Australian Government
Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY INVESTIGATION REPORT

Aviation Occurrence Report – 200501000

Final

Loss of control
7 km WSW of Tamworth Airport, NSW
7 March 2005
VH-FIN
Cessna 310R

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Map in Figure 1 - Google Earth
Excerpts (adapted) from the Cessna 310R Pilot's Operating Handbook in Figures 3 and 4 – Cessna Aircraft Company

Abstract

At about 1326 Eastern Daylight-saving Time on 7 March 2005, the pilot of a Cessna Aircraft Company 310R, registered VH-FIN, took off from runway 30 Right at Tamworth Airport, for Scone, NSW. Approximately 1 minute after becoming airborne, the pilot reported flight control difficulties. At about 1329, the aircraft impacted the ground in a cleared paddock about 7 km west-south-west of the airport. The pilot was fatally injured and the aircraft was destroyed by the impact forces and post-impact fire.

Examination of the aircraft's mechanical flight control systems, autopilot and electric trim system did not reveal any evidence of pre-impact malfunction. Those results, however, were inconclusive due to the extensive impact and fire damage. A bent hand tool found in the wreckage was not implicated in the development of the accident.

A periodic maintenance inspection carried out in the days before the flight resulted in the rudder trim tab being set at the full right position and possibly aileron and elevator trim tabs being set at non-neutral positions prior to the flight. There were indications that the pilot was rushed and probably overlooked the rudder and aileron trim tab settings prior to takeoff. The aircraft flight path reported by witnesses was found to be consistent with the effect of abnormal rudder and/or aileron trim tab settings.

The investigation found that aircraft operating checklists produced by aircraft operators did not always include the autopilot and electric trim procedures located in the supplements of aircraft operating handbooks/flight manuals. At the time of the accident, the training and guidance generally provided to pilots did not emphasise the management of flight control difficulties including autopilot and electric trim related difficulties.

Following the accident, the aircraft operator and the maintenance provider advised that they had reviewed and amended some procedures. The Civil Aviation Safety Authority advised that a Civil Aviation Advisory Publication titled *Multi-engine Aeroplane Operations and Training* will be issued by July 2007 and that three items have been forwarded to the Safety Promotion Branch for consideration/action.

THE AUSTRALIAN TRANSPORT SAFETY BUREAU

The Australian Transport Safety Bureau (ATSB) is an operationally independent multi-modal Bureau within the Australian Government Department of Transport and Regional Services. ATSB investigations are independent of regulatory, operator or other external bodies.

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.

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The object of a safety investigation is to enhance safety. To reduce safety-related risk, ATSB investigations determine and communicate the safety factors related to the transport safety matter being investigated.

It is not the object of an investigation to determine blame or liability. However, 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.

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About ATSB investigation reports: How investigation reports are organised and definitions of terms used in ATSB reports, such as safety factor, contributing safety factor and safety issue, are provided on the ATSB web site www.atsb.gov.au.

1 FACTUAL INFORMATION

1.1 Sequence of events

At about 1326 Eastern Daylight-saving Time[1] on 7 March 2005, the pilot of a twin-engine Cessna Aircraft Company 310R, registered VH-FIN, took off from runway 30 Right (30R) at Tamworth Airport for Scone, NSW. Approximately 1 minute after becoming airborne, the pilot broadcast to air traffic control (ATC) that he was experiencing flight control difficulties. At about 1329, the aircraft impacted the ground in a cleared paddock about 7 km west-south-west of the airport (Figure 1), fatally injuring the pilot. The aircraft was destroyed by the impact forces and post-impact fire (Figure 2).

On 2 March 2005, the aircraft was flown from Bankstown, NSW to Tamworth for scheduled maintenance. The pilot who ferried the aircraft for the Bankstown-based operator of the aircraft reported that the flight was normal and the only defects noted were stiff roll (aileron) trim control and inoperative instrument post-light bulbs.

Figure 1: Takeoff and accident location

1 The 24 hour clock is used in this report to describe the local time. Eastern Daylight-saving Time was Coordinated Universal Time (UTC) + 11 hours.

Figure 2: Accident site

A maintenance provider at Tamworth performed the 100-hour inspection on the aircraft, which was planned for completion on 4 March. Due to additional maintenance tasks, including an unscheduled right engine change, completion was delayed until 7 March, the day of the accident.

On the day of the accident, the Bankstown-based operator of the aircraft asked the maintenance provider to arrange for a pilot to ferry the aircraft from Tamworth to Scone. The chief engineer referred the request to the chief pilot of the Tamworth-based aircraft operator associated with the maintenance provider. Some time between 0830 and 0900, the chief pilot contacted the pilot at home and offered him the flight, following expected completion of the maintenance at 1200. The pilot accepted the flight.

The enroute flight time from Tamworth to Scone was about 20 minutes. It was reported that the pilot planned to return to Tamworth on the train that departed Scone at 1400, the only daily train service. The pilot reportedly did not want to spend the night at Scone.

The pilot arrived at the maintenance facility at about 1000 and was advised that the aircraft's departure would be later than had been previously indicated. It was reported by some of the maintenance staff that the pilot was concerned about the later departure time and appeared 'rushed' and 'edgy'.

At about 1220, the aircraft was moved out of the hangar and a licensed aircraft maintenance engineer checked the oil quantity, fuel quantity and fuel drains in preparation for routine post-maintenance engine runs. At the pilot's request, he accompanied the engineer during the engine runs.

At 1229, ATC cleared the engineer to taxi the aircraft to a designated engine-run area. The engineer reported that he carried out the usual engine ground runs, and flight control movement checks, and there were no abnormalities detected. According to the engineer, during the course of the engine runs, the pilot 'played' with the autopilot control unit a number of times, despite the engineer's disapproval. The engineer thought that the autopilot was off during the engine run. At about 1239, after completing the engine run, ATC approved the engineer to taxi the aircraft back to the maintenance facility.

As per normal practice, the engineer and maintenance staff de-cowled and inspected the engines for oil leaks. There were no abnormalities observed and the engines were cowled. On leaving the aircraft to complete paperwork, the engineer observed that the rudder trim tab was fully deflected to the right.

The pilot started one engine, but over the period of a few minutes had difficulty starting the other engine. The engineer assisted the pilot with the start of the second engine.

At 1319, ATC cleared the pilot to taxi from the maintenance facility to the holding point of runway 30R via the main apron. The pilot taxied via a different route. The investigation was unable to establish if the pilot conducted pre-flight checks and engine tests.

At 1325:14, after the pilot transmitted he was ready for takeoff, ATC cleared the pilot to 'climb straight ahead visual'. A pilot in an aircraft parked at the main terminal reported that there was no undue delay between issue of the take-off clearance and the takeoff. That pilot observed the takeoff and described the take-off roll, rotation and climb as normal with no pitching or yawing evident. The aircraft tracked straight ahead to a height reported by witnesses to be between 600 and 1,200 ft above ground level (AGL). The aerodrome controller reported that the aircraft rotated at about 1326 and a half (1326:30).

Two engineers were observing the takeoff from the maintenance facility and they considered that the takeoff was normal, but noticed that on a couple of occasions the wing dropped left or right momentarily. A controller in the tower cabin noted that the take-off profile was normal. A controller entering the control tower noticed that an engine sounded rough and the engines were out of sync (different engine RPM).

When the aircraft was at a position estimated by various witnesses to be between 800 and 1,200 ft AGL and up to 7.5 km upwind of the departure end of runway 30R, while in a turn to the left, the pilot and ATC made the following radio transmissions:

Time	Station	Recorded transmission
1327:32	Pilot	'Err Tamworth Tower this is Foxtrot India November uh (got) err ………….ight control difficulties.'
1327:42	ATC	'Foxtrot India November, the transmission was broken, say again and if you wish, make right turn to return to the field.'

