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Aviation Occurrence Investigation
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FINAL

Aero Commander Div

Shrike Commander

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FACTUAL INFORMATION

History of the flight

At 1629 Eastern Daylight-saving Time on 19 February 2004, an Aero Commander 500-S (Shrike) aircraft, registered VH-LST (LST), commenced taxying at Hobart for a Visual Flight Rules (VFR) ferry flight to Devonport. The pilot, who was the sole occupant, reported a departure time of 1643 to air traffic control, with an intention to climb to 8,500 ft and to fly a track of 319 degrees magnetic.

Due to following traffic, the pilot was required to report leaving specific altitudes. At 1646, the pilot reported leaving 4,500 ft, and was advised that air traffic services were terminated. The acknowledgement of that call was the last communication heard from the pilot.

At about 1800, the operator's staff at Devonport advised the Hobart base that the aircraft had not arrived. The operator advised AusSAR[1] and the Hobart air traffic control tower, and organised company search aircraft from both Hobart and Devonport. The non-flying occupant of the Hobart search aircraft sighted the wreckage at about 1930 (see Figure1). Shortly after, a search and rescue helicopter arrived at the accident site. The pilot of the aircraft was found fatally injured in the wreckage.

Figure 1: Main wreckage

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[1] Australian Search and Rescue – In general terms, AusSAR coordinates the response to aviation SAR incidents across Australia.

The wreckage was located 58 km from Hobart airport on a bearing of 320 degrees magnetic. Based on predictions of aircraft performance and the distance of the accident site from Hobart, the estimated time of the accident was 1656. There were no eyewitnesses to the accident.

Aircraft flight profile

The aircraft was not equipped with a flight data recorder or cockpit voice recorder, nor was it required to be. As such, and given that the aircraft was operating outside of radar coverage, there was no recorded flight profile information available. The pilot was not required to report cruising at 8,500 ft and there was no evidence to confirm that the aircraft had reached that altitude. However, based on the normal climb and cruise performance, forecast winds and the radio broadcasts made by the pilot, the aircraft should have reached an altitude of 8,500 ft approximately 35 km from Hobart at about 1651, which was 5 minutes prior to the estimated time of the accident at 1656.

Pilot qualifications, training and experience

The pilot obtained a commercial (aeroplane) pilots licence in August 2002 after training with a flight school on mainland Australia. In August 2003, the pilot moved to Tasmania to train for a multi-engine command instrument rating with the aircraft operator. Most of that flight training was conducted in Aero Commander 500-S aircraft. The pilot passed an instrument rating flight test conducted on 12 January 2004 in an Aero Commander 500-S. In addition to the training, the pilot was employed part-time by the operator to conduct VFR charter flights in single engine aircraft.

The ATSB investigation was unable to locate the pilot's Aero Commander endorsement and instrument training records. The chief flying instructor reported that they usually retained training records; however, the pilot's records had not been seen since the rating flight test.

Three Grade 1 instructors were involved in the pilot's Aero Commander 500-S endorsement and instrument rating training. They reported that the pilot was of a sound standard and prepared well for all the training flights. In their opinion, the pilot displayed sound airmanship and decision-making skills. It was reported that the pilot had training in recovery from unusual attitudes, turbulence penetration and autopilot use during the aircraft endorsement and instrument rating training. The operator encouraged the use of the autopilot during the enroute phase of instrument flight rules (IFR) navigational exercises to assist workload management. The pilot's training included four IFR navigational exercises in LST.

The pilot had logged a total aeronautical experience of 371 hours. The pilot had logged 40.6 hours experience on Aero Commander 500-S aircraft since commencing endorsement training with the operator, 20.5 hours of which were on LST. The pilot's logbook had no record of any aerobatic training.

The accident flight was the pilot’s third flight in an Aero Commander 500-S as pilot in command, the second solo flight in an Aero Commander 500-S, and the first solo flight in LST.

Pilot’s 72 hour history

Family members resided with the pilot during the week leading up to the accident. Those individuals advised that the pilot did not appear to be experiencing any personal distress, was happy and enjoyed flying with the operator.

Table 1: Pilot's 72 hour history

Date	Duty time	Total flight time	Comments
16/02/2005	0630-1700	4.9 hours	Pilot in command (PIC) of Flinders Island to Devonport ferry flight in Aero Commander. PIC of single engine Devonport to Devonport flight. PIC of Devonport to Hobart ferry flight in Aero Commander with company pilot.
17/02/2005	0800-1330	2.2 hours	PIC of single engine charter flight. Partial work day with aviation subject study, early retirement to sleep.
18/02/2005	Off duty	0.0 hours	Early retirement to sleep.

On the day of the accident, the pilot reportedly woke at about 0700 and arrived for work at 0900. The pilot was asked to ferry the accident aircraft between Hobart and Devonport later that day. The pilot returned home around mid-afternoon to collect some personal items and equipment to stay overnight in Devonport. It was reported that the pilot had eaten breakfast and lunch on the day of the accident.

According to records supplied by the operator, the pilot was within flight and duty time limitations prescribed in Civil Aviation Safety Authority (CASA), Civil Aviation Order 48.

Pilot medical issues

The pilot held a valid class-1 medical certificate with no restrictions.

There were reports that the pilot had experienced two episodes of dizziness while employed by the operator. The investigation was able to substantiate that one was related to a viral infection and that another was related to light headedness after the pilot stood up quickly having not eaten during the course of the day. The investigation did not reveal any evidence that the reported dizzy spells were associated with any underlying and ongoing medical condition, or that they contributed to the accident.

An aviation medical specialist's review of the pilot's medical records, the results of post-mortem examinations and toxicological testing, found no evidence of any pre-existing disease that may have influenced the pilot's performance.

Medication[2] was found in the pilot's personal effects at the accident site. A family member reported that the medications formed part of a travel kit for unforseen circumstances. The family member had no knowledge of the pilot ever needing to take the medications. Although the medications were common over-the-counter (OTC) products, they have the potential for unforseen side effects[3].

The CASA Designated Aviation Medical Examiner's Handbook (available at www.casa.gov.au/manuals/regulate/ dame/index.htm) advised that Imodium is a medication that is:

> ...not compatible with aviation related duties and…never to be approved for use by a medical certificate holder without prior specific written approval by CASA. [4]

The handbook also noted that herbal medications should be treated by aircrew as they would any other OTC medication and that:

> …there are no standards for quality, potency, safety or efficacy in their manufacture. Identical products may differ markedly between manufacturers or batches by the same manufacturer. Additionally, many drugs are derived from the same plants used in the herbal preparations. Therefore, many herbal preparations have the same potential side effects as manufactured drugs.

and that:

> CASA considers routine use of herbal preparations as being incompatible with flying or controlling duties.

As a consequence of limitations in the post-mortem toxicological testing, the investigation was unable to determine whether the pilot had recently used the medications. However, there was no evidence to suggest that the pilot would have needed to take such medications prior to the flight.

Meteorological information

The pilot obtained a printout of the relevant area forecast (ARFOR), aerodrome forecasts (TAF) and SIGMETs[5] that were valid for the duration of the flight. Those forecasts were found in a damaged condition in the wreckage of the aircraft.

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[2] 'Imodium' and 'Travel Calm Ginger'.

[3] Assuming recommended dosage, there is a very rare likelihood or less than 1/10,000 probability that Imodium will produce drowsiness and/or dizziness (Medical Director, 2005). The manufacturer of Travel Calm Ginger advised that there are no side effects noted in the literature at the recommended dosage.

[4] CASA Designated Aviation Medical Examiner's (DAME) Handbook – page 2.13-7. Note that issues such as the nature of the underlying medical condition being treated, the medication dosage and concentration, individual tolerance and variation to medications, and the potential for unlabelled or incorrectly labelled ingredients are important considerations.

[5] Information concerning en route weather phenomena that may affect the safety of aircraft operations.

The ARFOR winds were forecast to be from the south-west and increase from 15 kts at 2,000 ft to 45 kts at 10,000 ft above mean sea level (AMSL). Cloud en route was expected to be scattered[6] cumulus and stratocumulus with local broken[7] areas at a base of between 4,500 and 6,000 ft AMSL. The freezing level was forecast to be at 13,500 ft AMSL.

The ARFOR predicted occasional severe turbulence below 10,000 ft tending moderate after 1700. Mountain waves were forecast. A SIGMET, valid until 1700, warned of severe turbulence below 10,000 ft east of the Tasmanian ranges with weakening intensity. The location of the accident site could be interpreted as being east of the Tasmanian ranges.

The Hobart TAF indicated that cloud would be few[8] at 3,000 ft and broken at 5,500 ft AMSL. At the time of the pilot's departure from Hobart, the cloud was reported by the automatic terminal information service (ATIS) to be few at 5,000 ft AMSL and visibility exceeded 10 km.

The Bureau of Meteorology (BoM) provided additional information to the investigation that indicated that the airflow over southern Tasmania on the afternoon of the accident was a moderating south-westerly flow. While the winds on the surface and up to 11,000 ft had eased during the afternoon, the wind below 5,000 ft had decreased proportionally more than the wind above 5,000 ft. The BoM reported that this would have increased the vertical windshear between 5,000 ft and 10,000 ft and increased the potential for severe turbulence. Accordingly, the BoM considered that moderate to severe turbulence could have been encountered between 5,000 ft and 9,000 ft in the vicinity of the accident.

Although the wind below 5,000 ft had decreased, at 1657:30, a wind monitoring tower located 4.7 km to the south-east of the accident site at an elevation of 1,906 ft recorded a wind speed of 18 kts to a maximum of 22 kts from a direction of 230 degrees magnetic. According to the BoM, moderate to severe mechanical turbulence could have been encountered below 5,000 ft in the vicinity of the accident site. That may have included rotor activity[9] with the potential to produce rapid changes in the direction of relative airflow. The BoM also indicated that the level and degree of turbulence that were forecast were not uncommon weather conditions for Tasmania.

The BoM noted that there was mountain wave activity displayed on meteorological satellite photographs taken at 1549 and 1625, but that this activity was located south of the area of the accident (see Figure 2). They also indicated that mountain wave activity may have extended over the area at the time of the accident, but that it was not displayed on the photographs.

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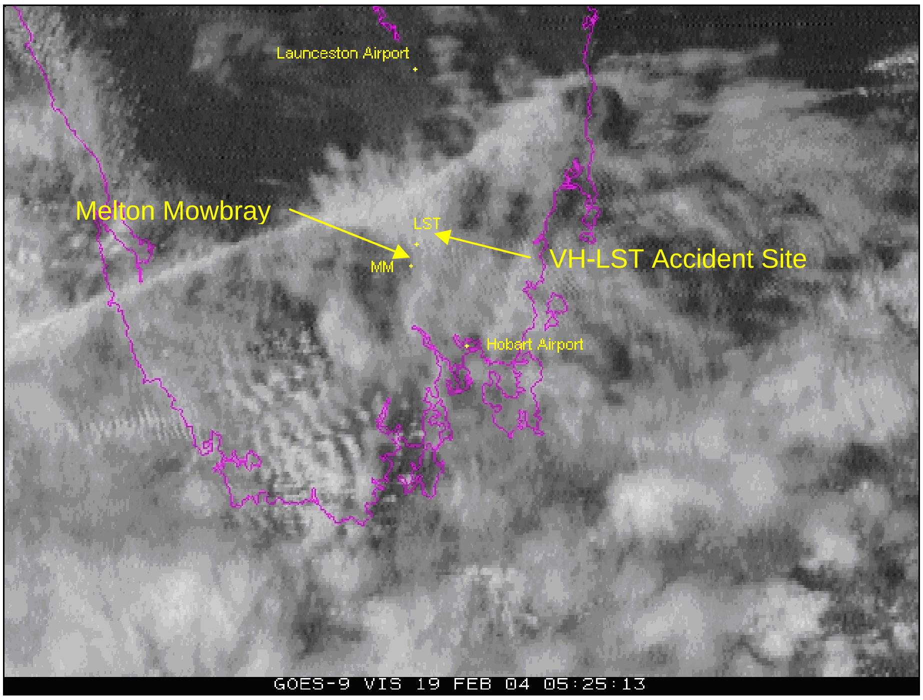
[6] Scattered - 3 to 4 eights of the sky obscured by cloud.

[7] Broken - 5 to 7 eights of the sky obscured by cloud.

[8] Few - 1 to 2 eights of the sky obscured by cloud.

[9] For additional information regarding 'rotor' phenomenon refer to ATSB report BO/200104092.

Figure 2: Meteorological satellite photo taken at 1625 (courtesy of BoM)



Pilots of an aircraft that was airborne immediately following LST, the pilot of another aircraft that was flying the same track as LST about 45 minutes after the departure of LST, and the crews of the search aircraft, all reported that the weather conditions were CAVOK[10] with no mountain wave activity or significant turbulence.

The aircraft

The aircraft was manufactured in the US in 1971, imported into Australia in 1989 and placed on the Australian register. Maintenance documentation relating to the aircraft prior to its import into Australia was reported to have been lost.

