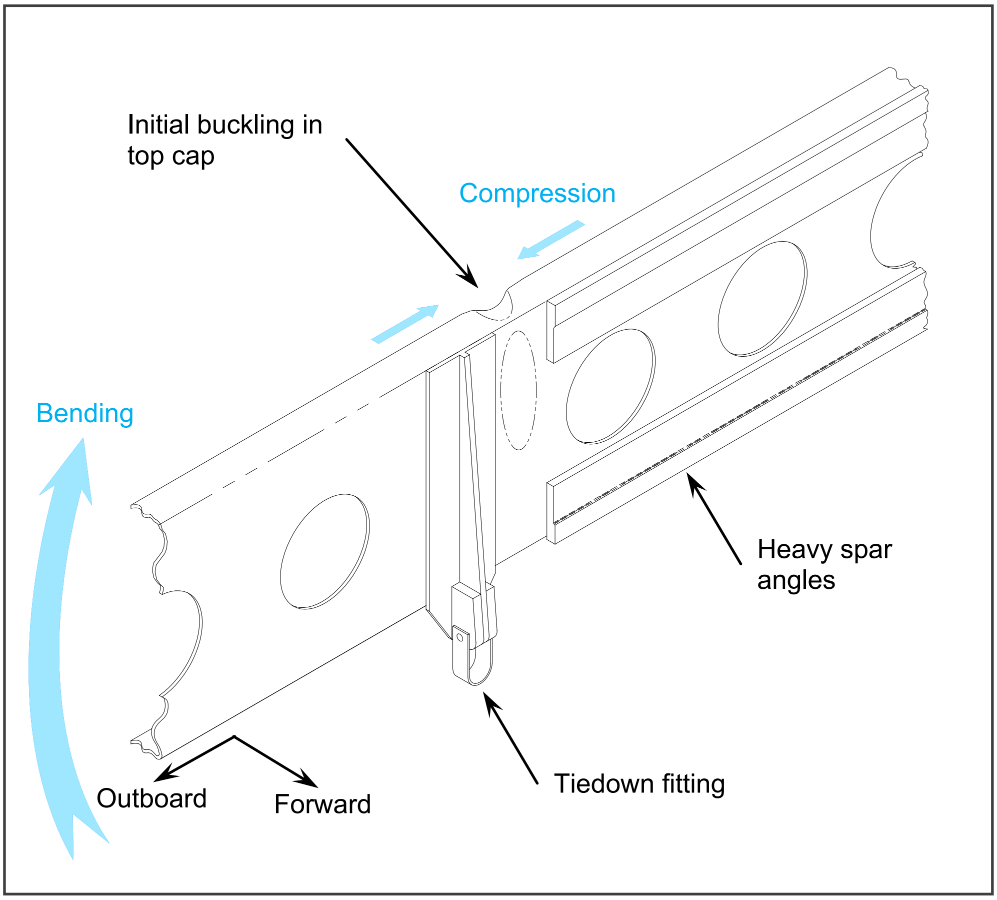
Ground impact marks and damage to the wreckage indicated that the aircraft was rotating about its longitudinal and vertical axes in an uncontrolled state just prior to impact, consistent with loss of control following separation of the right wingtip.

Wing failure

The primary structure in the wing contained deformation that was consistent with the wing failing due to overstress in an upward bending mode. This was primarily characterised by the general deformation and failure modes; tensile in the lower regions and compression in the upper regions. The indications of compression in the upper regions included buckling of the upper wing skins and buckling of the main upper spar cap.

The failure of the right main wing spar commenced with a localised buckling of the folded sheet C-section between the end of the upper heavy spar angle and the tiedown fitting (Figure 40). A buckling failure is an unstable failure, which means that the strength of the wing was suddenly and significantly reduced, and while the upward load was present the wingtip was able to rotate upward, effectively unhindered. There was no pre-existing damage identified that would have reduced the strength of the spar prior to the buckling. Thus, the buckle was likely a result of a compression load, and hence upward bending load that exceeded the strength of the spar.

Figure 40: Initial failure of main spar



As the upward displacement of the wingtip increased, and deformation at the buckle increased, the material began to tear. The tearing progressed down the web until it reached the lower cap (Figure 41 and 42), at which point the wingtip separated from the wing. The outboard section of main spar slipped forward of the inboard section and rotated about the lower spar cap. Sections of skin that were still attached to the outboard section scraped down the inboard section leaving the scoring identified in Figure 31.

Figure 41: Progressive tearing of the main spar

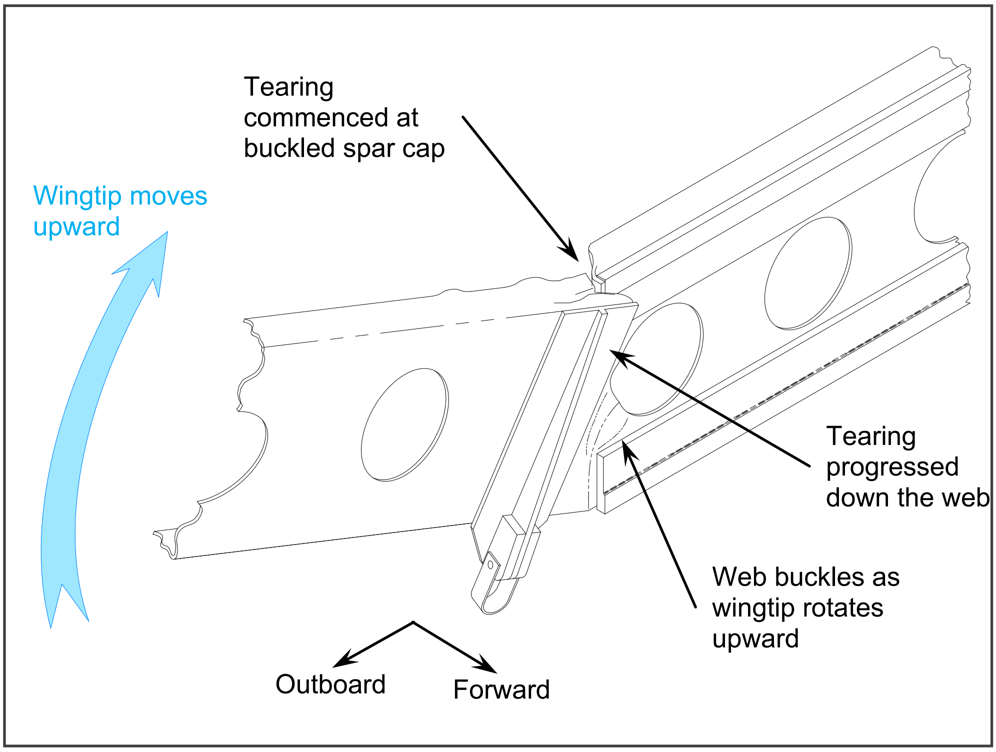
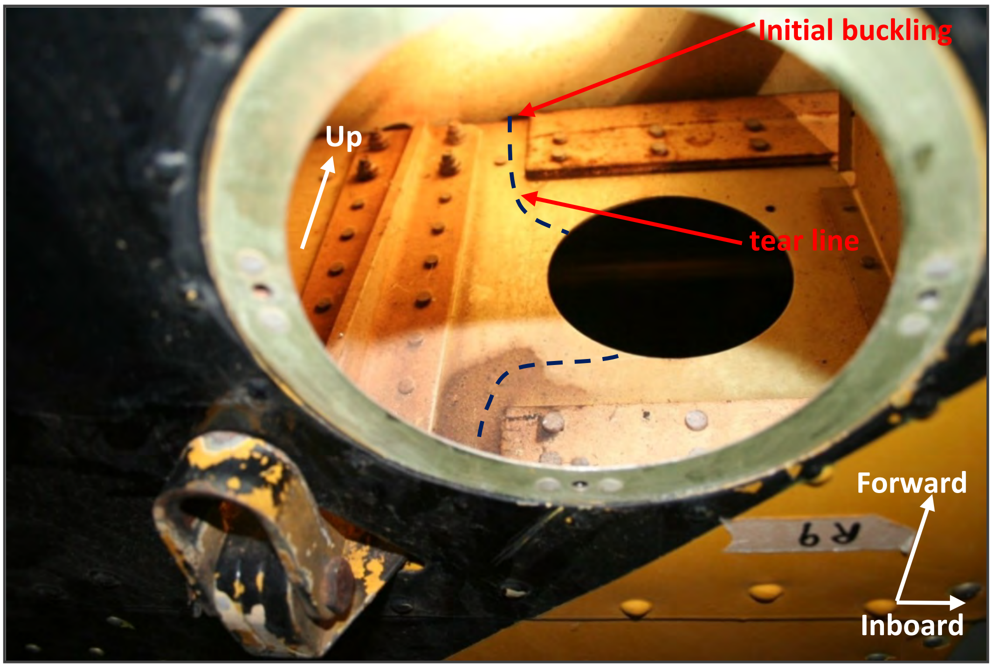


Figure 42: Main spar web tear line



Note: This image is of exemplar aircraft.