Witnesses at the airport reported that the aircraft turned left onto an apparent crosswind at an angle of bank not exceeding about 30 degrees. One of the witnesses reported that the turn was a series of small turns and that the aircraft appeared to be unstable. At some stage of the nominal crosswind, the aircraft pitched nose-down and lost between 200 and 300 ft before recovering to resume its altitude. The aircraft was reported to reach a maximum altitude of 1,200 to 1,400 ft AGL at the completion of the nominal crosswind leg.

It was estimated that the following transmissions were made sometime during the phase of the flight that corresponded to a crosswind segment of the departure runway.

Time	Station	Recorded transmission
1327:50	Pilot	'Foxtrot India November has got … (spurious/serious) control difficulties, I'm losing direction of the aircraft, the autopilot is not on, I don't know what the problem is.'
1328:06	ATC	'Foxtrot India November, roger, copied the details a left or right downwind is available as you prefer to return for landing.'
1328:19	Pilot	'Uh standby Foxtrot India November.'

It was reported that the pilot then made a level turn at a shallow angle of bank onto an apparent downwind heading. On or shortly after reaching a downwind heading, the aircraft was observed to roll and descend steeply in a nose-down attitude. Some of the witnesses reported that the aircraft may have rolled about its longitudinal axis at some stage on the final descent. The impact evidence showed that the aircraft struck the ground at about 35 degrees nose down and in a near wings-level position.

1.2 Meteorological environment

The weather information for Tamworth aerodrome at 1307 as broadcast on the automatic terminal information service was:

- wind variable at 8 kts with an occasional crosswind of 8 kts;
- CAVOK [2];
- temperature 27°C
- calculated mean sea level pressure datum (QNH) 1019 hPa.

1.3 General aircraft information

The aircraft was manufactured in 1977 in the United States (US) and was placed on the Australian civil aircraft register in 1978. At the time of the accident, the aircraft's total time in service was 12,453 hours.

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2 CAVOK was defined as:
- Visibility of 10 km or more
- No cloud below 5000 ft or below the highest minimum sector altitude whichever is greater
- No cumulonimbus clouds
- No precipitation, thunderstorm, shallow fog, low drifting snow or dust devils.

The aircraft was owned by an individual who leased the aircraft to a Bankstown-based operator. Scheduled maintenance was usually carried out by the maintenance provider at Tamworth.

The aircraft logbook statement specified that the aircraft was to be maintained in accordance with the CAA Maintenance Schedule[3]. The maintenance records indicated that in the days prior to the accident flight, the Tamworth maintenance provider had carried out a periodic inspection in accordance with that schedule and on the day of the accident had issued a maintenance release[4].

The CAA Maintenance Schedule included inspection of the flight control, electric trim and autopilot systems. The chief engineer reported that the autopilot was functionally tested during the periodic inspection and was found to be serviceable.

The following maintenance was carried out concurrent with the periodic inspection:

- lubrication of the rudder, aileron and elevator trim tab actuators
- replacement of the right engine with a serviceable assembly
- replacement of the left engine's number-5 cylinder and left muffler
- modification of the fuel boost pump system in accordance with revision 2 of Cessna service bulletin MEB88-3.

The pilot who ferried the aircraft to Tamworth reported that he departed Sydney with full fuel tanks. He calculated that a total of 120 litres of fuel was consumed from engines start in Sydney to engines shut down at the completion of the flight in Tamworth. There was no evidence that fuel was transferred within or drained from the aircraft.

The investigation estimated that at the commencement of the take-off roll, the quantity of usable fuel on board the aircraft was 458 litres. Based on that amount, the take-off weight of the aircraft was calculated to be 2,069 kg, which was 426 kg below the specified maximum take-off weight of 2,495 kg. The aircraft's centre of gravity was calculated to be within the specified limits and at the forward 23 percent point of the allowable centre of gravity range.

According to the Pilot's Operating Handbook (POH) applicable to the aircraft model, at the aircraft's take-off weight, zero bank angle, throttles at idle and with landing gear and wing flaps retracted, the stall speed was about 72 kts indicated airspeed. The POH stated that the power-on stall occurred at a very steep angle and that it was difficult to inadvertently stall the aircraft during normal manoeuvring.

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3 The CAA (CASA) Maintenance Schedule was a generic aircraft inspection schedule developed by the Civil Aviation Safety Authority's predecessors. A reprint of the schedule was included in Civil Aviation Advisory Publication 42B-1(0).

4 Issue of a maintenance release for an aircraft signified that all of the required maintenance had been performed in accordance with approved maintenance data and that if the Part 1 required maintenance was carried out, the aircraft should remain airworthy for the specified period.

1.4 Aircraft basic flight control systems

The aircraft's flight controls provided the means for a pilot to direct the aircraft along a desired flight path. The aircraft's primary[5] flight controls were mechanically operated and consisted of the rudder, aileron and elevator systems.

The rudder system provided directional control about the vertical axis. The main components of the rudder control system were a rudder surface hinged from the vertical stabiliser, rudder pedals in the cockpit and interconnecting cables with associated hardware such as pulleys. Fore/aft movement of the pedals in alternate directions operated the rudder to the left or right.

The aileron system provided roll control about the longitudinal axis. The main components of the aileron control system were an aileron surface hinged from each outer wing, control wheels in the cockpit and interconnecting cables with associated hardware such as pulleys. Rotation of the control wheel/control column operated the ailerons up and down in opposite directions.

The elevator provided pitch control about the lateral axis. The main components of the elevator control system were two coupled elevators hinged from the horizontal stabiliser, control wheels in the cockpit and interconnecting cables with associated hardware such as pulleys. Fore-aft movement of the control wheel/column operated the elevators simultaneously up or down.

One of each of the aircraft's primary flight control surfaces were fitted with inflight adjustable trim tabs (Figure 3). The main components of each system were the trim tab surface hinged off the parent control surface, mechanical jack-screw type actuator, trim control wheel in the cockpit and interconnecting cables with associated hardware such as pulleys.

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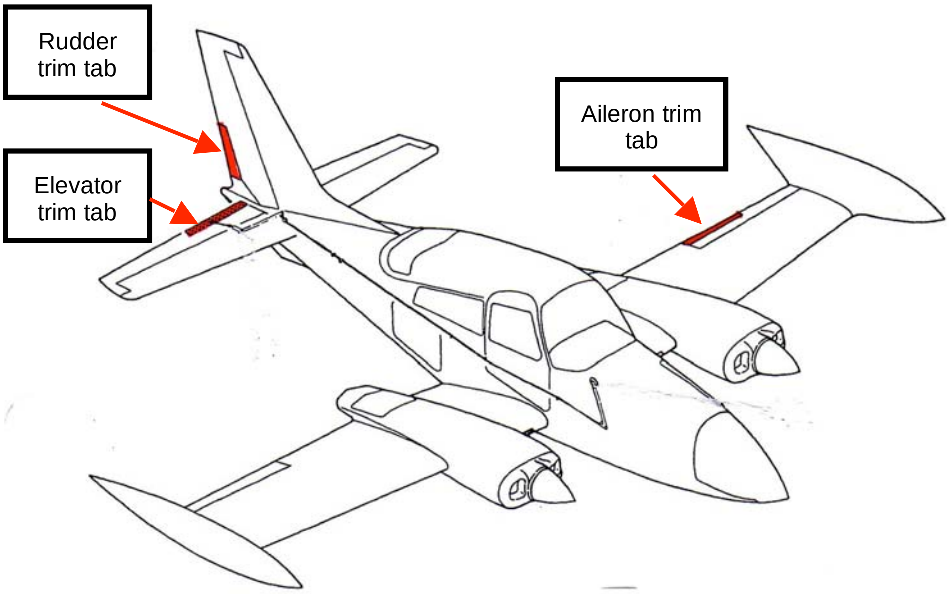
5 Primary flight controls were defined as those used by the pilot for the immediate control of the pitching, rolling and yawing of the aircraft.