Examination of the maintenance records from 1989 onwards revealed that the aircraft had been maintained according to approved maintenance schedules. The aircraft last underwent maintenance 14 days prior to the accident, when an avionics master relay was replaced. Since the last 100 hour inspection on 10 December 2004, the aircraft had accrued 75 hours time in service.

The Aero Commander 500-S aircraft was subject to a number of airworthiness directives (ADs) relating to the inspection and verification of the wing structural integrity. The maintenance records showed that the inspections had been carried out at the required intervals with no identified defects. The records also indicated that at the time of the accident, all applicable maintenance action for the aircraft, including ADs, had been complied with.

The aircraft was estimated to be within weight and balance limitations at the time of the occurrence.

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[10] CAVOK - no cloud below 5,000 ft and visibility greater than 10 km.

Wreckage description

The main wreckage of the aircraft, which comprised the cabin, aft fuselage, inboard wing sections and both engines, came to rest inverted on undulating terrain. The aircraft had moved approximately 4 m from the first impact position. The wing sections outboard of the wing flaps of both wings and the tail section of the aircraft were not co-located with the main wreckage. These items, along with other items from the aircraft, were located in an area that was downwind of the main wreckage. Some lighter items were found up to 1,300 m from the main wreckage.

The right and left wing sections outboard of the engine nacelles and flaps had separated from the aircraft at a similar span-wise location and in a downwards direction, indicating that the force was applied in a 'negative g'[11] direction.. The wing failures had occurred in the vicinity of wing station 145[12], where the inboard spar sections are joined to outboard spar sections. No evidence of corrosion, fatigue cracking, repairs or other pre-existing structural defects that could have degraded the strength of the structure was found in this location on either wing.

Damage to the outboard left wing section indicated that, during the separation sequence, it had impacted the left main landing gear and fairing, before striking both the left horizontal stabiliser and vertical stabiliser leading edges. That subsequently resulted in the separation of the empennage from the aft fuselage in an upwards direction. The separation of the empennage resulted in distortion and tearing of the aft fuselage. There was no evidence of the right wing impacting any aircraft structure during the break-up sequence.

The ailerons, rudder and elevator flight control surfaces all separated from their respective structures during the break-up sequence. All of the control surface hinges had failed as a result of overload, or had been torn from their supporting structures with no evidence of oscillatory movement indicative of flutter[13]. All control surface mass balance weights were intact.

The elevator trim tabs and actuators remained attached to their respective elevators. Both tabs were found at or close to the maximum aircraft nose down trim position.

Within the main wreckage, the left main landing gear was found in the extended position. The mechanism for locking the landing gear in the retracted position had fractured and showed overload damage consistent with the forces produced during the aircraft breakup and subsequent ground impact. The right main landing gear locking mechanism showed similar damage. The type of damage sustained by the locking mechanisms would not have occurred if the landing gear had been unlocked or extended at the time of breakup.

The aft baggage compartment door was located in the middle of the debris field of items that had departed from the aircraft during the in-flight breakup. There were no defects found during the examination of the cargo door.

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[11] Subject to acceleration in the vertical plane in the opposite-to-normal sense, eg, aircraft in sustained inverted flight or in pushover from steep climb to steep dive; wings are bent 'downwards' (relative to aircraft attitude).

[12] Wing Station 145 is 145 inches (3.68 m) from the centreline of the aircraft.

[13] Flutter is the rapid uncommanded and increasing oscillation of the control surface or airfoil section resulting from an unstable interaction between aerodynamic and inertial loads.

For further information on the structures examination refer to Appendix A.

Engine and propeller examination

The engines and propellers were examined at approved maintenance facilities, under the supervision of the ATSB. No pre-existing defects or anomalies were identified. The damage to the propellers indicated that they were likely to have been windmilling or operating at low power at the time of impact.

Pilot restraint

Rescue personnel indicated that the pilot did not appear to have been restrained by a seatbelt. Examination of the pilot’s and co-pilot’s seat belt assemblies revealed that the pilot’s inertia reel assembly had been subjected to a significant force in a forwards and outwards direction resulting in bending of the base plate. The clasp tongue of the buckle section of the belt was bent approximately 5 degrees in an outward direction. No similar damage was noted on the co-pilot’s seat belt assembly. The pilot’s seat had been subjected to a force, which resulted in downwards deformation of the seat pan. No similar deformation was found on the co-pilot’s seat.

Autopilot and electric trim examination

The autopilot and electric trim components were examined at an approved maintenance and repair facility, under the supervision of the ATSB. Although the damage to the components precluded a comprehensive examination, there was no evidence of any pre-existing defects or anomalies. Examination of the autopilot controller ‘engage’ annunciator light bulb indicated that it was not illuminated at the time of impact.

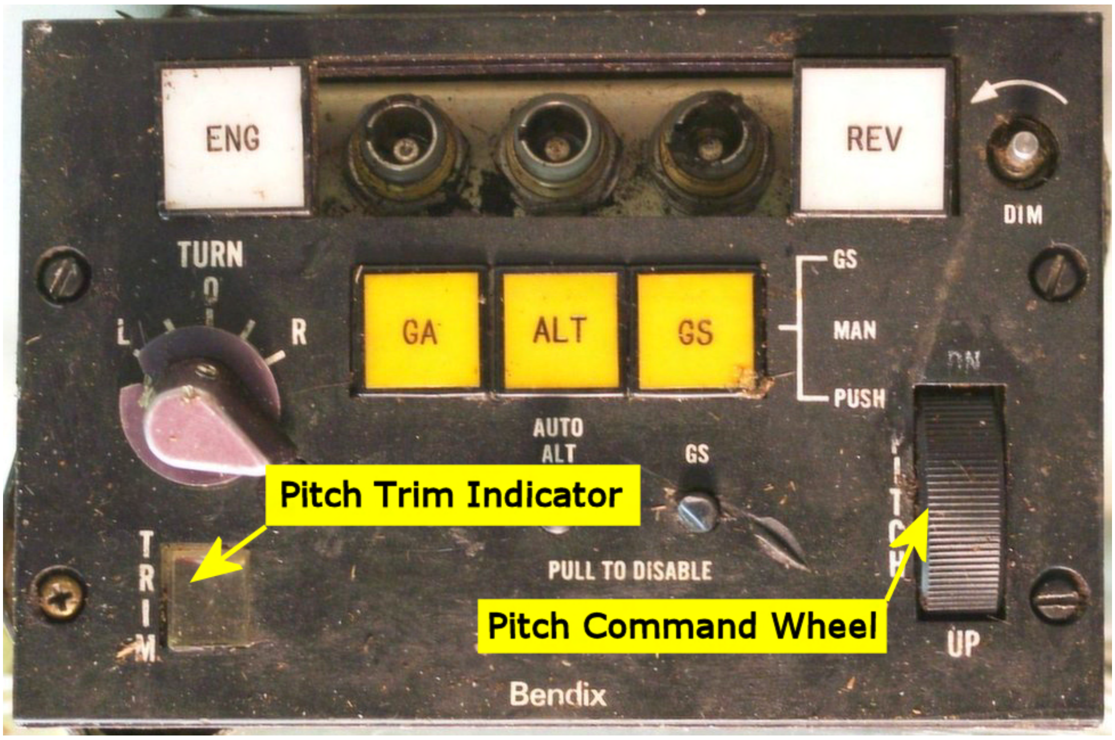
The autopilot controller pitch command wheel was found in the maximum aircraft nose down position.

Evidence from the pilot’s attitude indicator revealed that it was operating at the time of the impact.

Aircraft autopilot system

The aircraft was equipped with a Bendix FCS-810 autopilot system (see Figure 3). The operator’s two other Aero Commander 500-S aircraft were equipped with Century III autopilots.

Figure 3: Autopilot controller recovered from VH-LST



The Aircraft Flight Manual (AFM) was recovered from the aircraft wreckage. It contained a supplement specifying the autopilot limitations and operating procedures. The section of the supplement that addressed in-flight engagement of the autopilot was poorly printed and some of the text was illegible. That section would have read as follows:

> ENGAGEMENT – Manually adjust aircraft trim prior to engaging autopilot.
>
> Place aircraft in WINGS-LEVEL attitude. Adjust pitch trim indicator on controller to center needle by rotating pitch command wheel. Press the ENGAGE BUTTON [on the autopilot controller] which will light upon engagement.

Failure to correctly follow this procedure during engagement of the autopilot would result in the aircraft pitching up or down, if the position of the pitch command wheel on the autopilot controller did not match the attitude of the aircraft.

The FCS-810 autopilot incorporated automatic use of the electric pitch trim system. The AFM stated that any attempt to overpower the autopilot pitch axis would cause the pitch trim to oppose the applied force, resulting in an out-of-trim condition. For example, if the pilot applied a nose-up input to the control column, the elevator trim would be activated to produce a nose-down force. That behaviour is not exhibited by autopilot systems without automatic pitch trim such as the Century III.

The emergency operating procedures in the AFM autopilot supplement stated that if a malfunction in the autopilot was detected, the pilot must immediately disengage the autopilot by momentarily pressing the autopilot release switch on the control wheel. The autopilot could also be disengaged by switching off the autopilot master switch or by pulling the autopilot circuit breaker.

Section II of the AFM autopilot supplement was pre-flight check procedures. Those procedures included engagement of the autopilot and application of a force to the controls to determine if the autopilot could be overpowered. That was followed by disengagement of the autopilot by pressing the autopilot release switch on the control wheel. The operator's checklists did not include a pre-flight autopilot test item or autopilot emergency procedures.

The operator's operations manual contained information on the operation of the Aero Commander 500-S aircraft. The information relating to use of the autopilot pertained specifically to the Century III type autopilot fitted to the operator's two other Aero Commander 500-S aircraft. The installation of a Bendix FCS-810 autopilot in LST was not mentioned, nor was there any information in the operations manual on the operation of the FCS-810 autopilot.

Aircraft electric pitch trim system

The aircraft was equipped with a manual electric pitch trim system that could be operated automatically by the autopilot, or actuated by an electric trim switch on the pilot's control column. Movement of the switch from the spring-loaded centre position to a nose-up or nose-down direction activated an electric trim servo motor that moved the elevator trim in the selected direction.

The AFM autopilot supplement included a section on manual electric trim that stated:

> The Electric Trim System design is such that a single fault other than a stuck switch will not cause a runaway[14] trim. Other faults will be indicated by the trim warning light or by the pre-flight check. Illumination of the trim warning light indicates that a single fault has occurred but trim will not run away…

The emergency operating procedures in the AFM autopilot supplement stated that:

> Although unlikely, if runaway manual trim does occur in flight apply opposite electric trim and use manual trim as necessary. Pull electric trim circuit breaker.
>
> If a runaway trim should occur with autopilot on, the electric trim circuit breaker will pop with an out of trim condition of approx 10 lbs.

The AFM autopilot supplement included a section on electric trim pre-flight procedures. Those procedures included actuation of the electric trim switch in both directions and conducting a test procedure using a press-to-test button.

The operator's checklists did not include a pre-flight check of the manual electric trim system or the emergency operating procedures specified in the AFM.

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[14] Undesired operation of device when not commanded continuing to limit of travel.

Pitch trim malfunction study

Results of a study[15] suggest that runaway pitch-trim down failures may, in a significant percentage of cases, lead to significant altitude loss, overstress of the airframe, disorientation of the pilot, or destruction of the aircraft. When encountered during the approach to landing, a runaway pitch-trim down malfunction could lead to unintended ground contact when not responded to quickly enough. At altitude during cruise, this failure may lead to high rates of descent and over-speed if not detected and corrected in short order.

The study[16] indicated that both the time to detect a malfunction/initiate action (using autopilot disconnect, control wheel steering, panel mounted autopilot engage switch or circuit breaker) and the lag before initial action and pulling the pitch trim circuit breaker were of note. Average time to initial action was 12.2 seconds. It took on average, a further 36.4 seconds to pull the pitch-trim circuit breaker. Of note was that 13 of the 24 participants encountered ‘flight-terminating’ circumstances. Data collected during a runaway pitch trim encountered during climb while passing 6,500 ft, showed the pitch vary from + 2.6 degrees at onset of the failure, to -2.8 degrees after 1.6 seconds, progressing to -18.3 degrees at 6.7 seconds and concluding at -30.3 degrees just prior to ‘flight-terminating’ circumstances after just over 22 seconds (airspeed having increases from 140 kts to greater than 200 kts).

Aircraft characteristics

The wing of the Aero Commander type has a 3 degree forward sweep with a 6.5 degree washout[17]. The angle of incidence at the wing root was 3.0 degrees, reducing to -3.5 degrees at the wing tip. The zero lift angle of attack was -1.5 degrees.

The design manoeuvre speed (Va)[18] for the Aero Commander 500-S was 142 kts indicated airspeed (IAS). Above that airspeed, full and abrupt control movements or gust encounters can induce aircraft structural overload. The maximum permitted normal operating speed (Vno)[19] was 202 kts IAS. The never exceed speed (Vne)[20] was 252 kts IAS.