As the wing failure progressed, the leading edge skins were subjected to a vertical force from the downward movement of the upper spar cap at the spar failure point. This tore the upper edge of the leading edge skin inwards along the top spar and crushed it downward. The tearing progressed until just past the next leading edge skin joint inboard, at which point the joint failed. This section of leading edge remained attached to the outboard section of wing as it separated from the aircraft.

The rear spar was not designed as the primary wing bending member and as such, when the main spar failed, the rear spar did not have sufficient strength to withstand the loads on the wing, and similarly failed in an upward bending mode.

All of the damage observed was consistent with a single event. There was no indication that the wingtip had moved around in multiple directions as described by a witness. The witness that reported seeing the wing 'flapping' was observing the aircraft from a distance of approximately 700 m. At that distance, the reported 'flapping' may equally have been explained by some other event, such as the rolling movement of the aircraft as the pilot made a left then right turn. The investigation concluded that, rather than the wing physically flapping, leading to its failure, it was more likely that the wing failed in a single upward bending action.

When the outboard section of wing separated from the aircraft, the subsequent roll was so abrupt that the separated wing section made contact with the windscreen and hopper region. From the damage to the leading edge and wing section, it is likely that the inboard section of leading edge that was still attached to the separated wing section made the primary contact with the fuselage. That resulted in the most inboard portion of leading edge separating from the wing section and breaking into the two pieces that were located in the wreckage trail between the right wing section and the main wreckage.

The right aileron remained with the aircraft until ground impact. During that impact, the forces from the unrestrained aileron were sufficient to fracture the remaining, and damaged, rear spar. This resulted in the aileron, and attached section of rear spar, being flung forward and coming to rest beyond the main wreckage.

Examination of scenarios leading to the wingtip separation

Although the evidence showed that the outboard wing section separated in an upward bending mode, there was no evidence that provided a direct indication of the event, or events that initiated the upward bending failure. There was no evidence of pre-existing damage or defects, such as corrosion or fatigue that would explain a reduction in the spar's strength. Hence, the investigation considered a number of possible events that initiated the failure. These included:

- impact with a foreign object
- an aeroelastic event
- a meteorological event
- a control-induced overstressing event.

Before considering any of these scenarios in detail, the aircraft's flightpath is examined to determine if there were any unusual characteristics to indicate a problem prior to the breakup.

Flightpath

The data recorded by the SATLOC system showed that the pilot had planned to spray the major portion of the field using a right racetrack pattern and that he had programmed the three points required to define the pattern (points A, B and C) before the accident occurred.

The recorded spray applications indicate that the spray button was depressed 7 times. Even though the property owner reported that there had been no die-off in the application area, it is unlikely that, given the spray nozzles were readily visible from the cockpit, there had been a problem with the spray equipment from the start of the flight. Such a failure would have compelled the pilot to return to the loader, and that was not the case. The large size of the application area and the relatively small area sprayed provides a possible explanation for the lack of observed die-off.

Although the track data ceased at a location to the south of the application area, the marker file recorded by the SATLOC placed the aircraft at the northern end of the application area, about 22 m to the right of the swath up the western boundary at a time between the last track point and the accident. The additional spray area recorded in the marker file also equated to the expected area sprayed on a second northerly run along the western boundary, indicating that the pilot had completed an additional swath (swath #2 in the racetrack pattern) before the accident occurred. During this spray run, it is expected that the pilot would have briefly stopped spraying and climbed over the patch of trees surrounding a dam on the western boundary. The swath data for the final completed spray run in the system suggested that there were two spray applications during that swath.

The next expected swath in the racetrack pattern would have been swath #21, which would have been located approximately down the centreline of the field (Figure 43).

Figure 43 : Approximate location of next swath (#21, indicated by the orange line)

The bank angle data derived from the SATLOC indicated that the pilot consistently used 40° angle of bank during turns. If that trend was continued, the aircraft could not have made a sweeping turn to the right and aligned with the centreline, so either a tighter (higher bank angle) turn was required, or a procedure turn made with an initial left turn, to provide the necessary turning room before making the right turn. Given the pilot's consistent use of 40° angle of bank during the earlier turns, the investigation concluded that it is unlikely that he was making a tight right turn to align with swath #21.

The additional northward travel (compared to the turn between points B and C), and the north-easterly impact direction is consistent with the pilot conducting a procedure turn to facilitate his 'normal' right turn when the accident occurred. It is not consistent with the pilot attempting to position the aircraft for a landing along the road that was being used as a landing strip. The lack of a distress call would also suggest that the pilot was unaware of any problem with the aircraft before the accident, and that he was continuing with normal spray operations.

Impact with a foreign object

The investigation considered whether the aircraft may have struck a foreign object, such as a bird or tree during the operation, critically damaging the aircraft. The aircraft was operating in an area that was surrounded by trees and it is likely that the aircraft would have come in close proximity on a number of occasions during the flight.

At the speeds the aircraft was operating, striking a tree would be expected to cause significant damage to the aircraft. It would also be expected that there would be evidence such as broken branches and parts of the aircraft near any trees that were struck, similar to those described in the reports in the NTSB database. Certainly up to the point where the track data ceased, there is no indication that the pilot was aware of having struck any trees. Thus, if the aircraft had struck a tree, it was during the final swath, and the most likely places for a tree strike were in the south-western corner of the application area, around the dam, or at the north-western corner of the application area. The investigation team made several detailed inspections of the tree line in those areas and did not find any evidence of any broken branches or aircraft parts, or marks on standing branches consistent with having been struck by IGT.

Because of the significant forward speed during flight, a tree strike would be expected to leave impact damage on the aircraft with a significant rearward component. The majority of the damage observed in both the inboard and outboard sections of the right wing contained damage that was consistent with vertical forces, or forces along the span.

There were two places where the main spar exhibited a rearward deformation, at the tip of the remaining inboard section of main spar, and about 1 m inboard of that point (Figure 28). The bending at the tip of the remaining inboard section was not consistent with the straight spar (no rearward bending) exhibited in the separated outboard wing section. In addition, the front face of the web had a coating of soil in the bend region. Thus, the rearward deformation was consistent with impacting the ground during the ground impact, rather than with contacting a tree during flight.

The rearward bending about 1 m inboard of the tip of the remaining inboard spar was present in the upper spar cap only (Figure 29). This was more consistent with the upper spar cap buckling under upward bending, rather than from striking an object that only contacted the upper spar cap.

In addition, the damage to the leading edge attached to the spar at the locations of the bends in the spar exhibited vertical deformations, not rearward. Thus, the rearward deformation of the spar could not have occurred while the leading edge was still attached and hence occurred after the outboard section of the right wing had separated. Also, there was no organic material from a tree such as bark, timber or leaves within the damaged areas of the wing.

If the aircraft had struck a tree in normal operation, anything below the wing would also be expected to be struck by the tree. The spray booms were mounted below the wing and had no evidence of an impact with an object such as a tree. The deformation observed in the spray boom was in the vertical plane, not rearwards as would be expected from striking an object in normal flight.

The skins on the underside of the right wing were intact, other than at the fracture point. There was no rearward deformation at the fracture point that would have been consistent with a foreign object penetrating the skin and moving rearward. Also, the straight nature of the rear spar section that had separated with the aileron was not consistent with having been struck by a foreign object.

The only evidence in the wreckage of a possible bird impact was a small feather caught under a rivet in the leading edge. Because the feather had an aged appearance and there was no associated damage in that area that would have been consistent with a birdstrike, the investigation determined that the accident was not the result of impacting a bird.

The investigation concluded that, based on the physical evidence, it was highly unlikely that the aircraft had struck a foreign object prior to the wing separating and impacting the terrain.

Aeroelastic event

The investigation considered whether an aeroelastic event such as structural divergence, or flutter might have contributed to the accident. Aeroelastic events result from a combination of aerodynamic and elastic forces in the case of structural divergence, or aerodynamic, elastic and inertial forces in the case of flutter.

The aircraft was certified to a common design standard, which requires the aircraft to be free from aeroelastic effects within the flight envelope. The aircraft has a long flight history in aerial application and the investigation did not find any accidents that had been attributed to an aeroelastic event. Without some prior degradation of the structure, such as a detached control surface or weakening of the structure to induce an aeroelastic event, it is very unlikely to have occurred during normal operations. The investigation did not find any pre-impact degradation of IGT’s structure that could have lead to such an event.

Additionally, many aeroelastic events leave telltale evidence, such as a reversal of deformation, control surfaces travelling to both extreme positions, and/or separation of control surfaces (including trim tabs). The deformation damage to the aircraft's structure indicated that a single deformation event took place and that the ailerons had not travelled to both extremes. All of the aircraft's control surfaces were accounted for in the wreckage at the main accident site.