Figure 3: Cessna 310R trim tab location



1.5 Electric elevator trim system

The aircraft was equipped with an electric elevator trim system. The system provided the pilot with the means to electrically operate the elevator trim by activating a 'momentary on' two-way switch on the left control wheel (Figure 4).

The main components of the electric elevator trim system were:

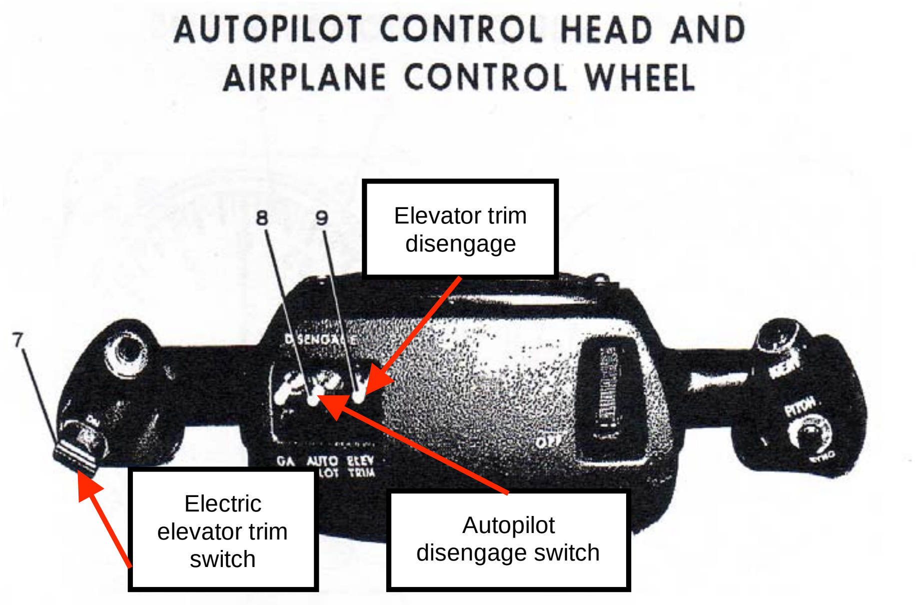
- electric trim control switch on left horn of left control wheel
- electric trim disengage switch on control wheel hub
- electric actuator assembly in aft fuselage
- associated wiring and control cables.

According to the *Cessna 310 Service Manual*, three revolutions of the trim tab wheel should take 23 to 25 seconds. The aircraft manufacturer advised that nine revolutions of the trim wheel were required to move the trim tab from the full down to the full up position. Therefore, pilot-commanded travel of the electric elevator trim from the full down to full up position was estimated to take 69 to 75 seconds.

The emergency procedures for the electric trim were located in supplement 4 of the aircraft's POH. The procedures in the event of an electric elevator trim malfunction were that the pilot must overpower the elevator control, disengage the electric trim and autopilot systems via the control wheel switches, and then manually trim the aircraft as required. Later model aircraft had a combined autopilot and trim disengage switch located on the control wheel horn.

When the autopilot was engaged, the electric pitch trim system was disabled and the aircraft could not be trimmed by the pilot using the pitch trim switch.

Figure 4: Cessna 310R control wheel arrangement applicable to VH-FIN



1.6 Autopilot system

The aircraft was equipped with a Cessna/ARC Nav-O-Matic 400B two-axis with altitude hold autopilot system that, when engaged, automatically commanded aircraft roll and pitch attitudes. The main components of the autopilot system were:

- control unit in cockpit
- spring loaded disengage switch on control wheel
- attitude gyro (artificial horizon) instrument
- directional gyro instrument (including heading selector or ‘bug’)
- computer amplifier unit and altitude sensor unit in aft fuselage
- roll actuator and pitch actuator
- associated wiring and control cables.

The autopilot was engaged by selection of the AP ON rocker switch on the control unit. When the autopilot was engaged, the roll and pitch modes of the autopilot were activated in accordance with the following:

- Turn command knob IN: the roll actuator would drive the ailerons to turn the aircraft towards the heading ‘bug’ on the directional gyro.
  Turn command knob OUT: the roll actuator would drive the ailerons to turn the aircraft in the direction corresponding to turn command knob position.
- The pitch channel of the autopilot was automatically synchronised with the pitch attitude of the aircraft when the autopilot was engaged. The pitch actuator would maintain that pitch attitude until the pitch command wheel position was altered or the ALT switch selected to activate altitude hold.

Once engaged, the autopilot utilised the electric elevator trim system to supplement the pitch actuator. If the pitch actuator was unable to produce the commanded pitch attitude within a 3-second period, elevator trim would be electrically applied in the desired sense.

A slip clutch was fitted to the roll actuator, which allowed the actuator to be overpowered by a pilot applying an opposing force to the control wheel of not more than 20 lbs (9 kg).

A slip clutch was fitted to the pitch actuator, which allowed the actuator to be overpowered by a pilot applying an opposing force to the control wheel of not more than 40 lbs (18 kg), provided the aircraft was trimmed. If the pitch actuator was jammed, the required control wheel force was no more than 50 lbs (22 kg).

The emergency procedures for the autopilot were located in supplement 23 of the POH. If the autopilot malfunctioned, the pilot was to overpower the elevator or aileron control and disengage the autopilot and electric trim systems using the control wheel switches. The POH noted that sustained elevator overpower would result in the autopilot trimming against the overpower force. Possible altitude loss if the autopilot malfunctioned in the cruise configuration was quoted as 600 ft.

The autopilot was designed to disconnect automatically when the aircraft reached a pitch angle of between 20 and 25 degrees nose-up and about 18 degrees nose-down. In addition, the roll and pitch actuators were fitted with a thermal cut-out device that disengaged the autopilot system in the event of excessive actuator heating produced by prolonged loading or malfunction.

1.7 Wreckage and impact information

The accident site was a paddock that was fenced and flat, with a slight slope. The ground was dry, hard-packed earth sparsely covered with grass.

Ground impact marks indicated that the aircraft struck the ground upright in a near wings level (slightly right wing low), nose-down attitude of between 35 and 40 degrees, on a heading of about 105 degrees magnetic (a downwind heading for runway 30R in nil wind conditions would have been about 121 degrees magnetic).

The wreckage trail covered a distance of approximately 217 m in length with a maximum width of 31 m. Small, high-density items such as instrument gyros were found at the end of the wreckage trail. The main section of the wreckage (Figure 5), consisting of the wings, fuselage and engine, was 23 to 29 m from the point of initial impact.

The aircraft was destroyed by the impact forces and subsequent fire. The cockpit area, including all instrumentation, experienced high impact forces, resulting in extensive fragmentation damage.

Figure 5: Main wreckage

Examination of the propellers and engines showed evidence of normal operation at the time of impact and there was no evidence of any pre-impact failure. The type and degree of damage to the engines and propellers was consistent with substantial power being delivered by the engines at impact. All propeller blades were accounted for.

All of the primary and secondary flight control surfaces were accounted for at the wreckage site. The wing flaps were retracted. There was no evidence of flight control system defects. Due to the extent of the damage to the aircraft, flight control continuity could not be conclusively established.