The aircraft’s normal cruise speed at 8,500 ft was 140 kts IAS.

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[15] Proceedings of the Human Factors and Ergonomics Society 41st Annual Meeting–1997, *Automation in General Aviation Part II: Four ways to reach zero feet AGL [above ground level] unintentionally – autopilot and pitch trim malfunctions,* Beringer and Howard, Human Factors Research Laboratory, FAA Civil Aeromedical Institute, Oklahoma City.

[16] As part of the study, 24 pilots participated in an experimental session that included reading excerpts from the autopilot manual, cockpit familiarisation and a 30 to 45 minute simulator flight using all autopilot modes, followed by data collection simulator flights of approximately 1.2 hours.

[17] The increase of the angle of incidence at the wing tips as compared to the angle of incidence of the wing root. Washout improves the stalling characteristics of a wing.

[18] Va – design manoeuvre speed. This is the highest airspeed at which the positive limit load factor can be applied.

[19] Vno – maximum permitted normal-operating speed. In smooth air Vno can be exceeded ‘with caution’

[20] Vne – Never exceed speed. An exceptional permitted maximum beyond Vno which can be used in exceptional circumstances and needs to be reported.

The design of the Aero Commander 500-S satisfied the certification requirements of US Civil Air Regulations (CAR) Part 3 for utility category aircraft. That CAR required the aircraft to be designed to an ultimate[21] flight load of + 6.6 g and -2.7 g.

Trajectory analysis

The wreckage pattern indicated that the aircraft broke up in flight. Two independent trajectory analysis calculations were performed to calculate the altitude at which the aircraft broke up.

The trajectory analyses indicated that the aircraft broke up at about 3,150 ft. The position of the breakup was calculated to be approximately 275 m south of the main wreckage location and about 30 m to the east of the main wreckage location. The trajectory analyses were consistent with the left and right wing having separated simultaneously at an airspeed of about 248 kts.

For more information on the trajectory analyses refer to Appendix B.

Characteristics of in-flight wing structural failure

Excluding an in-flight impact or collision, the possible causes of an in-flight wing separation are:

- A reduction of wing strength resulting from structural degradation
- Static wing overload
- Dynamic wing overload

Cracking, corrosion or other mechanisms that affect the integrity of the wing structural members can produce a reduction in wing strength. A number of Aero Commander wing spar structural failures have been attributed to fatigue and stress-corrosion cracking mechanisms, which led to the introduction of a number of airworthiness directives to address the problem.

Abrupt deviations from stable flight resulting from the effects of icing, severe turbulence encounters, a loss of the horizontal stabiliser or a malfunction/misapplication of the flight controls, have the potential to produce static overloading of the wing structure. Similarly, high speed aeroelastic mechanisms such as wing divergence[22] can produce aerodynamic bending and twisting effects on the wing sufficient to overload the structure. Aircraft with forward-swept wings, such as the Aero Commander type, are more prone to wing divergence due to the adverse coupling between bending and twisting of the wing.

The rapidly increasing dynamic loads produced by flutter will result in the failure and separation of the affected surfaces from the aircraft. The speed at which flutter occurs[23] is normally greater than the never exceed speed (Vne), but can be reduced by factors that adversely influence the dynamic inertia and stiffness of the affected surface.

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[21] Ultimate load is the greatest load that any structural member is required to carry without breaking. It may be permanently deformed at the ultimate load.

[22] Wing divergence refers to a state where at the very low angles of attack of high speed, two pressure centres develop, leading to static instability of a wing in torsion/twisting.

[23] Defined as the ‘critical flutter speed’.

In the absence of mass balance loss, trim tab separation, control surface over-travel in both directions, or reverse bending or twisting of the structure, a high speed dynamic event such as flutter was discounted as a contributing factor.

ANALYSIS

Introduction

The absence of any emergency broadcasts being received from the pilot and the lack of recorded information from either an on-board flight recorder, or from air traffic control radar and the lack of any eye witnesses, resulted in the investigation having limited factual information on which to base this analysis. The investigation found no evidence of corrosion, fatigue cracking, repairs or other pre-existing structural defects that could have contributed to the in-flight breakup. As a result, the investigation analysed the characteristics of the breakup and considered a range of scenarios that could have led to the apparent high speed descent and in-flight structural failure.

Aircraft descent

The investigation could not conclusively establish why the aircraft descended to 3,150 ft from a nominated altitude of 8,500 ft at a relatively high airspeed. The aircraft was appropriately maintained and no aircraft defects were identified. The pilot was qualified for the flight and had recent experience in the aircraft type. The nominated cruise altitude of 8,500 ft was below the forecast freezing level and clear of forecast cloud, indicating that there was a low risk of airframe icing.

Based on the limited information available to the investigation, three possible explanations for the high-speed descent from 8,500 ft remained:

- Pitch trim overpowering of pilot input
- Pilot incapacitation
- Aircraft encounter with severe meteorological conditions.

The aerodynamic force generated by a full nose-down elevator trim position (as found in the wreckage) could overpower the pilot control of aircraft pitch, leading to a high-speed descent. This could have resulted from a runaway pitch trim condition or autopilot commanded trim movement. The investigation did not find any anomalies relating to the operation of the electric pitch trim system. However, given the limitations on examination and testing of the autopilot and electric trim components due to disruption of the aircraft, and the circumstances of the in-flight breakup as determined from wreckage examination and the results of the trajectory analysis, runaway pitch trim could not be discounted.

Although it was not possible to establish if the autopilot was engaged during the flight, the encouragement to use the autopilot during the enroute phase of instrument flight rules navigational exercises may have influenced the pilot to engage the autopilot on the cruise phase of the occurrence flight. Given the pilot’s inexperience in the operation of the particular autopilot system, the marginal legibility of the relevant section of the aircraft flight manual and the absence of other instructional information, it was possible that the autopilot was engaged during cruise without the specified centring of the autopilot pitch trim indicator.

Had the autopilot been engaged in cruise with the pitch command wheel in the maximum aircraft nose-down position (as found in the wreckage), the aircraft would have immediately pitched nose down. The natural reaction of a pilot would be to arrest the movement by applying rearward control column pressure. If this pressure was sustained, the autopilot would have progressively driven the elevator trim to the maximum aircraft nose-down trim position.

The investigation was unable to explain why the electric pitch trim or autopilot was not disengaged if there had been a malfunction or autopilot engagement anomaly. However, the results of the Beringer and Howard pitch trim malfunction study (see footnote 15) indicates that there may be a significant amount of time before a pilot is able to recognise and deal with an automation-related emergency situation.

There was no evidence of any physiological or psychological factor having affected the pilot's performance on the day of the occurrence. Although unlikely in a young and apparently well person, it was not possible to discount a sudden or unexpected incapacitation of the pilot that could have resulted in an inadvertent nose-down control input that developed into a high-speed descent.

The weather conditions were such that mountain waves and/or severe turbulence could have been encountered by the pilot at 8,500 ft. There were indications that the conditions were improving and there were no reports of mountain waves or severe turbulence from the pilots of the aircraft following LST or from the pilots of the aircraft involved in the search.

In-flight breakup

It was apparent from the structural examination and wreckage distribution that the outboard wings and empennage had separated from the aircraft during flight. The trajectory analyses indicated that this separation occurred at an altitude of about 3,150 ft. This altitude was considerably lower than the cruising altitude of 8,500 ft nominated by the pilot.

The primary breakup of the aircraft was a result of failure and separation of both wings outboard of the engine nacelles. The separation of the empennage was as a result of contact with the outboard left wing section during the break-up sequence.

In the absence of any pre-existing material or structural defects, the downward failure of the wings indicated that the wings were subject to a downwards load that exceeded the design ultimate negative load factor (-2.7g).

A negative g situation on a wing occurs when the lift force is downwards. This is when the relative airflow over the wing is in a direction less than the zero lift angle-of-attack (–1.5 degrees for the AC500-S wing aerofoil section). Negative g loading on a wing can be a result of inverted flight, push-over manoeuvre (such as an outside loop), or encounter with gusts/turbulence. With reducing angles of attack, the 6.5 degree washout on the Aero-Commander wing results in the outboard wing sections being subjected to downwards loading prior to the inboard sections.

The symmetrical nature of the wing separations (same span wise position and direction) indicated that the aircraft was not in an asymmetric manoeuvre such as a turn, spin or spiral at the time of the breakup. Additionally this indicated that the wing failures occurred simultaneously due to forces that exceeded the design ultimate load factor.

The trajectory analysis indicated that the aircraft broke up at an altitude of about 3,150 ft and a speed in the vicinity of the never exceed speed (Vne). The difference between the nominated cruising altitude and the altitude of the aircraft at the time of the in-flight breakup would have readily allowed the aircraft to accelerate from cruise speed through Vne (250 kts) in a dive.

In this event it is possible that relatively low control forces or gusts encountered in the longitudinal (pitch) axis of the aircraft could result in the wings sustaining loads in excess of their ultimate strength. Similarly, wing divergence resulting in overload could not be discounted since it would be difficult to distinguish this failure mode from other static overload events.

Summary

The trajectory analysis provided the ATSB with a high degree of confidence with respect to the aircraft altitude and speed at the time of the in-flight breakup. The aircraft's speed could have readily accelerated to Vne during a rapid descent from the nominated cruise altitude of 8,500 ft to the break-up altitude of around 3,150 ft. At such a speed, a relatively small control input force or gusts encountered in the longitudinal (pitch) axis of the aircraft could have resulted in the symmetrical downward wing overloading and failure that occurred.

There is no compelling evidence to support any one reason for the departure of the aircraft from the cruise altitude into a high speed dive type situation. However, there are a number of factors that provide some weight to the possibility of a flight upset related to operation of the autopilot. These factors include:

- The lack of any reference in the operations manual to the installation of a Bendix FCS-810 autopilot in LST and the lack of information in the operations manual on the operation of the FCS-810 autopilot
- The pilot's relative inexperience in the operation of the particular autopilot system fitted to LST
- The operating characteristics of the autopilot system fitted to LST
- The illegible nature of the Aircraft Flight Manual supplement pertaining to the limitations and operating procedures for the autopilot system fitted to LST
- The autopilot controller pitch command wheel being found at the accident site in the maximum nose-down position
- Both elevator trim tabs being found at the accident site at or close to the maximum nose-down trim position.

However, it is not possible to discount other explanations for the departure from cruise flight, including a runaway pitch-trim condition, pilot incapacitation, the effects of mountain waves and/or severe turbulence, or a combination of any of the above.

On the evidence available to the investigation, it was not possible to conclusively determine the circumstances that led to the aircraft descending at speed to the altitude at which the in-flight breakup occurred.

SAFETY ACTION

Australian Transport Safety Bureau

The Australian Transport Safety Bureau proposes to publish an article based on this report in *Flight Safety Australia* that will draw attention to ensuring that operational systems information is included in relevant documentation.

Appendix A: Technical Analysis Report Summary

Australian Government

Australian Transport Safety Bureau

TECHNICAL ANALYSIS REPORT SUMMARY

Report No. 14/05

Occurrence No. BO/200400610

Summary of Structures Examination

Aero Commander 500-S, VH-LST

19 Feb 2004

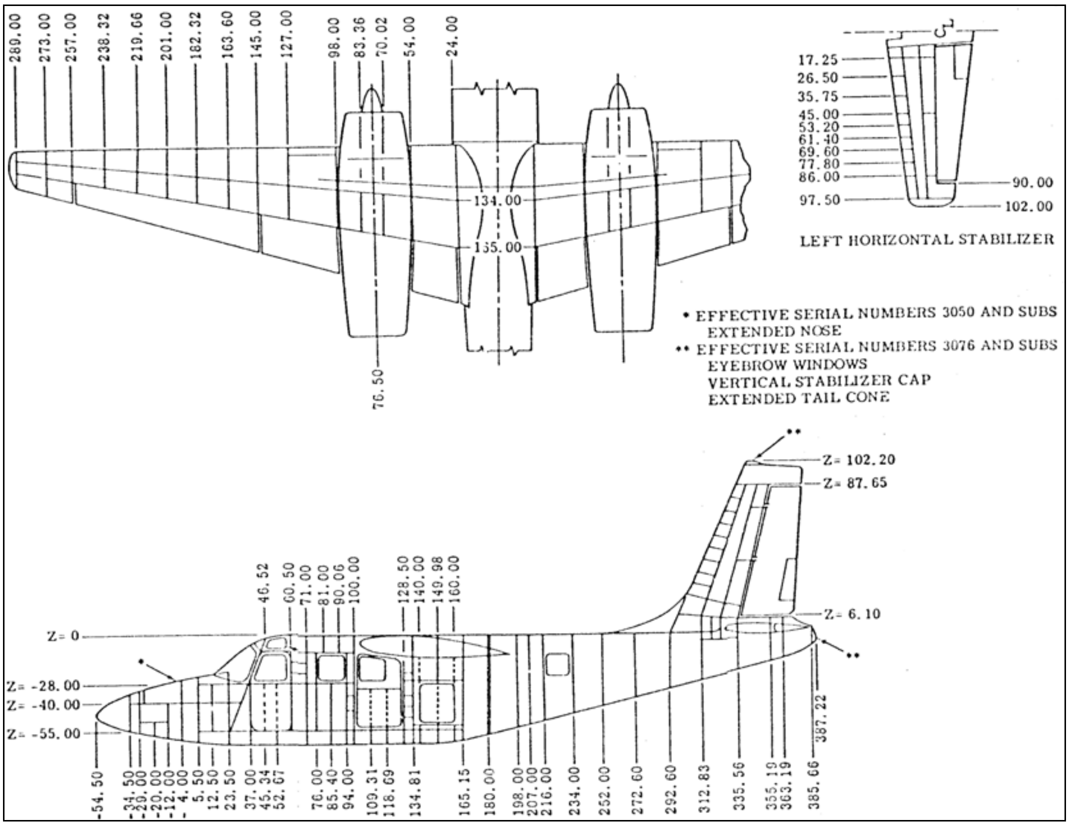
1. INTRODUCTION

1.1. Structure general

The Aero Commander Model 500-S is a high-wing, twin-engine aircraft of all-metal construction. The aircraft structure is divided into three major assemblies: the wing, empennage and fuselage.