Due to the lack of recorded data at the time of the accident, the investigation could not determine the airspeed at that time. However, the flight profile suggested that it was similar to the other turns made during the flight, which were made at airspeeds between 100 to 110 kts. Those speeds were below the aircraft's maximum manoeuvring and never exceed speeds of 120 and 121 kts respectively, for a weight above 4,700 kg. Aeroelastic events are associated with high airspeed and the aircraft's airspeed at the time of the wing separation would indicate that high airspeed was not a factor in the accident.

The investigation concluded that the accident was not a result of an aeroelastic event.

Meteorological event

The reported conditions at the time of the accident were fairly benign, except for the presence of willy-willies. Encountering a willy-willy, which is an intense localised rotating air mass, would be similar to encountering a wind gust with both vertical and horizontal components. Willy-willies were observed in the area on the day of the accident and, although no witness reported seeing one at about the time of the accident, they can only be observable if they contain significant dust. That being the case, the investigation could not discount the possibility that the aircraft encountered a willy-willy immediately prior to the accident.

As highlighted by the two Cessna 172 accidents in Western Australia in 2006 and 2007, the greatest hazard posed by willy-willies is the potential for a loss of control at low altitude leading to a collision with the terrain. The investigation considered that an encounter with a willy-willy alone would not result in the in-flight breakup of IGT.

Control-induced overstressing event

When control surfaces are deflected, they create stresses on the aircraft. Aircraft are designed such that the structure can safely withstand those stresses when the aircraft is operated within the design limitations. At an airspeed below the maximum manoeuvring speed (V_A), the structure can withstand a full control deflection without structural failure.

Given that at the time of the breakup, the aircraft was likely travelling at a speed below V_A, a single full deflection control input was considered unlikely to have overstressed the wing. However, there were two factors identified that could have applied stresses that were in excess of the airframe's strength.

The UK Air Accident Investigation Branch's investigation into the in-flight breakup of a Piper PA-28 identified a possible combination of control inputs that, combined with the dynamic response of the aircraft, could impart stresses on the airframe that exceeded the strength of the wing away from the wing root. Without undertaking the same level of engineering analysis, the investigation considered that there was the possibility that the M-18 Dromader could have a similar dynamic control input combination that could similarly fail the wing away from the wing root.

The main function of the aircraft's vortex generators (VGs) was to improve the wings' capability to produce lift. The VG manufacturer's claim that the installation of the VGs reduced the aircraft's stall speed by 7% indicates the potential for the VGs to increase the wing's lift production by about 15%. This additional lift means that the wing can produce more lift than the original design, and hence apply greater loads to the airframe.

Because the aircraft did not carry a system to record the pilot's control inputs, nor was it required to do so, the investigation could not determine any actions taken by the pilot, either intentionally or unintentionally, leading up to the separation of the right wing. As such, the investigation could not conclusively determine if the wing was overstressed as a result of a control input, or combination of inputs.

Summary

Due to the lack of corroborating physical evidence, it was highly unlikely that the in-flight breakup was the result of a collision with a foreign object, such as a tree. However, due to the significant disruption to the right wing structure as a result of the ground impact, the investigation could not definitively conclude that a tree strike was not a factor.

Given that M-18A Dromader aircraft have been operating for a number of years in the aerial application role, which includes an inherent high degree of manoeuvring flight, the investigation considered that the events leading to the in-flight breakup was most likely from a particular confluence of events that were, collectively, outside the design requirements for the aircraft. The investigation could not rule out that a particular sequence of control inputs and a dynamic response from the aircraft may have coincided with an external meteorological event to overstress the right wing. The resulting failure of the right outer wing allowed it to separate from the remaining structure, with a subsequent loss of control.

Overweight operations

Operation of IGT

Although an accurate fuel quantity at the start of the flight could not be determined, the zero fuel weight was above 4,700 kg and it was likely that the aircraft had a take-off weight of somewhere between 5,090 kg and 5,370 kg. Thus, the aircraft was being operated in aerial agricultural operations at a weight in excess of the basic, flight manual-approved maximum take-off weight (MTOW) of 4,200 kg. The speeds reached and bank angles obtained during the accident flight were within the flight manual limitations, but exceeded some of the additional limitations listed on the Type Certificate Data Sheet (TCDS) and the associated flight manual supplements for overweight operations. The inclusion of the supplements in the flight manual was optional.

Under Civil Aviation Safety Authority (CASA) exemption EX56/07, the aircraft could be operated up to a MTOW of 5,300 kg, the maximum weight listed on the TCDS. CASA exemption EX09/07 then permitted the pilot to exceed the MTOW listed in the flight manual, provided that the pilot complied with all other flight manual limitations.

The wording of the CASA exemptions appears to have been interpreted by operators such that the M-18A could be operated up to 5,300 kg while only adhering to the limitations contained within the basic flight manual. However, the TCDS contained additional restrictions on the operating limitations for flight above the original MTOW, including reductions in several of the operating speeds and load factors. Those restrictions were imposed by the manufacturer to retain an acceptable level of safety when operating at the higher weights. Hence, operation of an M-18A above 4,200 kg in accordance with the CASA exemptions may not provide the same level of safety as that intended by the manufacturer, and the European Aviation Safety Agency, when they approved the higher MTOW operations.

Operation of the aircraft in accordance with that interpretation of the CASA exemptions also denied the pilot additional safety information that was contained in the flight manual supplements for application to operations at the increased MTOWs (Supplement Nos 1 and 16). This included an additional limitation that was placed on the bank angle, a restriction on the operation type at those weights to firefighting only, and information that the aircraft had a dynamic longitudinal instability at weights above 4,700 kg.

While the recorded data did not provide information on the final moments of the flight, it did provide information on how the aircraft was being operated leading up to the accident. That information indicated that the aircraft was being flown within the limitations of the basic aircraft flight manual, but at speeds and bank angles in excess of the limitations listed in the TCDS and associated flight manual supplements.

Application of service life factors

Examination of the aircraft's maintenance records showed that, with the exception of a 150 hour difference due to a transcription error, the hour meter reading correlated with the total time in service that was recorded in the maintenance documentation. This indicated that there had been no factoring of the hours flown to determine the total time in service. Thus, either this was the aircraft's first flight at a weight above 4,700 kg, or the operator had not been factoring the hours when required. It could not be objectively determined if this was the aircraft's first flight above 4,700 kg as the operator did not record the take-off weight for each flight but, given the type of operation and CASA exemptions, it was considered unlikely that the aircraft had flown all previous flights at weights below 4,700 kg.

The purpose of the factoring was to account for the additional fatigue damage accumulated as a result of the increased stresses at the higher weights. Thus, without application of the factor, an aircraft's remaining fatigue life would have been unknown. However, a recalculation of IGT's service life carried out after the accident, which included a conservative application of the service life factors, indicated that the aircraft was still within the permitted service life.

The operator had no procedures that allowed the calculation of the service life factors for its M18 Dromader aircraft when operated at take-off weights above 4,700 kg. That resulted in the operator not applying the service life factor applicable for operations at those take-off weights to any of their aircraft. This non-application of the service life factors could have adversely affected the continued safe operation of the operator's M18 and M18A Dromader (TPE331) aircraft.

The only documentation that would have made the operator aware of the need to apply the service life factors for operation above 4,700 kg was contained in aircraft flight manual supplement 16 and in the aircraft's structural repair manual. According to the operator's interpretation of the CASA overweight exemptions, operation of the aircraft above 4,700 kg was possible without the need to include supplement 16 in the aircraft's flight manual. In that case a pilot, who was not required to consult the structural repair manual, would not have been aware of a need to either record the take-off weight, or to factor the flight hours.

In addition, the structural repair manual was normally only referenced by maintenance personnel for specific repair actions, rather than for routine continued airworthiness information. The operator's interpretation of the CASA exemptions, and the location of the service life factors in the structural repair manual, made it unlikely that the operator was aware of the need for such a procedure.

Furthermore, the records from a number of other operators' M18 Dromader (TPE331) did not include any service life factoring. That suggested that the non-recording of service life factors was more widespread.

FINDINGS

From the evidence available, the following findings are made with respect to the in-flight breakup of PZL M18A Dromader (TPE331) aircraft, registered VH-IGT, which occurred 58 km south-west of Nyngan, New South Wales on 29 December 2008. They should not be read as apportioning blame or liability to any particular organisation or individual.

Contributing safety factors

- The outboard section of the right wing separated from the aircraft following failure of the primary structure.
- Control of the aircraft was lost after the outboard section of the right wing separated in-flight, resulting in the aircraft impacting terrain.