All of the trim tabs were identified in the wreckage and were found attached to the parent control surfaces. All of the trim tab actuators were removed from the aircraft wreckage for detailed examination. Before the actuators were disassembled, each unit was x-rayed. There was evidence of positive thread engagement throughout and no indication of any abnormalities. The aileron trim tab actuator shaft was bent approximately 90 degrees, consistent with impact and break-up forces.

Each trim tab actuator's as-found extension was measured, translated into trim tab deflection and compared with the manufacturer's trim tab deflection limits. Those results were:

- rudder trim tab actuator extension corresponded to tab deflection beyond its right deflection limits (nose left tendency)
- aileron trim tab actuator extension corresponded to 12 degrees tab down deflection (left roll tendency)
- elevator trim tab actuator extension corresponded to tab deflection beyond its up travel limits (nose-down pitch tendency).

The investigation considered that the trim tab actuator extensions were probably influenced in some way by the ground impact and subsequent breakup, but it was not possible to determine the extent of any influence. The bending of the aileron trim tab actuator shaft increased the likelihood that the actuator extension after the accident was similar to the pre-impact extension.

During the on-site examination of the wreckage, investigators located a number of tools including a damaged hand tool (Figure 6) that would not normally be expected to be carried on the aircraft. The tool, known as a pin punch, was identified as belonging to an employee of the primary maintenance provider. That employee had not been involved in aircraft maintenance for the 6 months prior to the accident and the maintenance provider reported that the maintenance carried out before the flight did not include any tasks requiring use of such a tool. The investigation was unable to establish where the tool was located in the aircraft or when the tool was left in the aircraft.

Figure 6: Tool recovered on site

Specialist examination of the bending damage to the punch handle found that the tool had impacted against, or been struck by, a wrought aluminium component or structure before or during the accident ground impact. There was no evidence that the punch had been trapped within, or had in any way interfered with the control systems of the aircraft – indeed, the absence of reciprocal loading points on the punch handle (support points opposite the impact point) was evidence against such an eventuality.

While not quantified in terms of a mechanical assessment of the control systems of the Cessna 310, it was nevertheless considered unlikely that a force of the magnitude calculated (280+ kg) could be developed and placed against the punch handle under the conventional movement of the flight controls by the pilot.

1.8 Examination of autopilot and electric trim components

The extent of impact and fire damage to the aircraft's avionics systems significantly limited the examination of the autopilot system. The control unit, roll actuator, pitch actuator and trim actuator were the only autopilot and electric trim components able to be recovered from the accident site. Functional testing of those components was not possible, but the components were thoroughly inspected and comparative testing was carried out on exemplar units.

Laboratory examination of the control unit components found no defects or evidence of anomalous operation. Of note was a wire from a rear connector pin that showed evidence of significant thermal damage to the insulation, while the adjacent wires were not similarly affected. When examined microscopically, charred organic material consistent with plant matter present at the accident site was found embedded within the damaged wire insulation.

Specialist laboratory examination and micro-analysis found that the damaged wire insulation was PVC material. In comparison, the insulation of the adjacent wires was identified as Teflon (PTFE), which was specified by the manufacturer’s drawings. A series of laboratory evaluations found that the PTFE insulation had superior resistance to thermal degradation and damage when compared to PVC insulated products.

To investigate the possibility of an electrical overload having thermally damaged the control head wire, a series of tests was conducted on samples of wiring from an exemplar control head. The results of this work showed that the maximum electrical current able to be delivered from the autopilot supply was insufficient to produce the observed wiring damage.

Examination of the roll actuator found that the slip clutch breakout torque was within the aircraft manufacturer’s limits. The magnetic engagement clutch was found in the not-engaged position. The main switching transistors were secure and tested serviceable as did the resistors. There was no evidence of any malfunction.

Examination of the pitch actuator found that the slip clutch breakout torque slightly exceeded the aircraft manufacturer’s limits in one direction and was significantly below the limit in the other direction. The magnetic engagement clutch was found in the not-engaged position. The main switching transistors were secure and tested serviceable, as did the resistors. There was no evidence of any malfunction.

Examination of the electric trim actuator found that the slip clutch breakout torque was marginally higher than the aircraft manufacturer’s limits. The engagement clutch was found in the not-engaged position. There was no evidence of any malfunction.

1.9 Audio spectrum analysis

The ATC provider automatically recorded transmissions on the Tamworth ATC frequencies. A copy of the audio recorded between 1312 and 1354 was obtained and each of the pilot’s transmissions spectrally analysed by the investigation. The analysis yielded the following results:

- no aural alarms were detected from the recorded audio
- no information regarding autopilot operation could be adduced
- the engine/propeller RPM (+/- 50 rpm) at:
  - 1319:38 (taxi call) was, 1795 RPM
  - 1325:09 (ready call) was, 1836 RPM
  - 1327:32 (control difficulties call) was, 2650 RPM
  - 1328:19 (standby call) was, 2660 RPM
- no significant dissimilarities in engine/propeller RPM were detected.

The aircraft's maximum engine RPM was 2700. It should be noted that engine power was principally a product of RPM and manifold pressure. Manifold pressure could not be measured by audio analysis.

1.10 Pilot information

In 1999, the Civil Aviation Safety Authority (CASA) issued the pilot with a private pilot (aeroplane) licence and in 2000, CASA issued the pilot with a commercial pilot (aeroplane) licence. In 2001, the pilot qualified for a command multi-engine instrument rating and a Grade 3 instructors rating. In that year he was also endorsed on Cessna 310, Piper Twin Comanche and Piper Navajo/Chieftain type aircraft.

The pilot was reported to have flown gliders in the United Kingdom and the pilot's logbook indicated that he also did most of his flying training for the private pilot licence there. The pilot qualified for his private pilot licence with the Tamworth-based operator and continued flying with that operator. In addition to the flying training for the issue of licences, ratings and endorsements, the pilot had conducted a considerable number of commercial flights with the operator as pilot in-command-under-supervision and was casually employed as a charter pilot and instructor. Aeroplane flying experience was recorded as a total of 1,005.5 hours, which included 461.5 multi-engine hours.

According to the pilot's logbook, the pilot had flown at least nine different aircraft types, including single engine aircraft types, and had flown at least 16 different aircraft. Most of the pilot's multi-engine flying experience was on Piper Navajo and Chieftain aircraft and most of his flying in the 2 months before the accident was on a Chieftain.

Since being endorsed on the Cessna 310R in 2001, the pilot had flown a total of 50 hours on the aircraft type, including 1.8 hours in VH-FIN in 2001. Most of the pilot's C310R flying was in the operator's aircraft, VH-FVT, which the pilot last flew on a positioning flight on 31 January 2005.

On 15 October 2004, the pilot completed a flight proficiency check conducted by the operator's chief pilot in the operator's Navajo aircraft. The check was the pilot's second attempt after not managing a simulated engine failure appropriately on the first attempt. The chief pilot noted that the successful check flight was the best that the pilot had completed.

The chief pilot recalled that he never had concerns about the pilot's flying and that he handled the aircraft well. The chief pilot said that the pilot was always conscientious and followed the checklist.

The senior pilot who supervised a number of the pilot's in-command flights described the pilot's preparation for flights as 'impeccable'. The senior pilot did not recall the pilot having any problems with the Cessna 310R autopilot.

It was reported that in the 72 hours prior to the accident the pilot was adequately rested and had not engaged in any activity that would have adversely affected his ability to perform flight duties. The pilot held a valid class 1 medical certificate and there was no evidence that any physiological or psychological factors had affected the performance of the pilot.

1.11 Cessna 310R operating procedures and practices

Pilot's Operating Handbook

The Cessna 310R Pilot's Operating Handbook (POH) was the CASA-approved aircraft flight manual. It included normal procedures, emergency procedures and supplements sections. Although a POH was not recovered from the accident site, it was reported that a POH was onboard the aircraft.