The station diagram reproduced from the 500-S maintenance manual at Figure 1 has been used to identify and locate reference points on major components of the fuselage and wings. These reference points are numbered in inches from a zero datum.

Figure 1: Station diagram (Source: 500-S Illustrated Parts Catalogue)



1.2. Wreckage distribution

The main wreckage, comprising the aircraft forward and aft fuselage, inboard wing sections and flaps, came to rest inverted in undulating terrain approximately 560 metres above mean sea level at latitude 42.368 °S, longitude 147.211 °E. Both engines and propellers were located with the main wreckage. Both wing sections, outboard of the wing flaps, and the tail section of the aircraft, were not co-located with the main wreckage.

Figure 2: General view of main wreckage looking towards the cockpit from the tail

Note the outer wing panels and empennage had separated from the main fuselage and were located a distance away. Main wreckage impacted the ground inverted

The remainder of the aircraft structure, comprising forty-seven separate items was scattered east-north-east from the main wreckage with some lighter items up to 1,300 m away (0.8 NM). The extent of the wreckage distribution indicated that the aircraft had sustained an in-flight structural failure and separation of both wings and the tailplane from a relatively low altitude.

The ailerons, rudder and elevator flight control surfaces had all separated from their respective structure during the break-up sequence.

Wreckage distribution and photographs of the major separated structure of the right wing, left wing and empennage/fuselage is shown in Figures 3 - 5 respectively.

Figure 3: Wreckage distribution map with photos of major right wing separated items (original map courtesy of Tasmania Police)

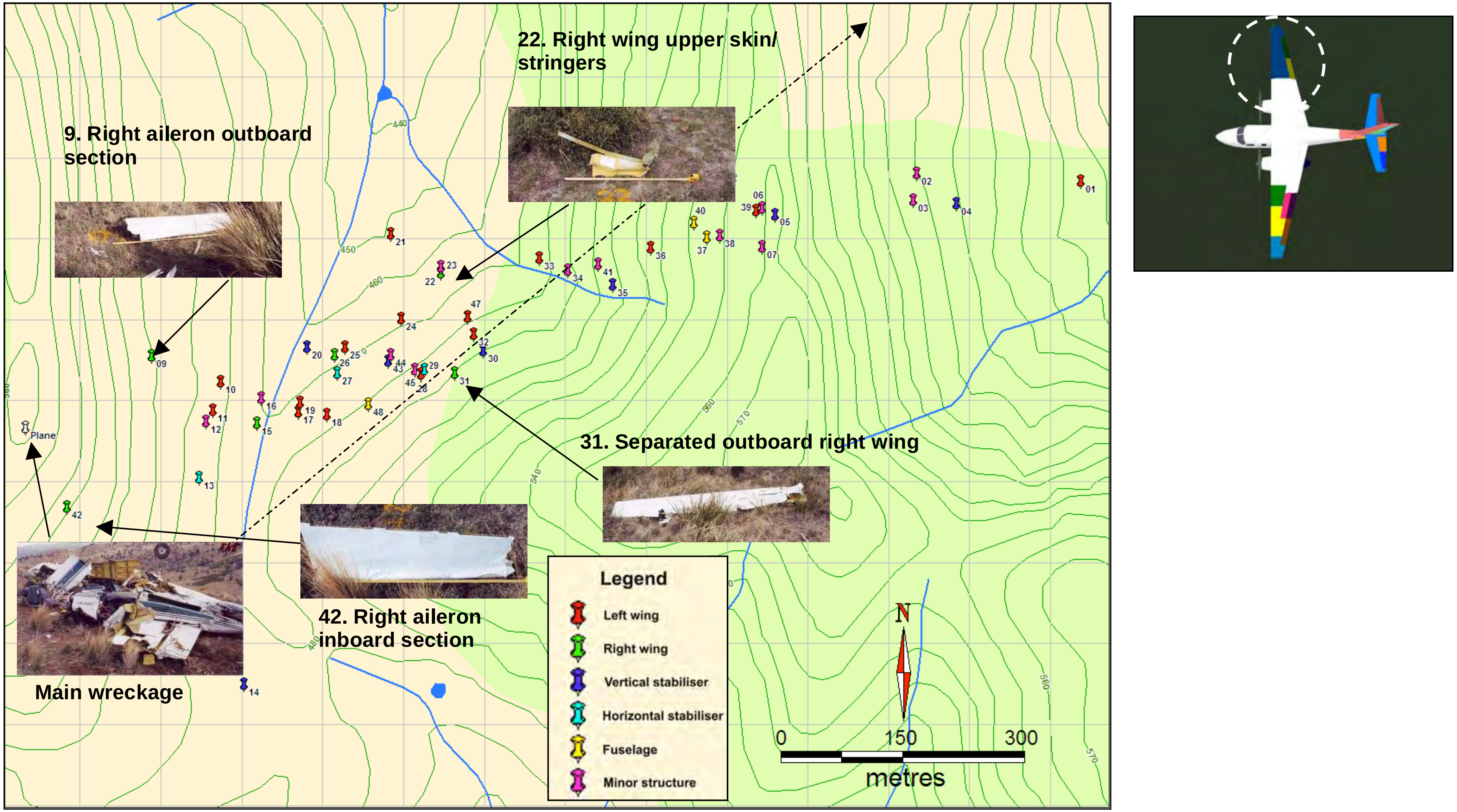


Figure 4: Wreckage distribution map with photos of major left wing separated items (original map courtesy of Tasmania Police)

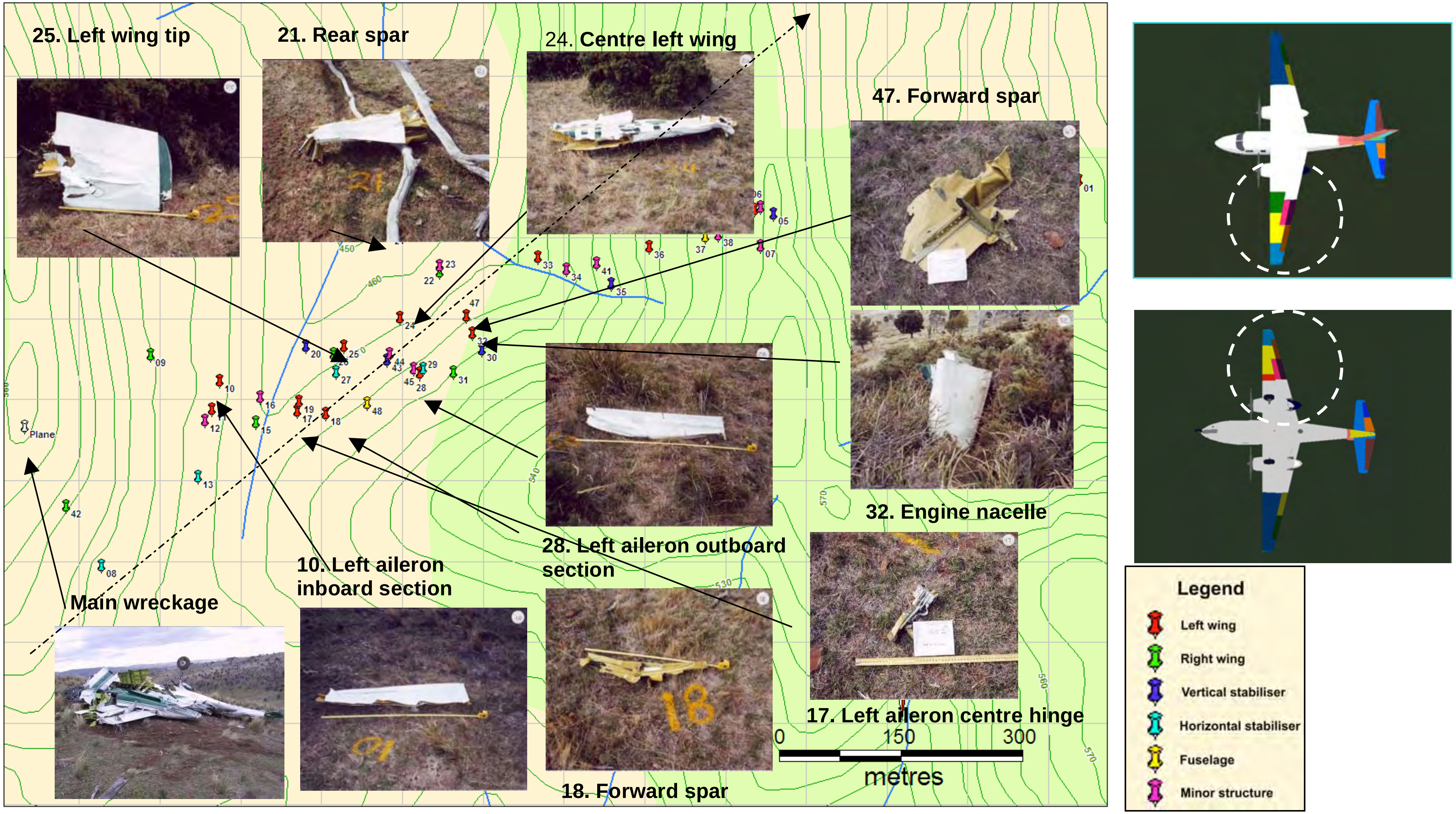
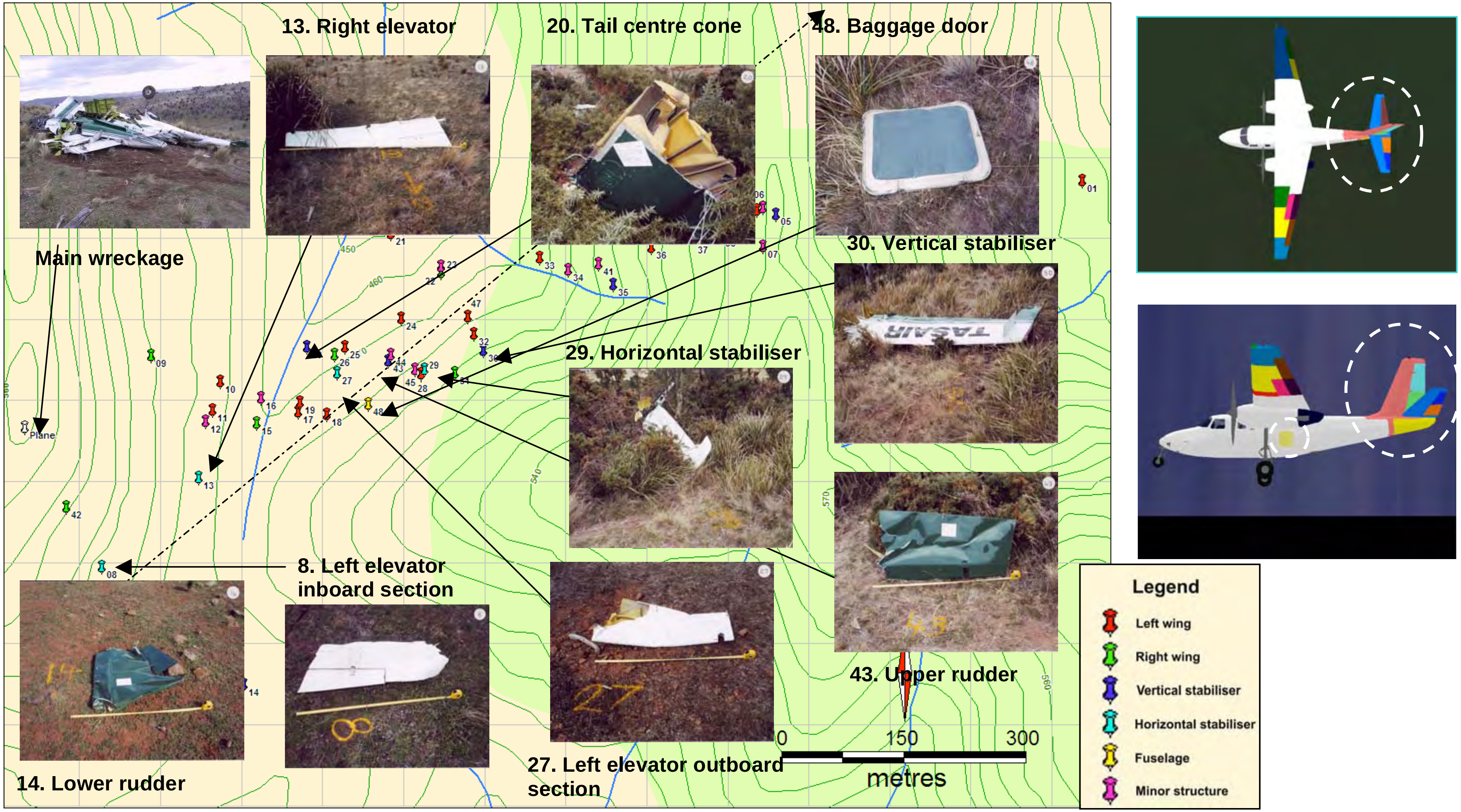