Other safety factors

- A number of operators of the PZL M18 Dromader aircraft had not applied the appropriate service life factors to the aircraft's time in service for operations conducted with take-off weights greater than 4,700 kg, as required by the aircraft's service documentation. Hence the operators could not be assured that their aircraft were within their safe service life. *[Significant safety issue]*
- Operation of the M-18A in accordance with Civil Aviation Safety Authority exemptions EX56/07 and EX09/07 at weights in excess of the basic aircraft flight manual maximum take-off weight (MTOW), and up to the MTOW listed on the Type Certificate Data Sheet, may not provide the same level of safety intended by the manufacturer when including that weight on the Type Certificate. *[Significant safety issue]*

SAFETY ACTION

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

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

Recording service life factors

Significant safety issue

A number of operators of the PZL M-18 Dromader aircraft had not applied the appropriate service life factors to the aircraft's time in service for operations conducted with take-off weights greater than 4,700 kg, as required by the aircraft's service documentation. Hence the operators could not be assured that their aircraft were within their safe service life.

Action taken by the aircraft operator

The aircraft operator has advised the ATSB that now that they are aware of the need to apply service life factors to operations above 4,700 kg, they have undertaken a retrospective process of applying the service life factors to their aircraft fleet. As a result of that review, all of the operator's M-18 Dromader aircraft were found to be within the permitted service lives.

ATSB assessment of action

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

Action taken by the Civil Aviation Safety Authority

On 17 November 2011, the Civil Aviation Safety Authority (CASA) informed the ATSB,

> ...that CASA has written to the registered operators of all Australian registered M18 Dromader aircraft type to verify that, where applicable, they have procedures for recording aircraft time in service conducting overweight operations, and for the proper factoring of overweight flight time for calculation of the airframe service life.

> Responses have been received and assessed and, where necessary, CASA has conducted follow-up with particular operators. Further verification of operator procedures is expected to occur in accordance with CASA's surveillance program.

ATSB assessment of response

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

Civil Aviation Safety Authority

Exemptions for overweight operations

Significant Safety issue

Operation of the M-18A in accordance with Civil Aviation Safety Authority exemptions EX56/07 and EX09/07 at weights in excess of the basic aircraft flight manual maximum take-off weight (MTOW), and up to the MTOW listed on the Type Certificate Data Sheet, may not provide the same level of safety intended by the manufacturer when including that weight on the Type Certificate.

Action taken by the CASA

On 2 December 2011, CASA advised that it would inform all M18A operators other than those that have a supplemental type certificate permitting operation to 6,600 kg, that the exemptions do not permit agricultural operations in the restricted category above 4,700 kg MTOW. CASA also advised that they will be revising the exemptions to ensure that the intended interpretation is clear to operators.

ATSB assessment of response/action

The ATSB is satisfied that, when completed, the action taken by CASA will adequately addresses the safety issue.

APPENDIX A: RECORDED DATA

A SATLOC Airstar V4.38 was fitted to the aircraft and was used to assist in the conduct of agricultural spraying operations and to record information on the flight. The system recorded Global Positioning System (GPS) data, heading, and GPS-derived groundspeed, altitude and spraying information about every 1.5 seconds. This data was recorded on a Compact Flash (CF) memory card, although there was a buffer between the recording of the data and it being written onto the CF card. Following the accident, the CF card was found ejected from the recording device.

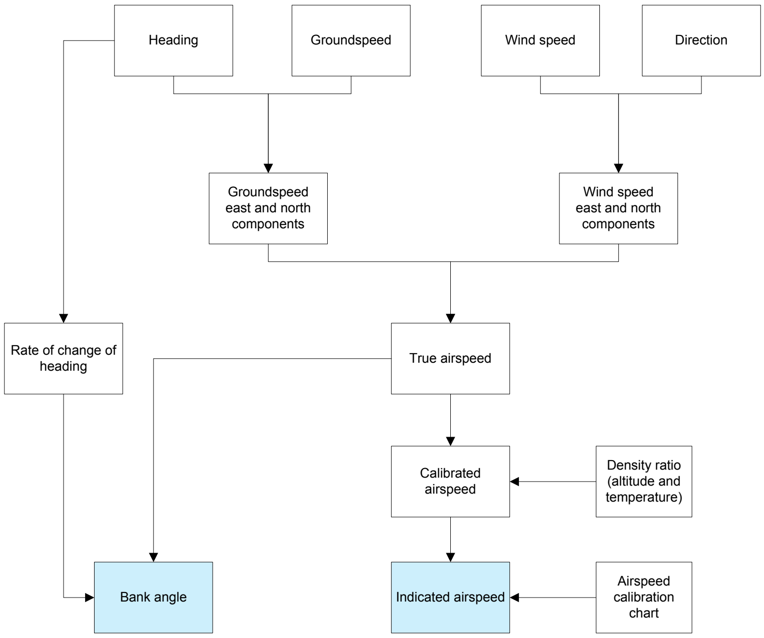
The SATLOC manufacturer advised that the associated software application writes to the volatile memory every 10 seconds. Then, depending on the version of the application, the data is written onto the non-volatile memory (CF card) at a time interval of either 30 seconds, 60 seconds or possibly longer. Volatile memory is lost when electrical power to the system is lost.

The CF card was downloaded and converted into an American Standard Code for Information Interchange (ASCII) file format using the manufacturer's software. The recorded data ceased at a point in the flight when the aircraft was turning right at a height of about 210 ft above ground level (AGL) and at a groundspeed of 117 kts, about 3,500 m south of the accident site.

The time taken to travel a similar distance on the previous southerly spray run was about 50 to 55 seconds. On that basis, and given the consistency of the recorded groundspeed, it is likely that the missing track data was in the volatile memory and yet to be written to the CF card when the accident occurred. The JOB and MARKS files that were written to the CF card after the last track point indicates that the system was functioning at that time.

The SATLOC GPS data was used to estimate the indicated airspeed and bank angles during the flight to enable a comparison of the aircraft's operating regime and the operating limitations. The methodology used to convert the data is shown in Figure A1.

Figure A1: Conversion of SATLOC data to indicated airspeed and bank angle



The true airspeed (V_T) was then converted to calibrated airspeed (V_c) by taking into account the density ratio (σ)[40] in the formula:

$$V_c = V_T \times \sigma$$

The calibrated airspeed was converted to indicate airspeed using the airspeed correction chart in section 5 of the M18A Dromader Aircraft Flight Manual.

The bank angle was derived using the calculated true airspeed and the rate of turn using the following formula:[41]

$$\emptyset = \tan^{-1}\left(\frac{ROT \times V_T}{1091}\right)$$

Where:

ROT is the aircraft's rate of turn (rate of heading change).
Ø is the aircraft's bank angle in degrees.
V_T is the aircraft's true airspeed in kts.

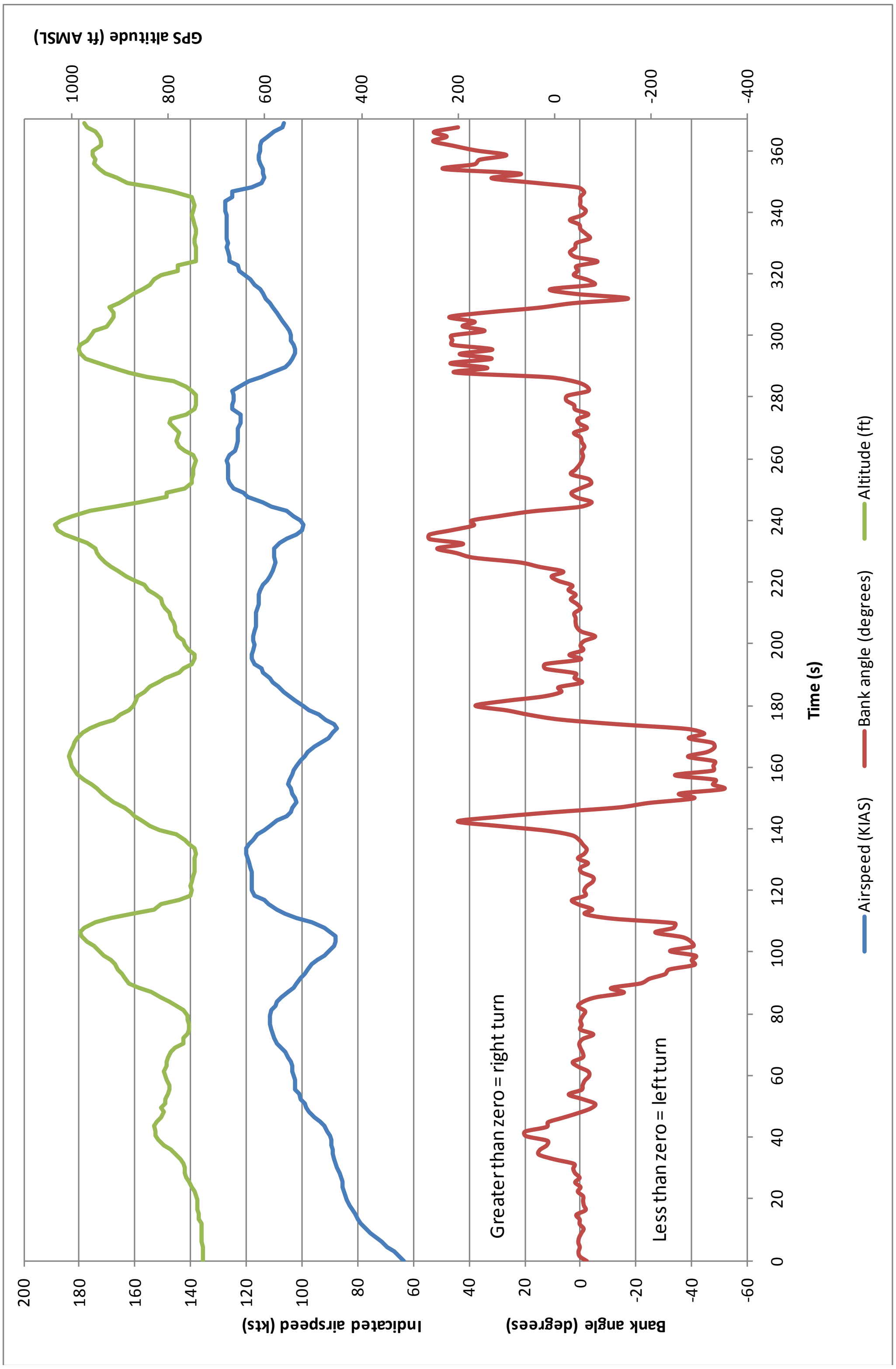
The wind speed and direction used was from the Bureau of Meteorology-reported conditions at Nyngan. The calculated indicated airspeeds in the reciprocal north and south spray runs (final two spray runs) indicates that the wind speed estimate was reasonably accurate as the pilot would be expected to maintain a constant airspeed during the spray runs, regardless of the spray direction.