The normal procedures section included pre-flight inspection procedures which were recommended for the first flight of the day. The procedures included setting the trim tab controls to neutral during the preliminary part of the inspection, then inspecting the tab position during the 'walkaround' component. Also included in the normal procedures section were Before Takeoff checks, which included setting of the trim tabs and a check of flight control movement.

As described in the electric elevator trim system and autopilot system sections of the report, the POH normal and emergency procedures related to those systems were contained in the supplements section. The introductions to the normal and emergency procedures sections of the POH included the following note:

> Refer to section 9 of this Pilot's Operating Handbook for amended operating limitations, operating procedures, performance data and other necessary information for airplanes equipped with specific options.

The POH supplement stated that the autopilot must be off for takeoff.

Tamworth-based operator

The Tamworth-based operator who tasked the pilot, published an operations manual that included aircraft-specific operating procedures. Based on those procedures, the operator produced a booklet-type checklist containing normal and emergency procedures for each aircraft type, which was available in each of the operator's aircraft.

The operator's Cessna 310R normal procedures checklist specified that the pre-flight inspection was as per the POH. The checklist included a trims-set check in the After Start checks and a flight controls full-and-correct-movement check in the Taxi and Pre-Takeoff checks.

The normal and emergency procedures checklist did not incorporate the autopilot-related pre-takeoff checks or emergency procedures specified in supplement 23 of the Cessna 310R POH.

The operations manual did not contain any procedures regarding the timing of autopilot engagement. Generally, use of the autopilot was encouraged and the chief pilot commented that the pilot was adept at their use. The chief pilot advised that the usual time to engage the autopilot would be once the aircraft was established in the climb after intercepting track and that the pilot had not previously engaged the autopilot at a low altitude after takeoff. The senior pilot reported that the standard practice was to engage the autopilot in the cruise.

For a departure from Tamworth, the chief pilot reported that it would have been usual for the pilot to have reduced power at 500 ft AGL. According to the POH, the normal after takeoff power setting was 24.5 inches Hg manifold pressure/2500 RPM and the normal cruise climb was at 115 to 130 kts indicated airspeed.

Operator of VH-FIN

The Bankstown-based operator of the aircraft produced a laminated booklet-type Cessna 310R checklist that was intended for use in the aircraft. The checklist contained normal and emergency procedures that reflected the content of the normal and emergency procedures sections in the Cessna 310R POH.

The engineer who assisted the pilot in the starting of the second engine prior to the accident flight reported that he did not notice the pilot using a checklist. The investigation was unable to determine if the pilot was using that checklist.

1.12 Aerodynamic effect of flight controls

A pilot controls an aeroplane by manipulating the control wheel/column and rudder pedals, which deflect the ailerons, elevators and rudder. Deflection of an aircraft's primary flight control surfaces changes the aerodynamic shape and therefore the amount of lift generated by the associated part of each wing, vertical stabiliser or horizontal stabiliser. Those local variations in lift resulted in changes to the aircraft attitude and consequently flight path.

Any deflection of the primary flight control surfaces into the adjacent airflow produced aerodynamic forces on the surface and corresponding loads on the control wheel or rudder pedals. The magnitude of the aerodynamic force was principally related to the amount of flight control surface deflection, airspeed, and trim tab deflection.

During flight, deflection of an aircraft's trim tab produced an aerodynamic force on the aft part of the allied primary surface. The tabs had the capacity, when adjusted in the opposite direction to the deflection of the primary surface, to modify the aerodynamic force on the surface and correspondingly, reduce the load felt by the pilot on the control wheel/column or rudder pedals. The effectiveness of a trim tab was principally related to the amount of deflection of the trim tab and the airspeed.

The aerodynamic effect of a certified aircraft's flight controls were required to meet certain criteria. The Cessna 310R was certified as a normal category aircraft complying with the design requirements of Civil Air Regulations Part 3 (CAR 3) and US Federal Aviation Regulations Part 23 (FAR 23).

The aircraft manufacturer provided information regarding aircraft controllability, derived principally from certification flight test data. That information included the following:

- the effect of jammed controls could not be predicted as testing for that condition was not required by CAR 3/FAR 23
- the effect of fully deflected trim tab surfaces could not be predicted because testing for those conditions was not required by CAR 3/FAR 23
- the directional and lateral stability demonstrated by the Cessna 310 implied that with a fully deflected rudder, bank angle could be commanded and controlled (with aileron) up to an airspeed of 148 kts.

Essentially, the CAR 3/FAR 23 requirements for trim stipulated that the load on the control wheel and rudder pedals was able to be reduced to zero in various normal aircraft configurations and associated airspeed ranges. The investigation considered that a trim system capable of meeting the CAR3/FAR23 requirements at relatively low airspeed would be sufficiently effective at relatively high airspeeds to generate significant aerodynamic force on the related primary flight control.

In response to the absence of data regarding the effect of full trim tab deflection on controllability, the investigation conducted a qualitative assessment of applicable Cessna 310R flying characteristics[6] in a representative[7] aircraft. With the landing gear and flaps retracted, and full power applied, sequences were flown with various individual and combined abnormal trim tab settings. During each sequence, the airspeed was varied between 95 and 148 kts. The assessment found that qualitatively:

- Coordinated flight with full right rudder trim tab setting (nose left yaw) required light rudder pedal load at 95 kts, which progressed to medium load at 120 kts and heavy load at 148 kts. Application of aileron in the right roll sense reduced the rudder pedal load, but added control wheel load. There was a significant left turning tendency.
- Coordinated flight with full down aileron tab setting (left roll) required light control wheel load at 95 kts, which progressed to medium load at 120 kts and heavy load by 148 kts. There was a significant left turning tendency.
- Coordinated flight with full right rudder trim tab setting (nose left yaw) and 12 degrees aileron trim tab down (left roll) required medium rudder/control wheel loads at 95 kts, which progressed to heavy loads at 120 kts and was excessive by 148 kts leading to a divergence from the desired flight path. There was a significant left turning tendency.
- Coordinated flight with full up elevator trim setting (nose down) required heavy control load at 95 kts, which quickly progressed to excessive loads before 120 kts leading to a divergence from the desired flight path.

The pilot flying during the assessment regarded the heavy flight control loads as unsustainable for any length of time and the medium control loads as having potential for pilot fatigue.

Following the flight assessment, the pilots timed a takeoff and departure. Maximum engine power was applied 20 seconds after timing was begun and remained selected during the sequence. A gentle turn was initiated at 1,000 ft and the climb continued at 120 kts to 2,000 ft, where the aircraft levelled. The pilots found that:

- At the time corresponding to the first airborne call, the aircraft had reached 1,900 ft

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6 The flying assessment was subject to a number of risk controls including two pilots, minimum altitude of 3,000 ft above mean seal level, visual meteorological conditions and specified recovery procedures.

7 The aircraft was a Cessna 310R that was operated about 120 kg heavier than the calculated take-off weight of VH-FIN and about 34 mm aft of the calculated take-off centre of gravity of VH-FIN. The variation between the aircraft used in the qualitative assessment and VH-FIN was not considered to be significant.

- At the time corresponding to the second airborne call, the aircraft was maintaining about 2,000 ft and had accelerated to 150 kts
- At the time corresponding to the pilot's last airborne transmission, the aircraft was maintaining about 2,000 ft and had accelerated to 178 kts.

1.13 Inflight management of flight control difficulties

Instructional requirements

The *Day VFR Syllabus – Aeroplanes* detailed the competency requirements for the issue of private and commercial pilot licences. The 'manage abnormal situations' units of the syllabus included 'flight control' among a number of other situations in the general 'manage abnormal situations' element.