Figure 5: Wreckage distribution map with photos of major empennage and fuselage separated items (TasmaniaPolice)



2. FINDINGS

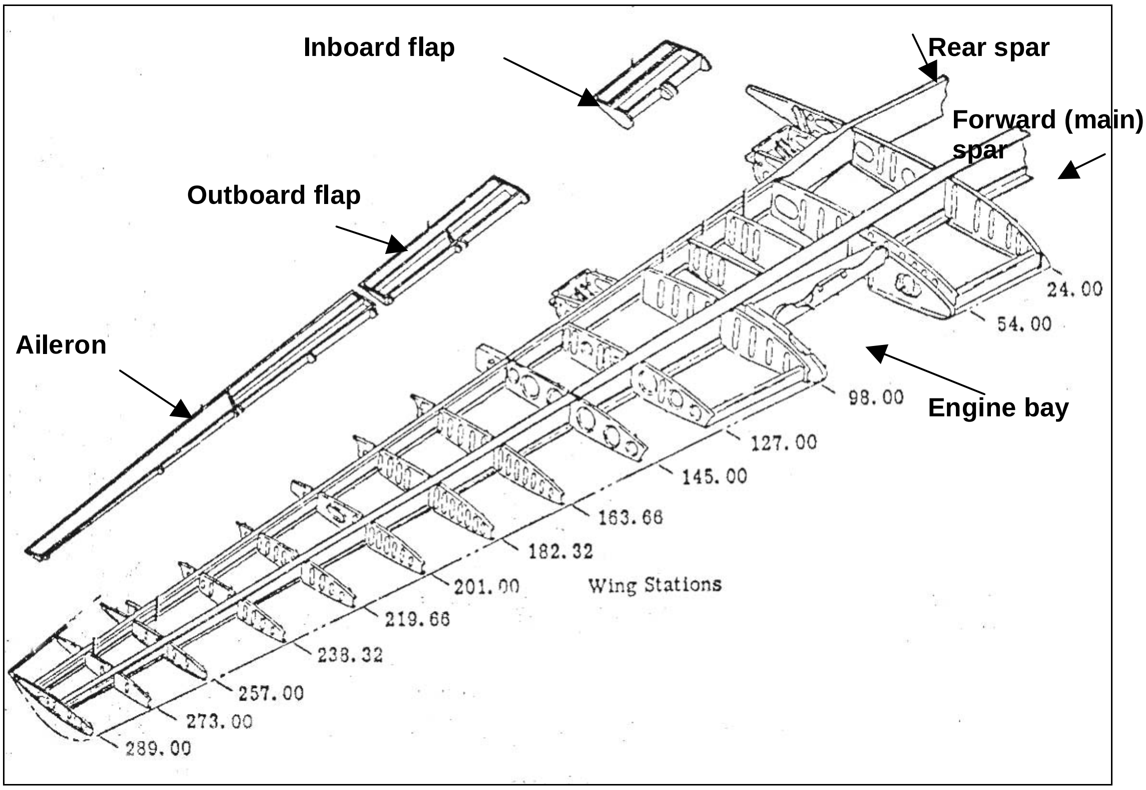
The photographs of the structure used to document and illustrate the failures observed have been oriented whenever possible to be in the correct orientation for a straight, level and upright aircraft. Where the orientation is not clear from the photograph or caption the following orientation indicators have been used.

Orientation indicators - legend used in figures

🟦	**Denotes upwards direction**
🟩	**Denotes forward direction**
⬜	**Denotes inboard direction**

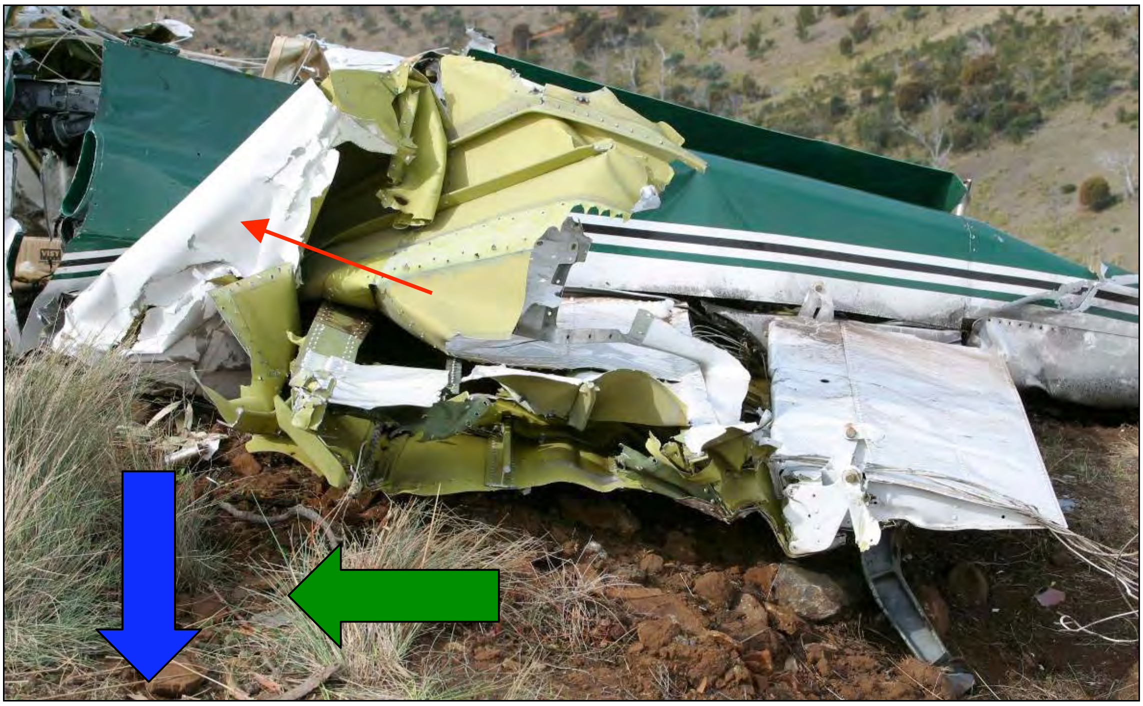
2.1. Wing structure separation

Figure 6: Aero Commander 500-S wing structure and stations (right wing shown)



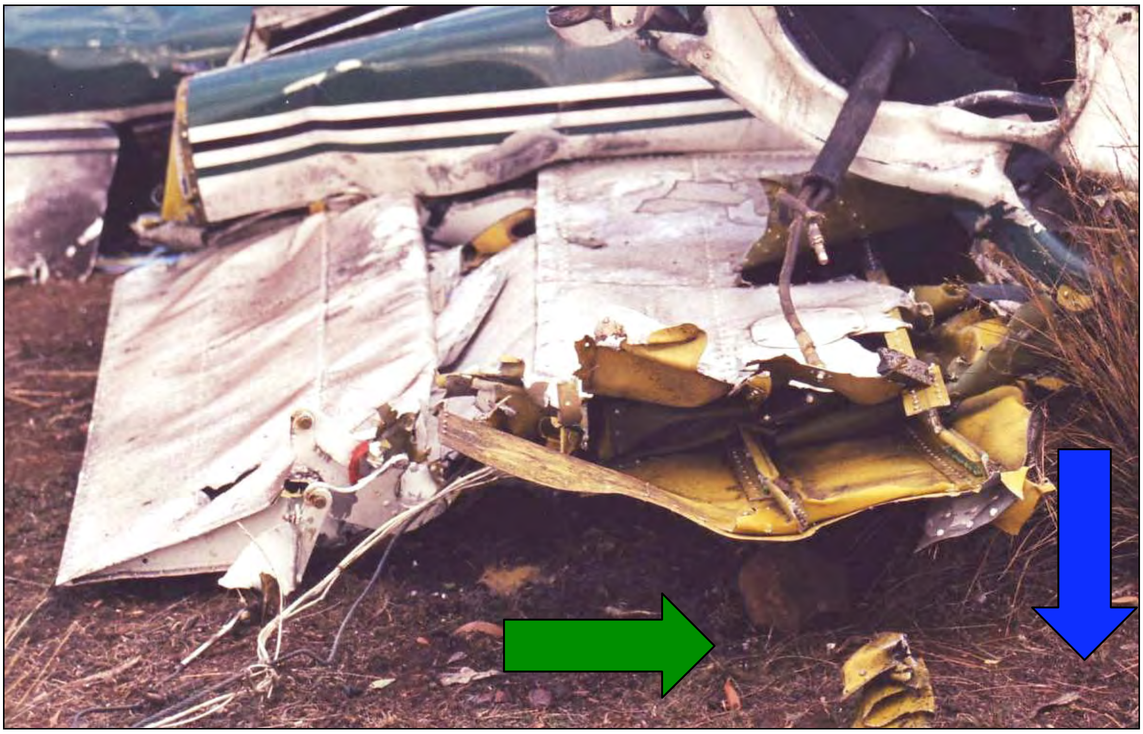
The left and right wings failed in a symmetrical manner at a similar span wise location. The general span wise location of the wing spar failures was at WS145, coincident with the location of a spar splice at the outboard end of the flaps/ inboard end of the ailerons. The fracture of all wing spars was either at WS145 or at the end of doublers supporting the spar splice. The fractures were all consistent with ductile failures under overload conditions. No evidence of pre-existing defects at these locations was found. The wings failed in a downwards and nose down direction, moving rearwards at separation.

Figure 7: Main wreckage - right inboard wing separation point with right outboard flap in right foreground



Note downward and rearward deformation of leading edge structure just outboard of nacelles (arrowed)

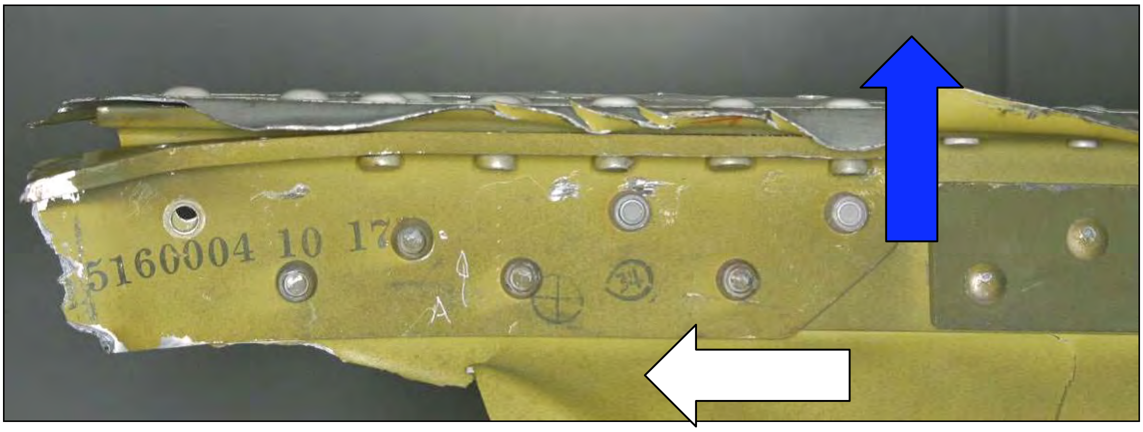
Figure 8: Main wreckage - left inboard wing separation point with left outboard flap in left foreground