40 The density ratio is the ratio of the local air density to the density at sea level. The local density is a function of the local pressure altitude and the temperature.

41 Wood, R. H., & Sweginnis, R.W. *Aircraft Accident Investigation*. Second Edition, Endeavour Books, Casper USA, 2006.

The derived bank angles for the flight are presented in Figure A2, together with the altitude data that was taken directly from the SATLOC track data.

Figure A2: Recorded data from the accident flight



APPENDIX B: TECHNICAL ANALYSIS REPORT

ATSB TECHNICAL ANALYSIS
AO-2008-084
Final

Engineering analysis - outboard wing section from a PZL M18A Dromader aircraft 58 km south-west of Nyngan, New South Wales 29 December 2008 VH-IGT

Released in accordance with section 26 of the *Transport Safety Investigation Act 2003*

SUMMARY

On 29 December 2008, a PZL M18A Dromader aircraft impacted terrain near a homestead, 58 km south-west of Nyngan, New South Wales. The pilot was fatally injured.

Wreckage from the aircraft was located in a flat paddock, where the trail of debris extended over a few hundred metres. The outboard section of the right wing was found to have separated from the aircraft during the flight and was the first item of wreckage within the debris field. The separated wing section was recovered from the accident site for detailed examination by Australian Transport Safety Bureau (ATSB) specialist investigators in Canberra.

The ATSB examination showed that failure of the principal load bearing sections of the wing section had occurred under conditions of gross overstress. There was no evidence of pre-existing mechanical damage, corrosion, or fatigue cracking that may have impaired the structural integrity of the wing section. The directionality of the permanent, plastic deformation associated with the main and rear spar failures was consistent with the wing failing in upward bending.

FACTUAL INFORMATION

Introduction

Late in the morning of 29 December 2008, the pilot of a PZL-M18A Dromader aircraft took off from a rural New South Wales property to conduct agricultural aerial spray operations. The aircraft was observed by two witnesses to have flown over the property's homestead and a short time later, one of the witnesses reported that they saw something release and fall from the aircraft. The aircraft was observed to immediately roll and descend before it impacted the ground. The pilot, who was the sole occupant of the aircraft, was fatally injured.

Preliminary on-site investigation by investigators from the Australian Transport Safety Bureau (ATSB) found the aircraft wreckage to be distributed within a level paddock approximately 900 m from the property homestead. The debris trail was spread over a distance of about 330 m. The main wreckage of the aircraft had sustained gross fragmentation as a result of impact forces. Items of note that had liberated from the airframe included the aircraft's engine and the propeller blades. Two of the propeller blades were located approximately 200 m forward of the main wreckage.

The outboard section of the right wing was located approximately 100 m before the fuselage impact point, and was the first item along the debris trail (Figure B1). Sections from the aircraft's hopper, the light bar and the pilot's canopy were also found before the main impact. The right aileron was found near the main wreckage, having broken into two sections along the same line as the wing failure.

Figure B1: Outboard right wing section - as found at the accident site

Examination scope

The outboard section of the right wing was examined at the ATSB's engineering facilities to determine:

- the principal modes and mechanisms of the structural failure
- whether any pre-existing defects or damage may have contributed to the wing failure.

Structural examination – right wing outboard section

Wing construction

The outboard section of the PZL M18A Dromader wing structure was primarily constructed of a main and rear spar, ribs and skin (Figure B2). The wing spars were the primary load bearing structure that transferred aerodynamic lift loads to the fuselage. The wing skin formed the aerofoil shape and endowed the structure with a degree of rigidity; the ribs transferred air loads into the spars. The spars were constructed from aluminium alloy sheet that had been folded to form a 'C-section'. The wing structure was assembled primarily with solid, aluminium rivets.

General overview

Representatives for the New South Wales Coroner, from the Civil Aviation Safety Authority (CASA) and for the aircraft operator were in attendance during the ATSB examination. Preliminary inspection of the recovered wing section focused on identifying the points of primary structural failure. The location of structural separation was identified as shown in Figure B2. Measurements showed that the wing failure had occurred effectively transversely through both the main and rear spars in a chord-wise manner, between 1.84 m and 1.88 m from the wing tip.

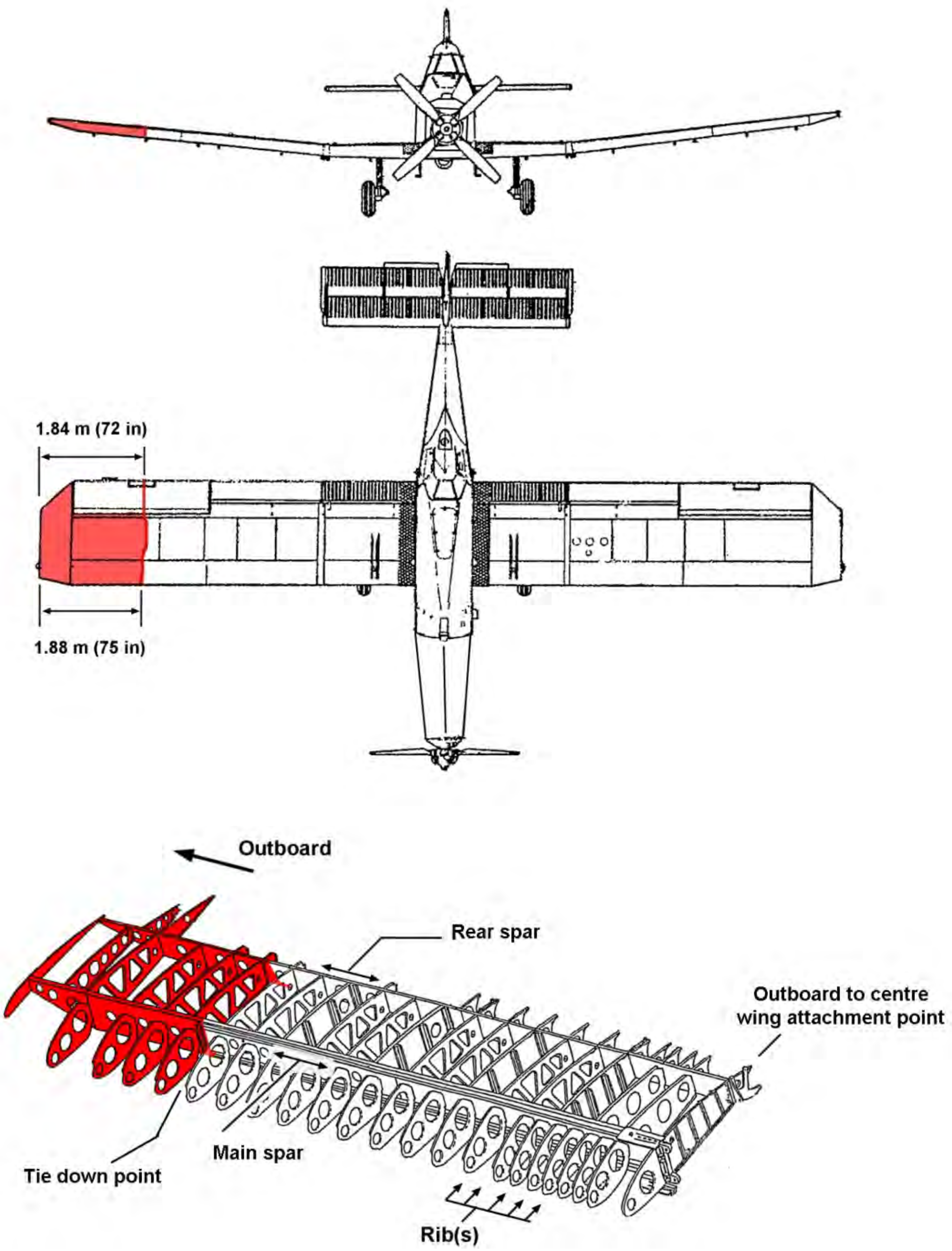
Crushing of the inboard leading edge region had occurred from impact with the ground (Figures B3 and B4). Soil from the accident site was dispersed within the folded sections of leading edge skin. Several minor indentations were also observed along the leading edge, close to the wing tip. It could not be determined whether or not the indentations had been produced during the accident sequence.