The syllabus of training for the initial issue of a multi-engine aeroplane type endorsement was contained in Civil Aviation Advisory Publication (CAAP) 5.23-1 (0). There was no specific reference to automated flight control systems in the ground briefings, questionnaire or air exercises. The associated flight assessment report included a 'recognition and control of runway [sic] trim (if applicable)' item and a 'demonstrate ability to use all aeroplane systems … autopilot and flight director' items. These items were checked as having been completed on the flight assessment report completed for the pilot's C310R endorsement.

As part of a long-running regulatory reform program, CASA was developing a draft Civil Aviation Safety Regulation (CASR) Part 61 to prescribe the requirements and standards for the issue of flight crew licences, ratings and other authorisations. At the time of writing the report, CASA had produced a draft CAAP titled *Multi-engine Aeroplane Operations and Training* to support the new CASR. It contained a discussion of autopilot and electric trim issues and introduced autopilot/electric trim topics into the underpinning knowledge requirements and questionnaire.

Flight control difficulty occurrences

In June 2004, the Australian Transport Safety Bureau (ATSB) produced an aviation research paper titled *General Aviation Fatal Accidents: How do they happen?* The report found that between 1991 and 2000 inclusive, there were 215 fatal accidents that included 74 accidents categorised as uncontrolled flight into terrain (UFIT). Of those, there were three fatal aeroplane accidents that resulted from loss of control after airframe or system problems.

A search of the ATSB database was made for flight control difficulty occurrences involving aircraft below MTOW[8] of 5,700 kg that occurred between 1991 and 2000. In that period, there were 13 reported events of unexpected aircraft behaviour attributed to autopilot malfunction, including one Cessna 310 occurrence. In the same period, there were reports of 177 occurrences where the event type related in some way to flight control problems, including four Cessna 310 occurrences. It should be noted that the accuracy of each event type designator was not verified.

8 Maximum take-off weight.

1.14 Human Factors

Time pressure

Human factors research has consistently shown a strong relationship between the time taken to complete a task and the accuracy of a person's performance (known as the speed-accuracy trade-off). That is, the faster a task is done, the more likely that errors will be made. Time pressure can also lead to stress, which can have many effects, including a narrowing of attention to the more salient aspects of the pilot's task, decreased searching or scanning behaviour, task shedding, and impaired memory retrieval.

Time pressure has been identified as contributing to pilot errors in many aviation incidents and accidents. One research study analysed 125 confidential pilot self-reports of time-pressure related incidents to the US National Aeronautics and Space Administration aviation safety reporting system (ASRS) from two-crew air carrier and commuter operations. The study found that most errors related to time pressure occurred in the pre-flight or taxi-out phases of flight. The consequences of these errors, however, were most likely to occur in the taxi-out, take-off, or initial climb phases of flight. The study found that 60 per cent of errors were errors of commission, where the pilot conducted some element of their required task incorrectly, such as rushing checks and/or completing them by memory and as a result, missing pertinent information. Other errors related to time pressure (38 per cent) were errors of omission, where the pilot did not conduct some element of a required task, such as not completing required checklists or not checking the flight log before flight.

Workload

A pilot can successfully manage high workload tasks provided they are familiar or have been rehearsed. Novel tasks (such as diagnosing an unusual problem with an aircraft), however, impose a higher workload on a pilot because there are generally no operating rules that can be applied. Instead, the pilot generally has to rely on knowledge of first principles such as aircraft aerodynamics and systems knowledge to successfully diagnose and rectify the situation. Such knowledge-based activity requires time and cognitive capacity that a pilot may not have available in some situations.

Task related stress generally results in the pilot focusing attention on the task generating that stress. To reduce workload a pilot may ignore other aspects of the environment competing for attention. However, when one of these environmental cues is important to the safety of flight, focussed attention on the stressful task can lead to the pilot missing important information. There have been a number of examples of this leading to aircraft accidents[9]. If task related stress gets too high, the pilot's ability to process information can start to breakdown, significantly increasing workload.

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9 One example is the crew of a US Eastern Airlines L-1011 flight, crashed into the Florida Everglades in 1972 due to the crew focusing their attention on a landing gear light malfunction and not noticing that the altitude hold function of the autopilot had disengaged.

Rudder and aileron trim control ergonomics

The rudder trim wheel was located below the autopilot control unit in the centre pedestal (Figure 7). A white-tipped pointer above the trim wheel provided an indication of the rudder trim tab position. In Figure 7 it is indicating that the trim tab is in the full nose-left position.

The aileron trim wheel was located below the rudder trim wheel in the centre pedestal (Figure 8). A white-tipped pointer above the trim wheel provided an indication of the aileron trim tab position. In Figure 8 it is indicating that the trim tab is in an approximate neutral position.

The rudder and aileron trim controls were located outside of the lower right quadrant of the pilot's visual field. That would have minimised the pilot's ability to detect the status of the rudder and aileron trim indicators which were located in the lower portion of the centre pedestal.

Figure 7: Rudder trim wheel (circled) viewed from behind the pilot's seat

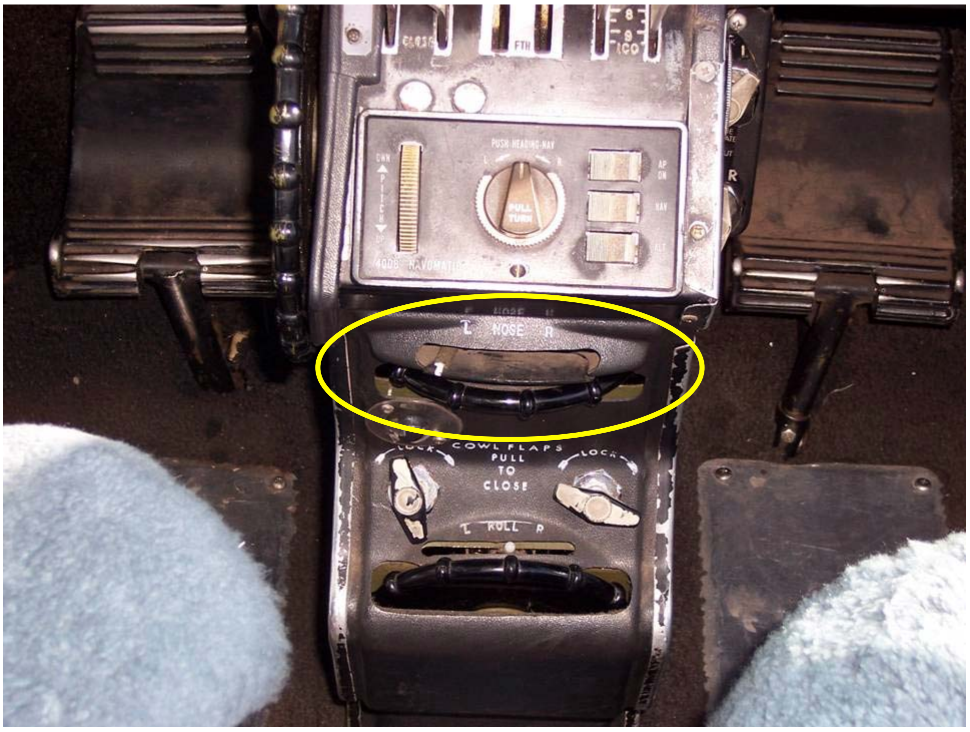
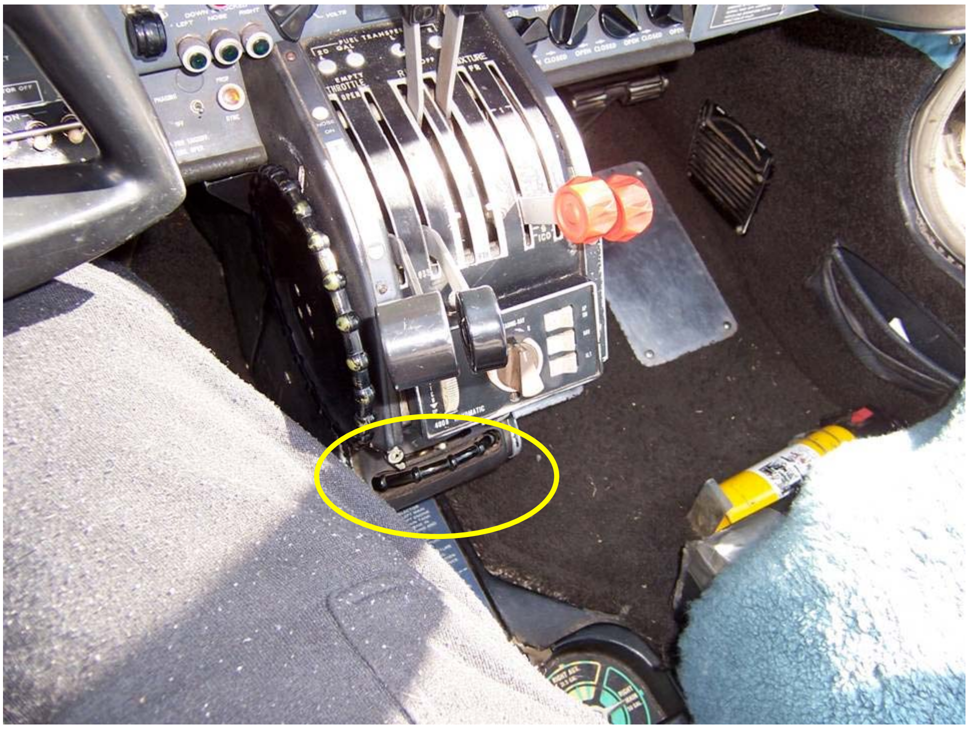