Note missing rear engine nacelle

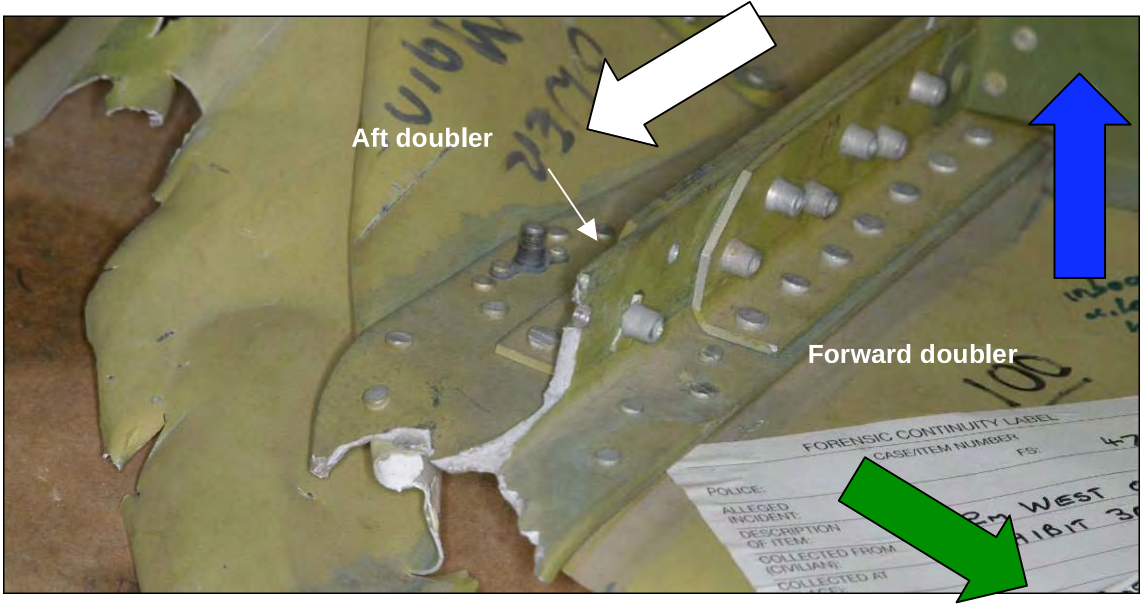
Figure 9: Separated left wing sections in reconstruction. Lower wing surface shown

Figure 10: Right main spar upper cap showing fractured aft doubler and outboard extent of rear doubler (nested angle)



Note downward loading

Figure 11: Left main spar, lower cap failures on Item 47. View of inboard fracture



Note downward plastic deformation and tearing of T-section centre leg near the inboard end of the aft doubler

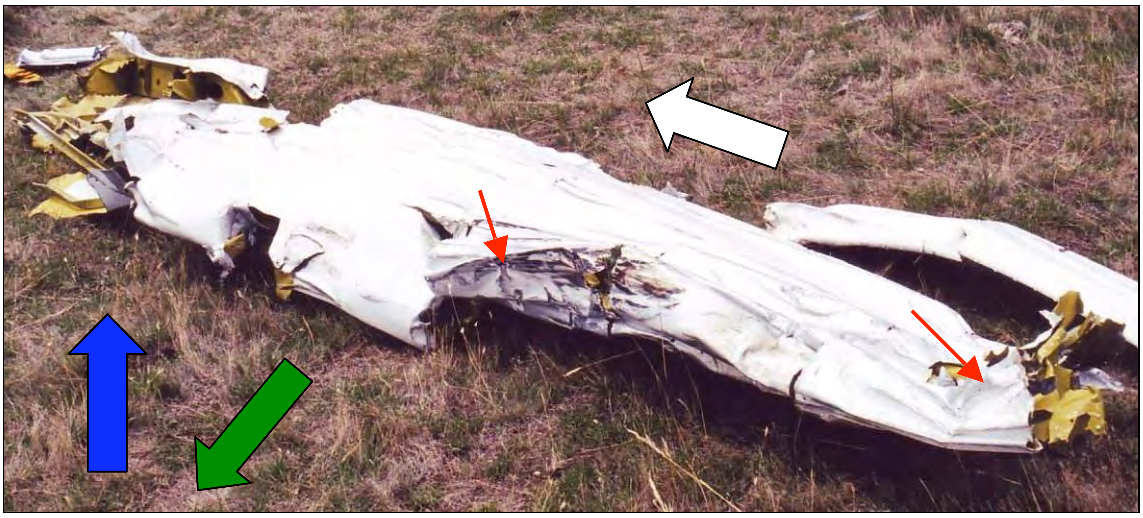
The ailerons separated at the centre hinge and were torn from the wing rear spars. The nature of the aileron failure (twisting around the centre hinge) indicated that the aileron fracture and separation were a consequence of the wing spar fracture. The ailerons therefore separated from the wing at the time of the wing separation.

Figure 12: The separated right wing with the aileron reconstructed in the respective position

2.2. Wing contact marks

The separated right wing section had no evidence of contact with other parts of the aircraft following its separation. The separated left wing leading edge and upper leading edge had damage consistent with contact with the left landing gear and aft nacelle. The left wing leading edge and lower surface had deformation and green paint transfer, consistent with contact with the aft fuselage.

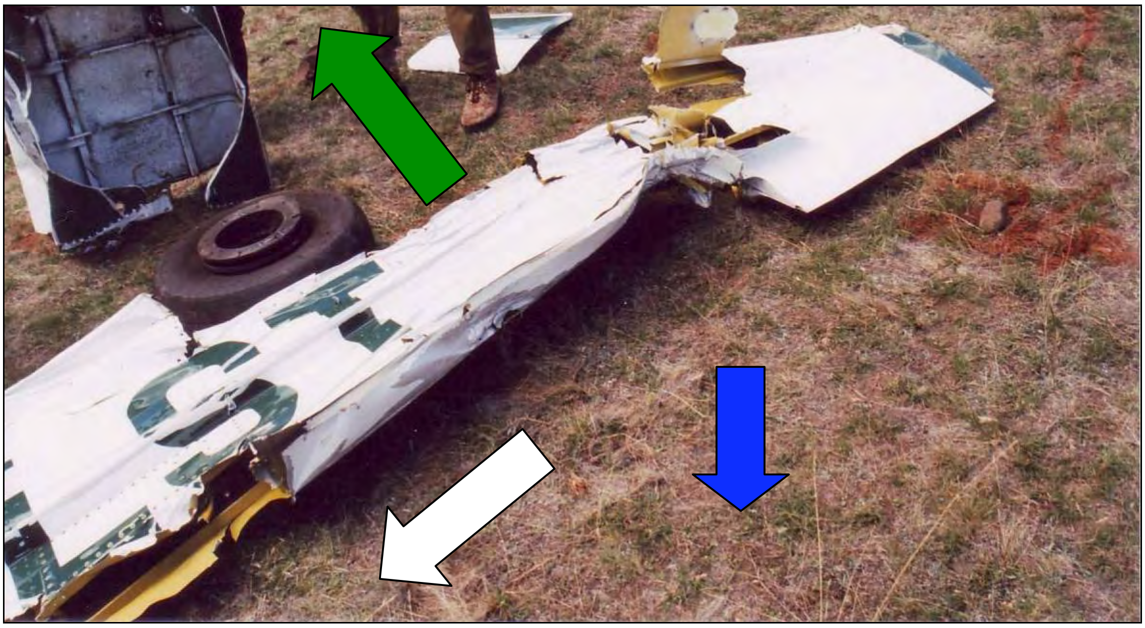
Figure 13: Separated left outer wing panel



Note extensive leading edge damage with black rubber like smears and upward deformation at outboard end (arrowed)

The left wing trailing edge had deformation consistent with contact with the leading edge of the horizontal stabiliser, which resulted in a secondary fracture of the rear spar.

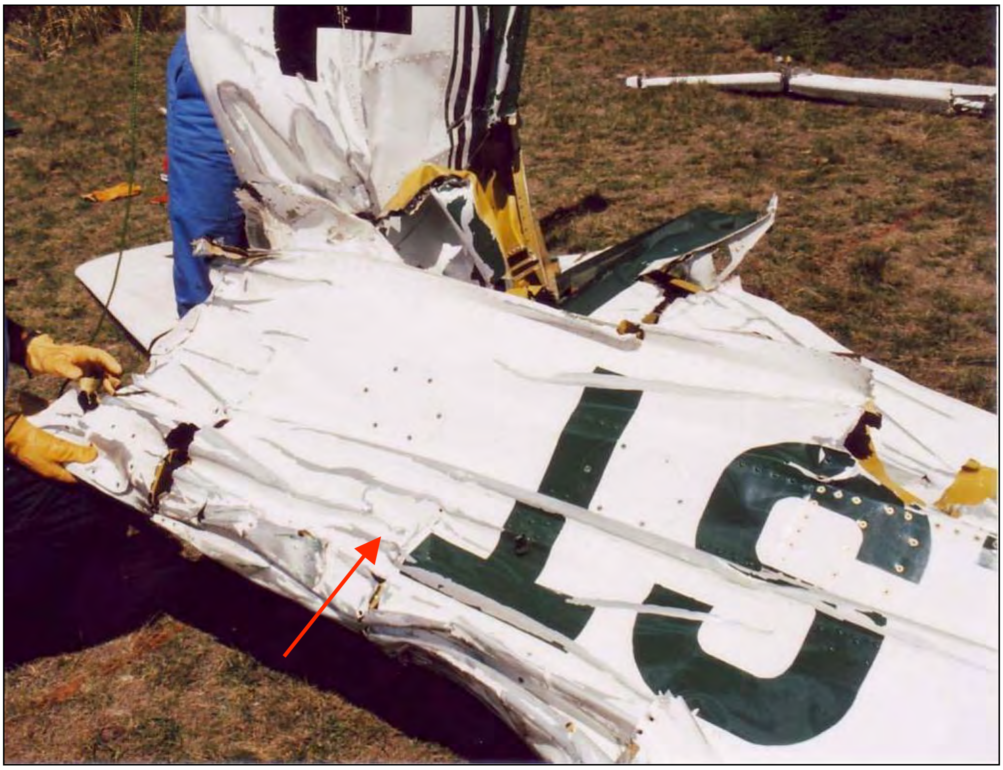
Figure 14: Trailing edge damage from impact with fin and horizontal stabiliser



Note also separated wing tip and upwards deformation at separation point

The left wing tip and trailing edge had deformation consistent with contact with the leading edge of the vertical stabiliser.

Figure 15: Left wing outboard trailing edge contact with vertical stabiliser leading edge. View from left side. Inboard section of wing would be lower for trailing edge contact with horizontal stabiliser



Note arrow denotes green witness marks (outboard of left tyre impact) from subsequent aft fuselage contact

2.3. Empennage structure separation

The horizontal stabiliser had significant contact marks on the left leading edge close to the junction with its aft fuselage attachment. The vertical stabiliser sustained heavy impact damage on its lower leading edge near its junction with the aft fuselage.

Figure 16: View of vertical stabiliser from the left with separated horizontal stabiliser in correct relative position

Note compression deformation at root of vertical stabiliser and aft frame at FS312 (arrowed)

The horizontal and vertical stabiliser spar fractures were consistent with being as a result of damage sustained from impact with the separated left wing structure while under considerable load (immediately after wing separation).

The horizontal stabiliser separated from the aft fuselage at, and with aft fuselage frame FS335.56 attached to its front spar. The horizontal stabiliser spars had fractured close to the aircraft centreline and deformation of the stabilisers was generally downward. The rear spar had displaced to the left. The forward spar had buckled rearward and upward on the right side and also fractured further outboard as a result of this buckling.

The vertical stabiliser separated from the aft fuselage at and with aft fuselage frame FS312.83 attached to its front spar. The vertical stabiliser rear spar fractured at its attachment to fuselage frame FS335.56 and the horizontal stabiliser front spar. The vertical stabiliser rear spar had deformed to the left. The vertical stabiliser appeared to have separated from the aircraft in an upward and left direction with the tail-cone moving to the left.

The control surfaces attached to the empennage had separated in reaction to the spar and stabiliser deformation. The left elevator separated with the inboard torque tube moving upwards, and the right elevator with the inboard torque tube moving downwards. The rudder and left elevator separated at the centre hinge location, indicating some twisting forces while still attached to the respective stabilisers. The right elevator, although not fractured, had evidence of creasing at the centre hinge point.

The excessive over travel observed on the elevator and rudder hinges (predominantly upwards and to the left) was considered to be a result of control cable tensile forces applied during the separation sequence.

2.3.1. Elevator trim

Both trim tabs were found in a fully trailing edge up position (nose down trim).