Other damage associated with the fracture and separation of the wing section included span-wise tearing and wrinkling of the upper wing skin. The tearing followed the rear spar in an outboard direction across several ribs.

The examination revealed no sooting from exposure to fire, or pre-existing mechanical damage to the wing structure that might have affected the structural integrity of the outboard wing section. All of the surfaces were relatively clean and free from the effects of environmental damage such as corrosion. Careful scrutiny of the entire separated wing section did not reveal any evidence of a tree impact.

No evidence was found that the failed section had been repaired or modified. The surfaces of the alloy spars and ribs presented a uniform golden-green colouration, consistent with the application of a chromate conversion coating[42].

Figure B2: Illustration of the PZL M18A Dromader aircraft and wing structure depicting the approximate location of the in-flight wing separation



42 Corrosion resistant coating that is formed when a bare aluminium surface is immersed or sprayed with an aqueous solution of chromic acid and chromium-rich salt.

Note: Separated outboard section of right wing is highlighted in red.

Figure B3: View of the separated right wing as received

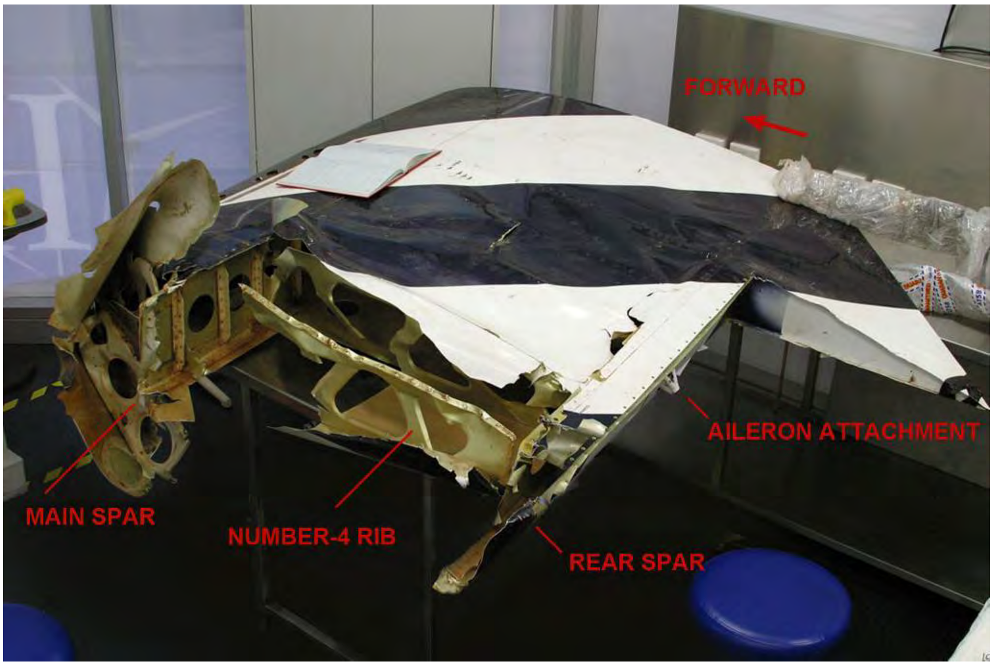
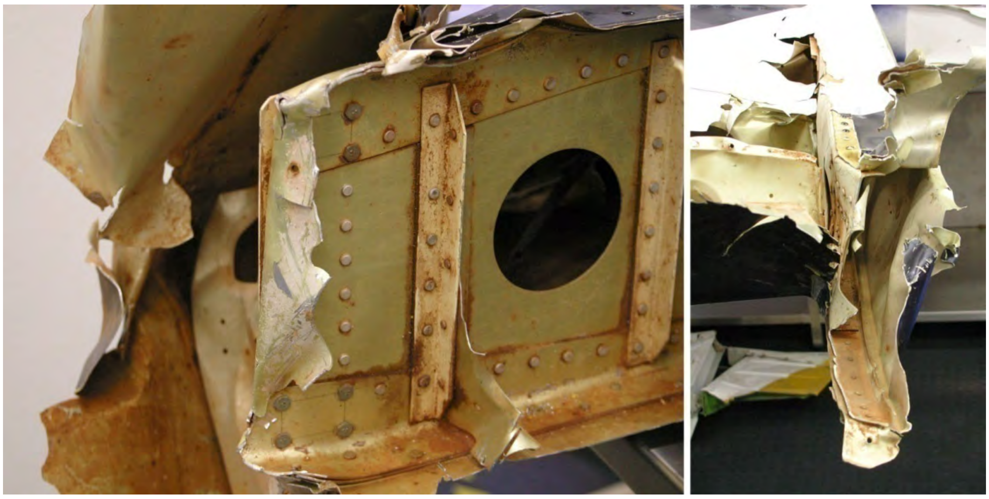


Figure B4: Composite image showing alternate views of the main spar (left) and rear spar (right) as received



Primary wing structure - spar examination

The main and rear spars formed the primary load bearing structure for the Dromader's wing. Visual examination of that structure showed that the point of fracture through the main spar was located slightly inboard of the front tie down strap (Figures B5 and B6). Measurements showed that the rear spar had fractured through the spar caps and web, approximately 200 mm inboard from the number-4 rib (Figures B7 and B8).

Similar levels of plastic deformation were present in both the main and rear spars. Adjacent to the fracture of each spar, both the upper skin and cap surfaces were wrinkled, consistent with compression loading. Conversely, the lower caps for each spar were permanently deformed and had been bent in an upward manner. Elongation of one of the rivets from the main-lower spar cap in the vicinity of the fracture was consistent with exposure to tensile loading (Figure B9).

Wing spar fractography

The wing spar fracture surfaces were excised from the main structure to enable a more detailed examination. Optical microscopy of the spar fracture surfaces was performed using a range of magnifications. The examination showed that all of the fracture surfaces presented characteristic ductile shear and/or tensile overstress features consistent with combined tension and bending loads (Figures B10 and B11). There was no evidence of pre-existing cracking, mechanical or corrosion damage that could have compromised the overall strength of the wing and contributed to the failure.