Figure 8: Aileron trim wheel (circled) viewed from the pilot's seat



1.15 Aircraft maintenance provider

The Tamworth-based maintenance provider was a CASA-approved maintenance organisation. As such, the maintenance provider was subject to regular on-site audits, the most recent of which was in June 2003. The audit report indicated that the company was operating at an acceptable level of compliance.

CASA regularly completed safety trend indicator questionnaires (STI) on approved maintenance organisations. CASA completed the most recent STI related to the maintenance provider on 22 December 2004. The CASA respondent considered that the organisation did not have a mature, well-functioning safety system, which was the only high risk response recorded. The maintenance provider advised that CASA did not inform them of the STI results. Overall, the respondent did not know or was unsure about the performance of the organisation compared with 12 months before or relative to other organisations.

A review of the maintenance documentation for the periodic inspection conducted prior to the accident showed that the worksheets and logbooks were completed and the certifying engineers were appropriately licensed to certify for the airworthiness of this aircraft.

The maintenance provider used schedule worksheets that included the following item or a similar item at the end of each category:

> …a post inspection check must be made to ensure that no tooling, maintenance equipment rags have been left in the aircraft and all panels, access doors, detachable fillets have been correctly secured.

Civil Aviation Regulation (CAR) 30 (2D) required that all approved maintenance organisations had a documented system of quality control that included control of the work carried out and control of equipment. Civil Aviation Advisory Publication (CAAP) 30-4(0) *Certificate of Approval - Maintenance Organisation* Appendix 3 stated that:

> Tools and equipment should be controlled so that their location is always known. There should be a procedure to ensure that at shift changes, or when the aircraft leave the organisation, all tools and equipment are accounted for.

The maintenance provider did not have a formal system to track the location of tools and equipment during aircraft maintenance.

2 ANALYSIS

2.1 Introduction

The circumstances of this accident are consistent with the pilot losing control of the aircraft at a point corresponding to an early downwind position of the departure runway circuit. Although the pilot transmitted that he was experiencing a flight control difficulty, severe impact and fire damage to the aircraft, and a lack of recorded data limited the amount of information available to the investigation and precluded a conclusive result.

Based on the evidence that was available, it was most unlikely that the following factors were involved in the development of the accident:

- flight control system mechanical failure
- aircraft structural failure
- lateral asymmetries such as engine failure or asymmetric flap
- centre of gravity limit exceedance
- pilot incapacitation.

The following factors remained possibilities and the evidence relating to each factor is discussed in the analysis. One of the factors was identified as the most likely contributing factor in the accident:

- flight control interference
- electric trim runaway
- autopilot related
- abnormal trim tab settings.

2.2 Nature of flight control difficulty

The first indication of a problem was the pilot report of flight control difficulty about 1 minute after the aircraft became airborne, which was probably about the time the left turn started at about 1,000 ft. The takeoff up to that point was observed to be normal, albeit with some movement in roll that may or may not have been related to the control difficulty.

An indicator of an abnormality was the identification in the first airborne radio transmission of propeller RPM that was close to the maximum power value. Given propeller RPM was normally reduced to a climb setting at about 500 ft, that higher-than-normal RPM may indicate that the pilot workload was significant from at least 500 ft. Although the investigation was unable to pinpoint the onset of the flight control difficulty, the condition may have existed since the take-off roll.

The left turn after takeoff was probably started before ATC cleared the aircraft to turn left if required. In that case, it is possible that there was a strong left turn tendency and the pilot allowed it to go that way. The reported altitude deviation on the crosswind sector and the apparent ability of the pilot to recover the altitude indicates that the pilot had some pitch control.

The second pilot transmission airborne indicates that the autopilot was off and suggests that, to the pilot, the aircraft behaviour was consistent with an autopilot type problem. The pilot description of losing direction of the aircraft can be interpreted as a reference to the direction of the aircraft in a lateral sense or more broadly as losing control of the aircraft.

The third and last pilot transmission airborne indicates that the pilot's workload was high. The aircraft's departure from generally level flight appears to have included some roll and to have been progressive.

2.3 Flight control system interference

The location of the bent hand tool in the wreckage raised the possibility that it may have contributed to the flight control difficulty. Despite the tool being found in the wreckage, it was not possible to establish whether it was in an internal section of the aircraft that contained part of a primary flight control system or when it had been introduced.

The bending damage to the tool was found to be consistent with severe impact and breakup forces and there was no evidence that the tool had interfered pre-impact with a control system. Such evidence, however, may not have been detectable post-accident.

There was no work carried out during the maintenance activities preceding the flight that appeared to require use of such a tool. It is possible that the tool had been in the aircraft for some time and had not been detected during the recent periodic inspection. In any case, given the engineer checked the full and free movement of the flight controls prior to the flight, there was no evidence of any event or condition likely to precipitate ingress of the tool into a flight control mechanism before, during or after the takeoff.

Any interference in a flight control system, by the tool or any other mechanism, was likely to be in one axis only and to be readily identifiable by the pilot. However, the pilot's radio transmissions while airborne gave the impression that he didn't understand the nature of the flight control difficulty.

The investigation surmised that any sustained interference in a flight control system was likely to have a continuous effect and to be most critical in the case of interference in the elevator system then aileron system. In those cases, the aircraft would be expected to diverge from controlled flight soon after onset and the condition to progressively worsen until impact. Such aircraft behaviour was not observed by the witnesses. According to the aircraft manufacturer, a Cessna 310R with sustained interference in the rudder system was controllable through use of the ailerons.