Figure 17: Right trim tab position (trailing edge up)

2.4. Aft fuselage

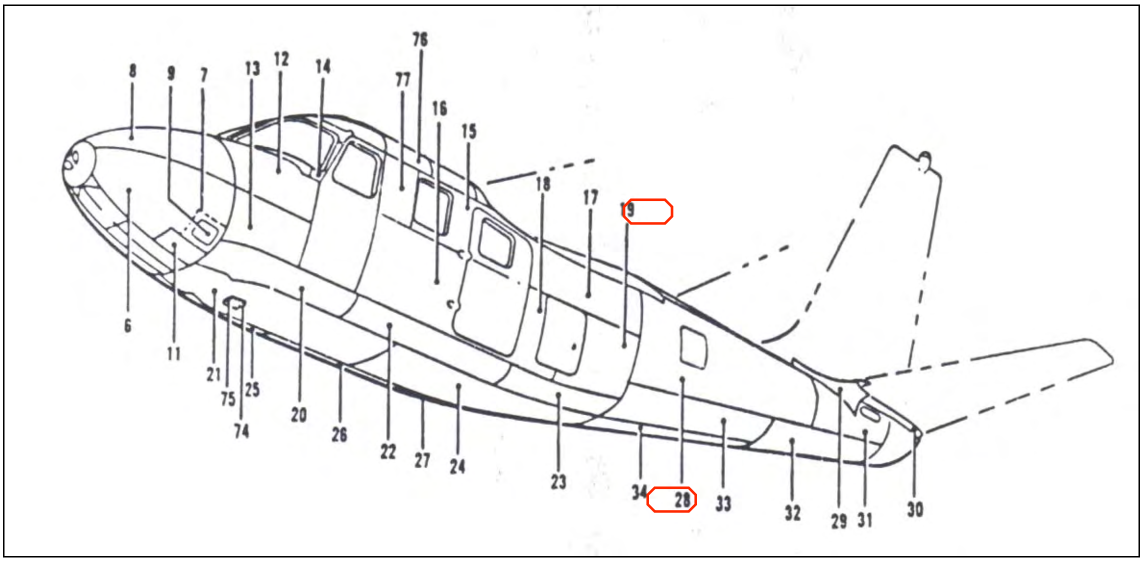
The empennage had separated from the fuselage generally at the FS312.83 frame, the location of the vertical stabiliser main spar. The aft fuselage was subsequently torn open just left of the aircraft centreline, on the upper surface from the vertical fin, in a forward direction. The aft fuselage section had collapsed on impact with the ground and was loosely attached to the centre fuselage section. The aft fuselage could be easily removed from the main wreckage once control cables were severed. The left side fuselage baggage door had separated during the in-flight break-up sequence and was found in the middle of the wreckage trail.

Figure 18: General view of aft fuselage flattened out left to right

2.5. Fuselage Baggage door

The fuselage baggage door, located on the left side of the aircraft, had separated during the in-flight break-up sequence and was found in the middle of the wreckage trail. The hinges were found to have failed in tensile overload. It was considered that deformation to the aft fuselage section resulted in fuselage skin deformation near the door lock mechanism, subsequently releasing the door and resulting in its separation during the breakup.

Figure 19: Fuselage plating showing plating 19 at baggage door lock and its relationship to aft fuselage plating 28



2.6. Sequence of failure

The fracture and separation of the left and right wing outboard sections at or around WS145 was the initial failure of the aircraft structure. This symmetrical failure was considered to be the result of excessive load applied in a downward direction. No evidence was found in the failed area of the wings of corrosion, fatigue cracking, repairs or material defects which could have degraded the strength of the structure. Subsequent failures resulted from the severed left wing striking and detaching the aft fuselage and tail section. Some ground impact damage was evident on the leading edge of control surfaces where mass was concentrated.

Appendix B: Technical Analysis Report Summary

Australian Government

Australian Transport Safety Bureau

TECHNICAL ANALYSIS REPORT SUMMARY

Report No. 06/05

Occurrence No. BO/200400610

Summary of Trajectory Analysis

Aero Commander 500-S, VH-LST

19 Feb 2004

1 FACTUAL INFORMATION

1.1 Wreckage Distribution

The distribution and identification of the separated components is shown at Attachment B-1 and B-2 to this appendix. The identification numbers nominated by the Tasmanian Police were used throughout this report. The main wreckage (plane) was inverted and on a heading of 310 degrees True (T) (forward fuselage) to 340 T (rear fuselage). The main wreckage impacted the ground approximately wings level and inverted.

Ground scars at the accident site indicated that following impact with the ground, the main wreckage moved approximately 3.6 m north and 1.5 m east. This indicated direction of movement of 348 degrees magnetic (M), which equated to 003ºT.

Most separated items were in an east-north-easterly direction from the main wreckage. The extent of the wreckage distribution indicated an in-flight breakup had occurred.

The estimated weight of the aircraft at the time of the accident was calculated as 2,656 kg (5855 lbs).

The position of all separated items was recorded by the Tasmania Police using their Global Positioning System equipment and is shown in Attachment B-1. All major separated items were weighed and measured by ATSB staff. These measurements are shown in Attachment B-3.

1.2 Wind Profile

A wind profile at the time of the accident was developed from combining the available meteorological information and is shown below.

Table 1: Wind profile of speed and direction (2,000-10,000 ft)

Altitude (ft)	Wind Speed (knots)	Wind Direction (degrees True)	Source
2,000	25	230	Use of amended forecast wind direction and speed, using winds below 5,000ft 10 knots stronger. Confirmation of this increased wind strength provided at Spring Hill tower observation (1657:30).
5,000	30	255	Use of amended forecast wind direction and speed from BoM - using winds below 5,000ft 10 knots stronger. Confirmation of this increased wind strength provided at Spring Hill tower observation (1657:30)
7,000	30	230	Use of amended forecast wind direction and speed from BoM
10,000	45	230	Use of amended forecast wind direction and speed from BoM

2 ANALYSIS

2.1 Introduction

Two trajectory analysis techniques were used. The first method applied Aeronautical Research Laboratories (ARL) Woomera trials data and characteristics of all separated wreckage items to determine a position and altitude of the breakup (wind drift/terminal velocity technique). The second technique utilised the US National Transportation Safety Board (NTSB) developed program “Ballistic” for the same purpose. To obtain an accurate solution of the break-up point, careful consideration was required prior to assignment of significant input parameters such as wind profile and drag determination for the various parts.

2.2 Wind drift/ terminal velocity technique

This approach was initially used to estimate the break-up position (altitude and location) of the aircraft.

This technique was developed around the philosophy that all wreckage items are of importance and each can make a contribution to the total picture that emerges. The final picture should be consistent and compatible with all wreckage items. This philosophy recognized that the analytical approach, in working with a few selected items only, tended to disregard too much evidence and to place too much reliance on a small minority of items which may or may not have been a truly representative sample.

All wreckage items were considered in three groups, light, medium or heavy.

2.2.1 Light wreckage items

Light items are characterised by a low weight / surface area ratio and are considered to lose all their forward velocity shortly after separation from the aircraft and their trajectories are essentially determined only by wind drift. Light items lie downwind from the break-up point, scattered about the line of the mean wind. All light items which separated at the break-up point are generally contained within a 30 degree sector with the apex at the break-up point. Any light item not within the sector separated at some other time.

2.2.2 Heavy wreckage items

Heavy items have a high weight / surface area ratio. They are little affected by wind drift and their trajectories depend primarily on the velocity of the aircraft at the time of the breakup. Heavy items lie close to the mean line of the extended flight path of the aircraft. A mean line drawn through the ground impact points of heavy items will define the extended flight path of the aircraft with sufficient accuracy. The heavy item sector will be positioned symmetrically about this mean line with the apex at the break-up point.

2.2.3 Medium wreckage items

Medium items are those which have trajectories that are influenced in varying degrees, by both wind drift and forward velocity. They will be located in a sector downwind of the extended flight path and forward of the break-up point

2.2.4 Application of procedure

Calculation of the weight divided by surface area ratio was made to enable classification of the separated components as light, medium or heavy. Consideration was given to the impact orientation as witnessed from impact damage and mass distribution of the item.

The mean wind direction was 230T up to 5,000 ft. The mean wind speed varied between 25 to 29 knots. Attachment B-4 shows a 30 degree sector containing all the light wreckage items, with the centre line coincident with the line of the mean wind. This was drawn for an average wind direction of 230T corresponding to a break-up altitude of 2,000 ft to 5,000 ft. The apex of the 30 degree sector was considered to be the break-up point. The measured drift of light item groups (1-6) i.e. their distance from the break-up point measured along the line of the mean wind was entered into a spreadsheet and an estimation of corrected break-up altitude was obtained.

The elevation of the item or group was added to the corrected altitude to determine the break-up altitude. The break-up altitude was therefore calculated for mean wind velocities of 25 to 30 knots at 2 knot increments.

2.2.5 Result

The break-up altitude was calculated at 3,271 ± 206 ft for a wind speed of 25 kts and 2,989 ± 206 ft for a wind speed of 30 kts. The position of the breakup was determined to be approximately 313 m south of, and 13 m to the west of, the main wreckage location.

2.3 NTSB Ballistic Program technique

The NTSB has developed a software program ‘Ballistic’ that has been used with some success in recent aircraft in-flight breakup trajectory analyses such as the TWA 800 in-flight breakup near Long Island in 1996. The fundamental basis of this program is that the path of a separated component is determined by its ballistic coefficient where:

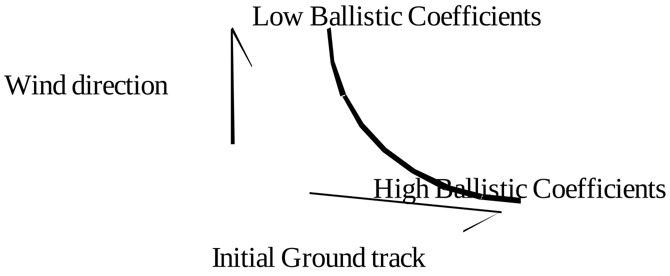
Ballistic Coefficient = $W/ (C_D S)$

W = weight, C_D = drag coefficient, S = item surface area.

2.3.1 Philosophy

The philosophy used is that a separated component with a high ballistic coefficient will align with the aircraft heading at breakup and low ballistic coefficient components will approach the wind direction. The break-up position will be near the intersection of the wind direction line and heading line.

Figure 2: General ballistic coefficient curve for in-flight breakup



If objects with different ballistic coefficients are released with a common velocity from a common initial position, their final position on the ground will describe a curve. The low ballistic coefficient end of this curve will approach alignment with the wind direction. The high ballistic coefficient end of the curve will approach alignment with the initial ground track direction.

The initial position and velocity vector of an in-flight breakup can often be determined from the shape and size of the wreckage curve on the ground, assuming a common initial velocity and ballistic behaviour. A wreckage curve for the VH-LST wreckage distribution is shown at Attachment B-5.

2.3.2 Application of technique

The inputs required for the program were the ballistic coefficients and relative position of the ballistic components (x (East), y (North) and elevation) and a wind profile. An approximate ballistic coefficient curve of aircraft separated components is shown at Figure 3 of attachment 1.

It was noted that separated major parts of the aircraft structure such as left wing (Items 18, 21, 24, 25, 32, 47), right wing (Items 22, 31), horizontal stabilizer (Item 29), vertical stabiliser (Item 30) and tail cone (Item 20) were located close to the mean wind line and between the end of Group 1 and Group 3 (see Attachment B-4).

It was also noted that some items, although comparatively lighter appeared to be in the higher ballistic coefficient end of the curve (i.e. Items 14, 08, 42, 13, 09, 10) and at a greater distance from the mean wind line. These items were all separated control surfaces (ailerons, elevator and rudder) that had most of their weight concentrated in the leading edge. Additionally, damage to the items was consistent with ground impact of the leading edge first. The determination of a ballistic coefficient for these items was challenging. The final position of these items was considered to be a combined result of ballistic coefficient and lifting forces on the aerofoil sections. These items were therefore not included in the ballistic program runs.