Figure B5: Segment of outboard main wing spar – view looking forward

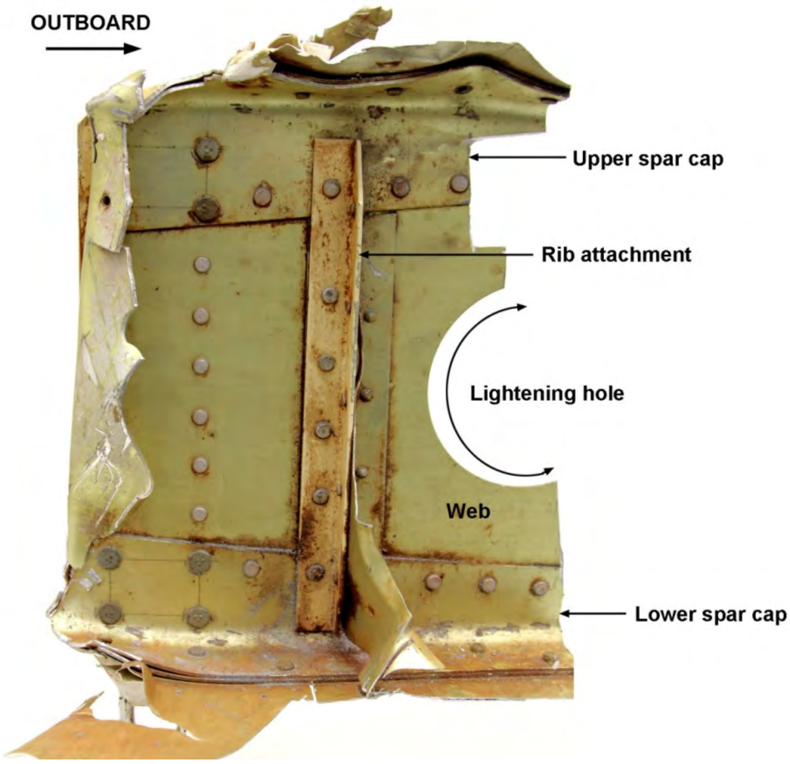


Figure B6: Segment of outboard main wing spar – view looking rearward

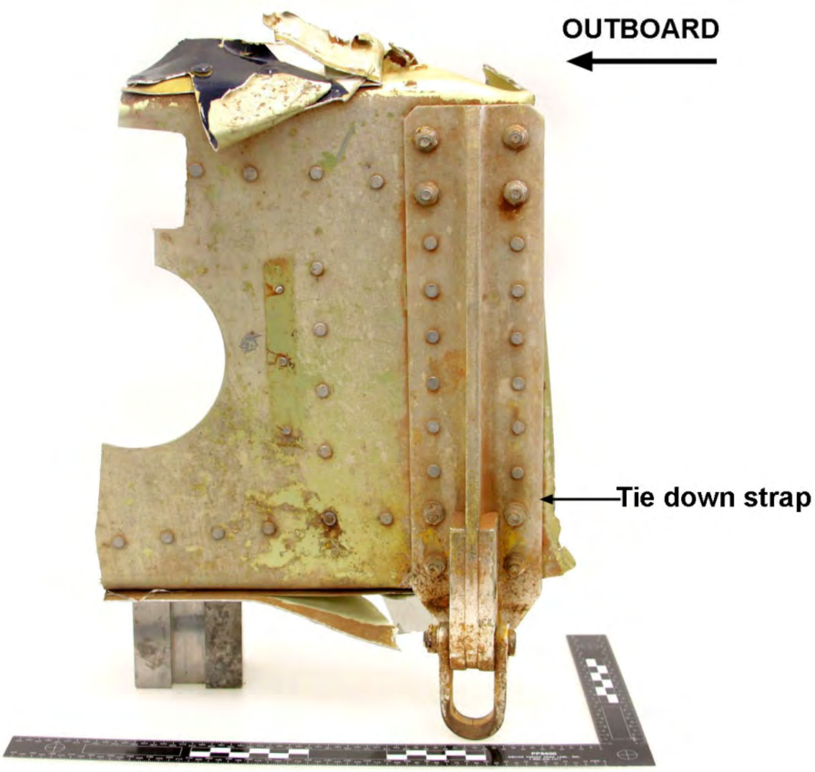


Figure B7: Segment of rear outboard wing spar – view looking rearward

Figure B8: Segment of rear outboard wing spar – view looking forward

Figure B9: Elongated rivet from the main spar lower cap - adjacent to the fracture surface

Figure B10: Detailed view of the fracture surface from the main spar lower cap region - ductile shear features present

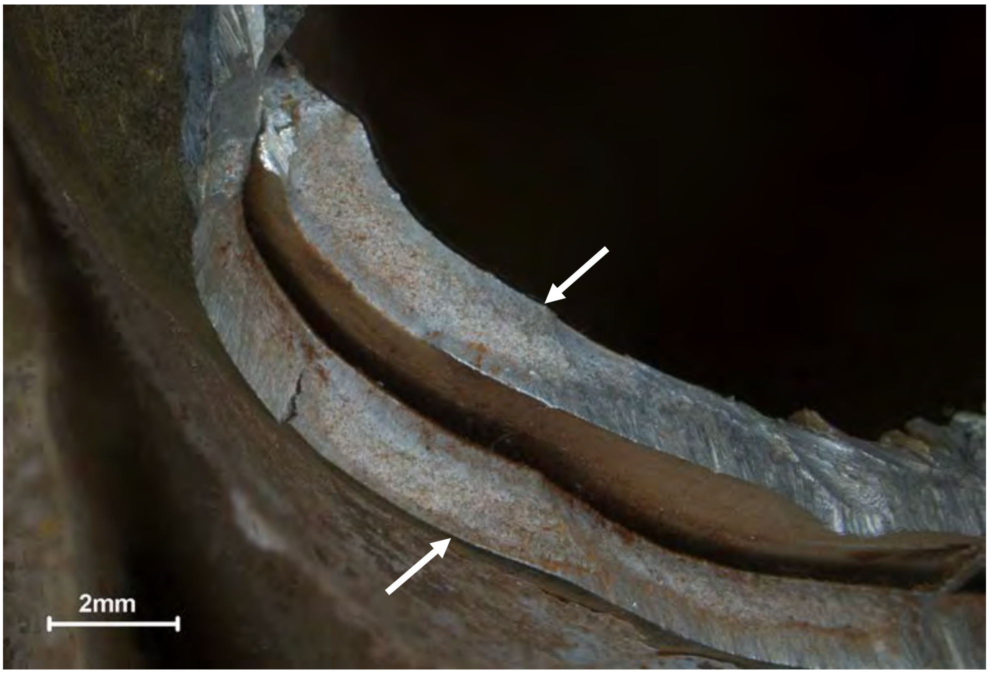
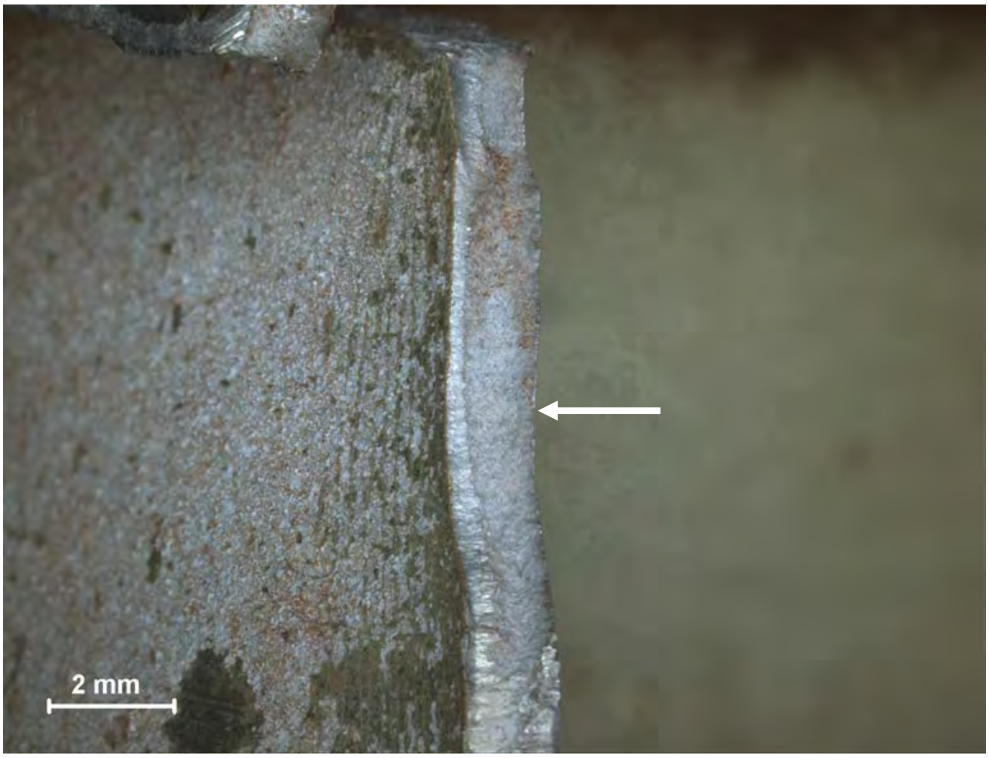


Figure B11: Detailed view of the fracture surface from the main spar web region - ductile shear features shown

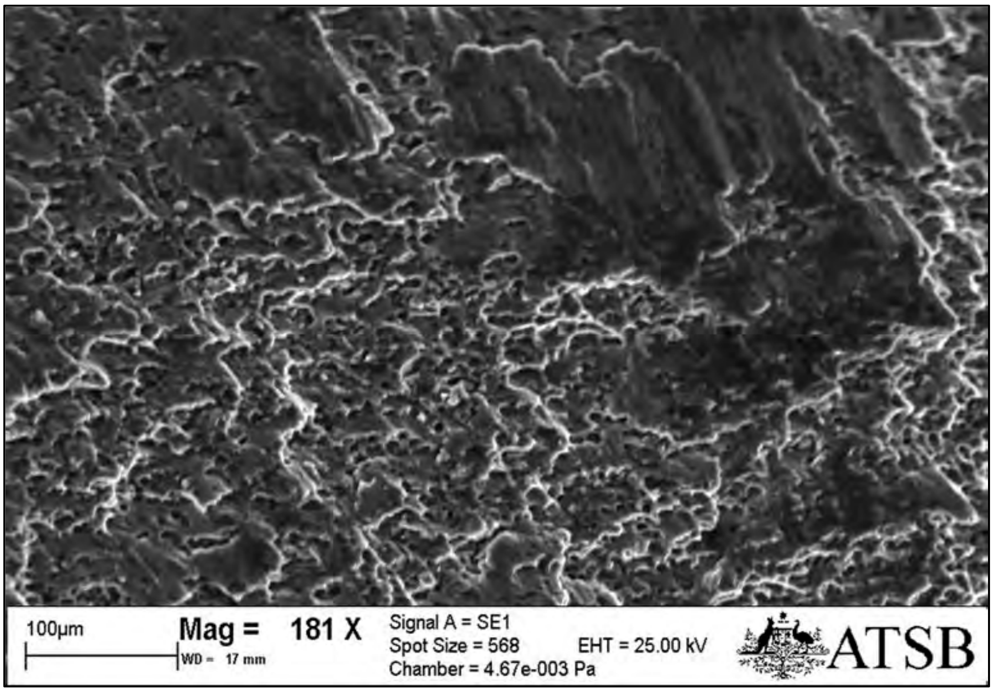


Additional testing

Scanning electron microscopy

Scanning electron microscopy (SEM) techniques were used for further detailed examination and characterisation of the fracture surfaces of the main and rear spar at several areas that were representative of the fracture as a whole. Under the SEM, each region exhibited either angular or dimple-type rupture features. Those rupture features were consistent with rupture as a result of a combination of either shear and/or tensile overstress (Figure B12).