2.3.3 Result

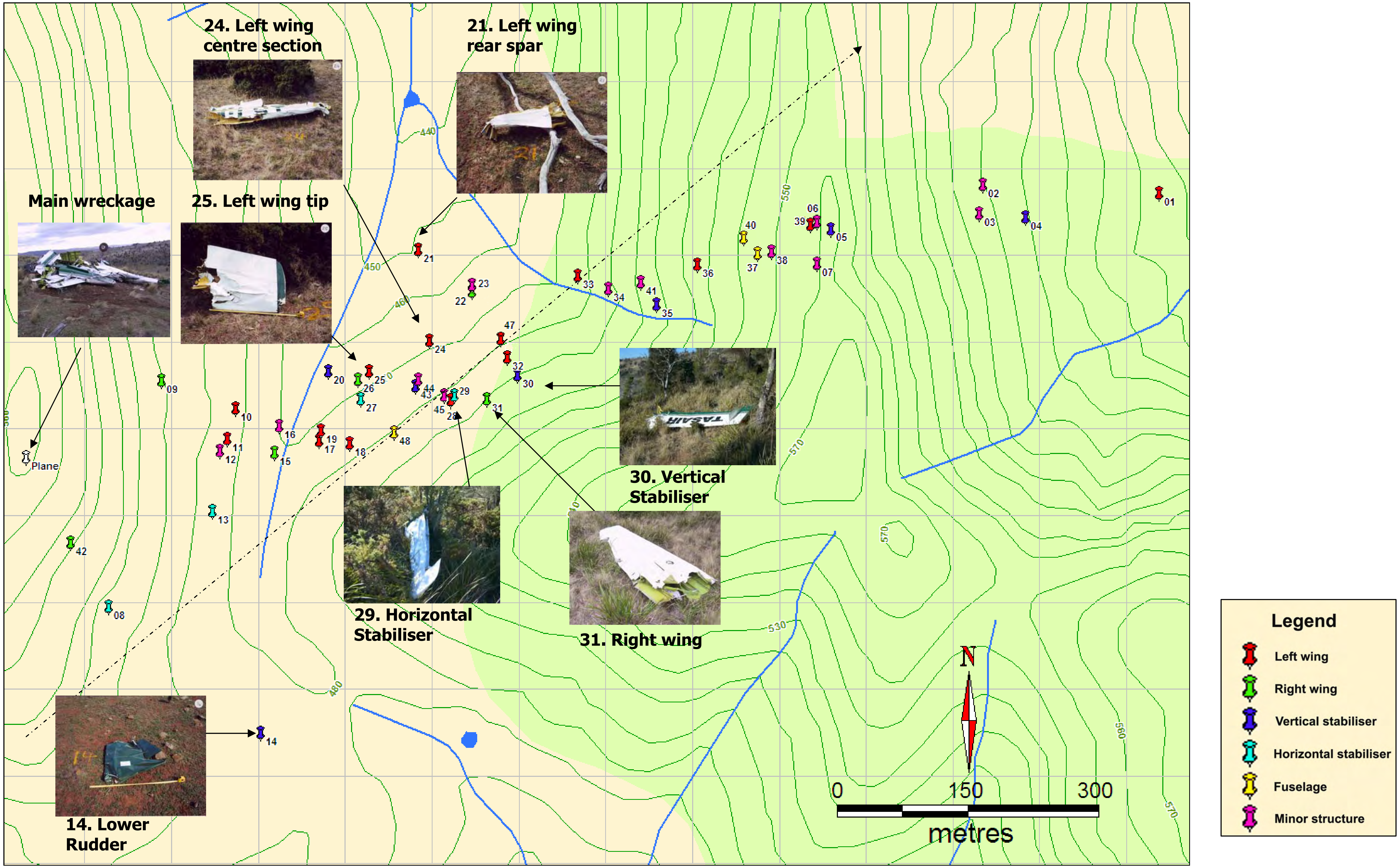
A summary of the best solution for the break-up condition as calculated by the program is at Table 2.

Table 2: Best solution for break-up condition

	x – East (metres)	y - North (metres)	best altitude (ft)	Best flight path angle (degs)	best heading (degs)	best airspeed (knots)
right wing/ plane	50	-250	3200	-56	-25	266
left wing/ empennage	50	-250	3200	-35	30	230

Table 2 shows that the break-up position of the aircraft was found to be 50 m east and 250 m south of the main wreckage final location. This occurred at an altitude of 3,200ft. The aircraft was on a heading of 335 and 030 degrees T with an airspeed of between 230 and 266 kts. This break-up position provided good correlation for the trajectory, impact and track of the main wreckage.

Attachment B-1: Wreckage distribution map with photos of main items (original map courtesy of Tasmania Police)



Attachment B-2: Nomenclature for wreckage distribution

Item Number	Description	Aircraft Position	
Plane	Main wreckage - forward fuselage, cockpit and cabin area. Inboard wings and engines.		
01	Control cable access cover	Left	
02	Wing skin		
03	Wing skin		
04	Rudder	Right	Lower
05	Vertical stabiliser just below #30		
06	Wing skin		
07	Wing stringer		
08	Elevator	Left	Inboard
09	Aileron	Right	Outboard
10	Aileron	Left	Inboard
11	Wing two stringers & skin	Left	Inboard
12	Wing rib		
13	Elevator	Right	
14	Rudder	Lower	
15	Fuel vent line	Right	
16	Rubber grommet		
17	Aileron hinge	Left	Centre
18	Wing main spar	Left	Upper and forward
19	Fuel vent line	Left	
20	Tail	Centre	Cone
21	Wing rear spar	Left	Top and Bottom
22	Wing skin & stringers	Right	Upper
23	Rubber washer		
24	Wing	Left	Centre
25	Wing	Left	Tip
26	Wing stringer and skin	Right	Lower
27	Elevator	Left	Outboard

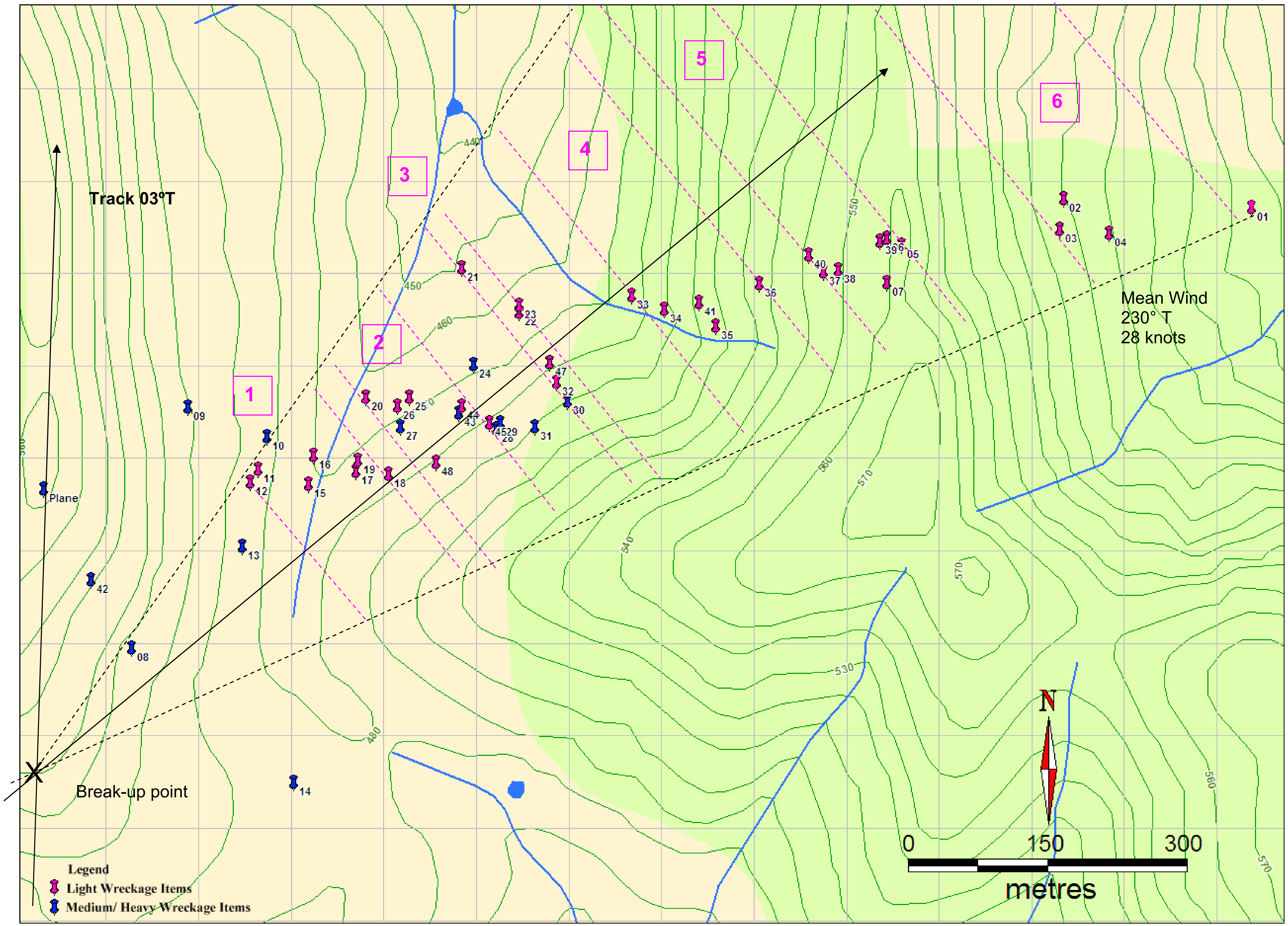
Item Number	Description	Aircraft Position	
28	Aileron	Left	Outboard
29	Stabiliser	Horizontal	
30	Stabiliser	Vertical	
31	Wing	Right	Outboard
32	Engine Nacelle	Left	
33	Wing 1 stringer	Left	Inboard
34			
35	Tail clear perspex		
36	Wing rib	Left	Inboard
37	Fuselage stringer	Aft	
38	Rudder or aft fuselage skin & unidentified rib		
39	Wing tip light perspex red	Left	Outboard
40	Fuselage	Aft	?
41	Skin		
42	Aileron	Right	Inboard
43	Rudder	Upper	
44	Unidentified structure		
45	Light		
46	Newspaper (blown against fence)		
47	Wing main spar	Left	Lower
48	Baggage Door	Left	

Legend
- Left Wing
- Right wing
- Vertical Stabiliser
- Horizontal Stabiliser
- Fuselage
- Minor structure

Attachment B-3: Leading particulars of all major separated items

Aircraft Position Item Number	**Description**	**Weight**		**Dimensions**				**Areas**				**Weight/Surface Area ratio**	
				L_1	L_2	L_3	thickness	S_1	S_2	S_3	S_e	W/S_1	W/S_e
		kg	lbs	(cm)	(cm)	(cm)	(cm)	ft^2	ft^2	ft^2	ft^2	lb/ft^2	lb/ft^2
Left wing													
1	Cable access cover	0.02	0.04	17	8.5		0.20	0.16	0.00	0.00	0.10	0.28	0.44
10	Inboard Aileron	6.00	13.23	150	30		7.62	4.84	1.23	0.12	3.87	2.73	3.42
17	Aileron hinge	0.36	0.79	24	9		8.00	0.23	0.21	0.04	0.28	3.42	2.84
18	Wing main spar (upper and fwd cap)	2.45	5.40	94	30		9.00	3.03	0.91	0.15	2.51	1.78	2.15
21	Wing rear spar (top and bottom spars)	3.30	7.28	142	70		15.00	10.70	2.29	0.56	8.27	0.68	0.88
24	Wing (centre section)	26.00	57.33	262	75		12.70	21.14	3.58	0.51	15.75	2.71	3.64
25	Wing tip	7.00	15.44	110	81.5	67.5	12.70	8.82	1.50	1.02	6.57	1.75	2.35
28	Aileron outboard	5.50	12.13	136.5	30	26.6	7.62	4.16	1.12	0.23	3.36	2.92	3.61
32	Engine Nacelle	10.00	22.05	110	72		72.00	8.52	8.52	2.79	10.86	2.59	2.03
47	Wing main spar (lower cap)	1.22	2.69	46	30		17.00	1.48	0.84	0.27	1.48	1.81	1.82
Right wing													
9	Aileron outboard	6.00	13.23	150	29.5		6.99	4.76	1.13	0.11	3.75	2.78	3.53
22	Wing upper skin	1.04	2.29	90	30		9.00	2.91	0.87	0.15	2.41	0.79	0.95
31	Wing outboard	39.50	87.10	370	113	70	8.89	35.15	3.54	1.08	24.65	2.48	3.53
42	Aileron inboard	6.00	13.23	139	33		7.62	4.94	1.14	0.14	3.87	2.68	3.42
Empennage													
8	Left Elevator inboard	8.50	18.74	102	62	52	9.21	6.26	1.01	0.56	4.63	3.00	4.05
13	Right Elevator	14.00	30.87	211	63	29.8	9.53	10.53	2.16	0.48	8.09	2.93	3.82
14	Lower Rudder	10.00	22.05	96.5	83	65.5	10.16	7.71	1.05	0.81	5.58	2.86	3.95
20	Tail centre cone	10.00	22.05	143	50		40.00	7.69	6.15	1.08	8.82	2.87	2.50
27	Left Elevator outboard	6.00	13.23	108	41	28	6.35	4.01	0.74	0.24	3.02	3.30	4.38
29	Horizontal Stabiliser	36.00	79.38	474	50		11.75	25.50	5.99	0.32	20.06	3.11	3.96
30	Vertical Stabiliser	31.50	69.46	280	84		11.75	25.31	3.54	0.53	18.38	2.74	3.78
43	Upper Rudder	7.00	15.44	118	70	49	10.16	7.55	1.29	0.65	5.63	2.04	2.74
Fuselage													
48	Baggage Door	2.60	5.73	52	61.8		4.00	3.46	0.22	0.13	2.35	1.66	2.44
Main wreckage													
0	Main wreckage	2416.01	5327.30	782.32	355.6			270.62			270.62	19.69	19.69
Estimated aircraft Weight		2656	5855										

Attachment B-4: Wind drift/ terminal velocity technique: wind 230 deg T - Weight/mean surface area - light items



Attachment B-5: Ballistic coefficients curve