Figure B12: SEM micrograph showing ductile shear failure of wing spar material



Chemical analysis

Semi-quantitative chemical analysis of both the main and rear wing spar material was performed using energy dispersive spectroscopy (EDS). The EDS analysis showed that the wing structure had been manufactured from an aluminium/copper/magnesium alloy consistent with the 2024 grade specified by the aircraft manufacturer.

Hardness and electrical conductivity

Sections were removed from the upper and lower cap, and the central web regions of both spars for hardness and electrical conductivity measurement. Vickers hardness testing showed no discrepancy between the hardness levels of either spar in the areas examined, with all levels falling between 155 and 157 HV[43], consistent with a 2024 aluminium alloy in the T3, or T4 temper condition[44].

Electrical conductivity measurements on the spar structure returned results between 27 and 28 % IACS[45], again consistent with the properties of a 2024 aluminium alloy.

Right wing – outboard aileron attachment

The right aileron had also separated into two sections as a result of the wing failure. Both sections of the aileron were found near the main wreckage and had failed in a manner coincident with the outer wing failure. The tubular outboard aileron attachment fitting remained bolted to the rear spar of the separated wing section, but had fractured at the welded juncture of several inboard reinforcing sections (Figure B13). The aileron attachment was subsequently unbolted from the rear spar and examined using a stereo-microscope.

The examination revealed features that were consistent with a gross overstress fracture. Some corrosion product had formed on the fitting fracture surfaces, but the corrosion was light and consistent with having developed during the post-accident time-frame. All fracture features were angular in nature with no evidence of fatigue cracking or other anomalous damage.

Examination of the aileron combing showed no evidence of oscillatory movements or flutter that might have otherwise indicated an issue with the control surface. The surface paint in that area was generally intact and free from contact damage.

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43 Vickers hardness (HV) testing was used to measure the hardness properties of the wing spar material. The tests were performed using a diamond pyramid indenter and a 0.2 kg indentation load.

44 The ‘T’ temper designation system denotes a stable temper for wrought aluminium products that are strengthened by heat treatment.
T3 temper – solution heat treated, cold worked and naturally aged to a stable condition.
T4 temper – solution heat treated and naturally aged to a stable condition.

45 International Annealed Copper Standard is the electrical conductivity as a percentage of pure copper.

Figure B13: Right wing outboard aileron attachment point

ANALYSIS

Structural failure and damage

It was evident from the Australian Transport Safety Bureau (ATSB) examination that the outboard section of the right wing had separated from the aircraft under conditions of gross overstress. Based on the spar fracture surface morphology and the associated localised deformation, it was evident that the right wing had been subjected to bending loads that exceeded the ultimate strength of the wing section at the point of failure.

It was noted that the main spar web fracture surfaces had been deformed and bent toward the wing tip (Figure B3). Deformation of that orientation was consistent with failure occurring under upward bending loads. It was probable that the buckling of the spar web occurred under the influence of those loads during the wing failure sequence.

The examination found no evidence of progressive cracking or mechanical damage, nor evidence of corrosion that may have otherwise reduced the strength of the wing at the point of fracture. No manufacturing anomalies were observed, nor was there any evidence to indicate that the separation of the wing section was as the result of an external, foreign-object impact (such as a tree strike).

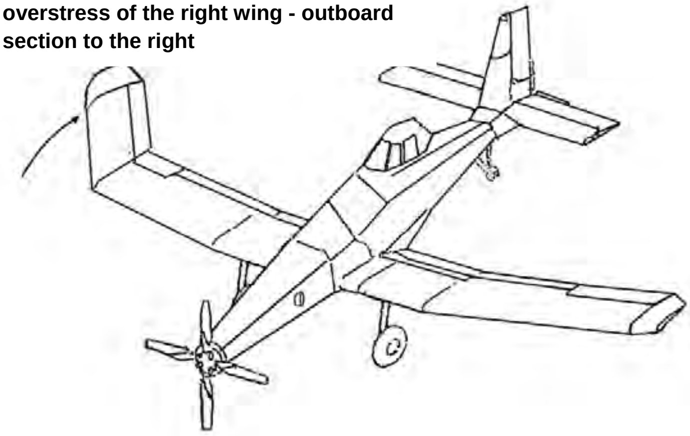
Breakup sequence

The physical evidence was consistent with exposure of the wing to significant upward loading. The bending moments thus produced resulted in the localised upward bending and fracture of the wing structure, approximately 1.8 m from the wing tip. Once the primary load bearing structures (main and rear spars) had fractured, it was likely that the wing separated from the aircraft and impacted the canopy. This conclusion was supported by the presence of the outboard section of the right wing before the main wreckage impact point, along with pieces of hopper, light bar, and windscreen that were found in the area around the separated wing section. Figure B14 provides an illustration of the likely breakup sequence.

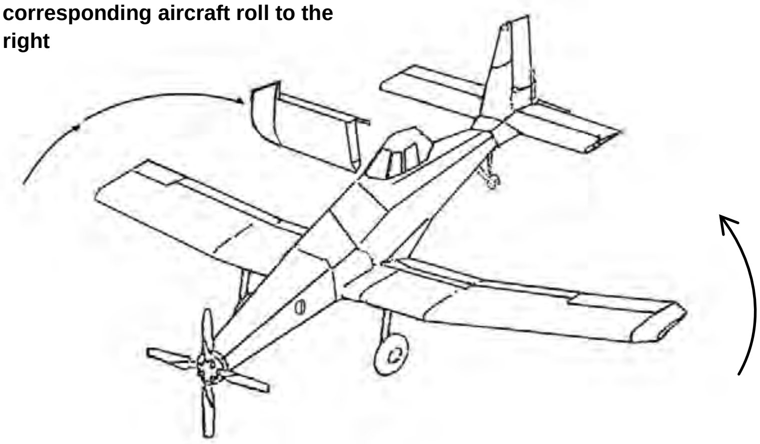
Figure B14: Illustration of the PZL M18A Dromader aircraft showing the primary failure sequence

1.

2. Upward bending and structural overstress of the right wing - outboard section to the right



3. Separated wing section impacts the cockpit canopy, with corresponding aircraft roll to the right



CONCLUSIONS

The following statements are a summary of the conclusions drawn during the structural examination of the outboard section of the right wing from PZL M18A Dromader aircraft, VH-IGT:

- the separation of the outboard section of the right wing, inboard of the aircraft tie down point, was consistent with structural overstress initiated by upward bending loads
- there was no evidence of material or manufacturing abnormalities within the aircraft wing structure that may have contributed to the right ring fracture and separation
- there was no evidence of pre-existing corrosion, fatigue cracking or mechanical damage that might have affected the wing structure at the location of the failure.

APPENDIX C: SOURCES AND SUBMISSIONS

Sources of Information

The main sources of information during the investigation were the:

- Aerial Agricultural Association of Australia (AAAA)
- Air Accidents Investigation Branch of the United Kingdom (UK AAIB)
- Bureau of Meteorology
- Civil Aviation Safety Authority (CASA)
- Civil Aviation Regulation (CAR) 35 organisation responsible for Supplemental Type Certificate (STC) SVA521 (STC SVA252)
- US Federal Aviation Administration
- manufacturer of the SATLOC
- manufacturer of the M18 Dromader
- US National Transportation Safety Board (NTSB)
- New South Wales Coroner
- New South Wales Police Force
- operator of the aircraft
- Poland Air Accident Investigation Board.

Submissions

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

A draft of this report was provided to the aircraft operator, the AAAA, CASA, the CAR 35 organisation responsible for STC SVA252, the manufacturer of the M18 Dromader, the NTSB and the Poland Air Accident Investigation Board.

Submissions were received from the aircraft operator, the AAAA, CASA, the CAR 35 organisation responsible for STC SVA252, the manufacturer of the M18 Dromader, the NTSB and the Poland Air Accident Investigation Board. The submissions were reviewed and where considered appropriate, the text of the report was amended accordingly.

In-flight breakup - PZL M18A Dromader, VH-IGT,
58 km SW of Nyngan, NSW, 29 December 2008