While the limited evidence did not allow the investigation to rule out interference in a flight control system as a possible contributing factor, in the context of this accident it was considered to be unlikely.

2.4 Electric trim runaway

Although there were no defects identified in the electric trim system post-accident, impact and fire damage precluded a conclusive assessment. The finding of the elevator trim tab actuator extension beyond the specified up (nose-down) travel limits was consistent with an inflight electric trim runaway in that direction, but was also possibly attributable to the aircraft breakup on impact.

If the electric trim system had started to runaway in the nose-down direction during the takeoff, it follows that the effect was apparent to the pilot before the first airborne radio transmission at 1327:32. Assuming that the trim tab was in a neutral position (nominally half travel range) prior to any runaway, the time taken for the trim tab to reach full deflection would be no more than about half the time taken for full travel, which would make it about 36 seconds. Therefore, in any runaway, the trim tab would have been fully deflected by 1328:08 at the latest. The pilot's last radio transmission was initiated at 1328:19.

Once the aircraft reached about 1,200 ft and then descended momentarily on crosswind, it is likely that the aircraft would have accelerated to well above 120 kts. In that situation, the investigation's flight assessment showed that a Cessna 310R with full nose down elevator trim would probably continue the descent rather than recover the altitude momentarily as observed.

There were indications that the pilot was experiencing directional control difficulties. By itself, electric trim runaway does not provide an explanation for any directional control difficulties.

While the limited evidence did not allow the investigation to rule out electric elevator trim runway as a possible contributing factor, in the context of this accident it was considered to be unlikely.

2.5 Autopilot related anomaly

As an aircraft system that had a potential influence on roll and pitch, the autopilot was a possible explanation for the flight control difficulties, especially in regard to any directional control aspects. The investigation examined the possible effect of a functioning autopilot as well as a malfunctioning autopilot.

The functional testing of the autopilot during the periodic inspection prior to the flight was evidence that the autopilot system was functioning correctly. There were no events after the testing considered likely to alter the serviceability of the autopilot. In addition, the autopilot had apparently functioned properly on the pervious flight and there was no history of significant or recurring problems with the autopilot in that aircraft.

The examination of the autopilot components recovered from the wreckage did not find any defects, but the damage to the components meant that the examination was inconclusive. It was not possible to determine if the autopilot was engaged before or during the ground impact and breakup sequence.

The second pilot transmission airborne that the autopilot was not on and the relatively simple on/off switch on the control head led the investigation to surmise that the autopilot was probably off during the takeoff. That was supported by the information that the pilot was not in the habit of engaging the autopilot before an outbound track was intercepted and in the circumstances was not going to gain any time advantage if he did so.

If for some reason the autopilot had been selected on at a relatively low altitude and produced an undesired aircraft attitude command, the system was designed to allow the pilot to overpower the autopilot-produced control force. Importantly, the normal actuator slip clutch settings measured after the accident was evidence that the pilot should have had the capability to overpower the autopilot. Sustained overpowering of the pitch actuator clutch can result in autopilot-commanded elevator trim movement against the overpower force. In this case, however, there was no apparent reason for the pilot to engage the autopilot then overpower it without selecting the autopilot disengage switch on the control wheel hub.

According to pilot records and information from senior pilots who had trained or supervised the pilot, the pilot had received the prescribed training for licence issue and aircraft type endorsements. Along with the 50 hours of C310R operation including the flight 35 days before the accident, that information indicated that the pilot was competent and familiar with the aircraft type. Given that information, the investigation could not explain the pilot's behaviour with the autopilot during the post-maintenance engine run prior to the flight.

While the limited evidence did not allow the investigation to rule out an autopilot related difficulty as a possible contributing factor, in the context of this accident it was considered to be unlikely.

2.6 Abnormal trim tab setting

The witness observation pre-flight of the rudder trim tab in the full right position and the distinct possibility that the aileron and elevator trim tabs were also at abnormal settings as a result of maintenance was strong evidence for the existence and therefore influence of abnormal trim tab settings on the flight.

It was not possible to determine if the pilot used a written checklist or relied on memory to check the pre-takeoff status of the aircraft. In any event, as the human factors research indicated, the time pressure experienced by the pilot increased the risk that some pre-takeoff items would not be checked. With the prominent location of the elevator trim wheel/indicator, and the routine adjustment of the elevator trim tab for each takeoff, the investigation considered it unlikely that the pilot overlooked any abnormal elevator trim tab setting. In contrast, the relatively obscure location of the rudder and aileron trim wheel-indicator assemblies and the only occasional need to adjust those trim wheels before takeoff, combined to increase the risk that the pilot overlooked them.

Given the witness descriptions of the takeoff as normal, it is likely that the aircraft airspeed increased from about 90 kts at rotation to about 120 kts during the climb. Based on the behaviour of the Cessna 310 noted during the investigation's flight assessment, it is likely that during the takeoff and climb the aircraft would have been controllable with abnormal rudder and/or aileron trim tab settings, but would not have been controllable with full nose down elevator trim tab settings.

The left turn after takeoff, probably prior to a clearance to do so, is consistent with a strong left turning tendency produced by an abnormal rudder trim setting in the sense observed prior to takeoff and the aileron trim tab setting measured after the accident. The erratic bank angles and altitude deviation could also be symptomatic of the pilot trying to manage a strong left turn tendency.

When the aircraft was generally level with high power selected, it would have accelerated to well above 120 kts and progressively strengthened any left turn tendency. At some point, the control wheel/rudder pedal load would exceed the pilot's strength and lead to a turn and descent, which would explain the departure from level flight and development of the steep descent before impact. Alternatively, the pilot may have had the strength to counteract the left turn tendency, but may have become distracted by a task, such as troubleshooting, and allowed the aircraft to diverge from level flight. While the impact signature did not indicate that the aircraft was turning at impact, it is likely that the pilot was resisting the control loads and may have been in the process of recovering control.

As the flight control problem developed, the pilot was in a difficult situation. Given the usual high workload associated with takeoff and initial climb phases of flight, as well as the additional workload created from the pilot needing to diagnose the source of a novel aircraft problem, it is very likely that the pilot was experiencing a very high workload during the flight. There are a number of reasons why the pilot didn't recognise the source of the flight control difficulty or recognised it too late to take effective corrective action.

The pilot, like almost all pilots, would not have experienced aircraft behaviour with rudder and/or aileron trim tabs at the limit of travel. That behaviour, the investigation considered, was not obviously what would be expected from abnormal trim tab settings and could easily have been interpreted as autopilot-related. Any such connection would have been reinforced if the aircraft seemed to be turning towards the heading bug on the directional gyro. If the pilot focussed all of his attention on the autopilot, due to the stress of increasing control difficulty, other aspects of flight control may have been overlooked. There were also no salient indicators of rudder and/or aileron trim tab position, and there was no reason for the pilot to suspect that those tab settings were abnormal.

The limited evidence did not allow the investigation to be certain about the existence of abnormal rudder and/or aileron trim settings during the flight. However, in the absence of any other likely factor and with supporting evidence, the investigation considered that the pilot probably took off with abnormal rudder and/or aileron trim settings and with increasing airspeed, was unable to maintain control.

2.7 Operational safety issues

Based on an airborne time of 1326:30, a flight time of 20 minutes and an allowance for time to intercept heading on departure and to position for a landing at Scone, the earliest time the pilot was going to touchdown was about 1350. That meant that the amount of time available for the pilot to complete his duties and catch the train scheduled to depart Scone at 1400 was marginal at best and likely to result in time pressure on the pilot.

Time pressure is an expected part of operating an aircraft in a commercial environment and the pilot had some experience in commercial operations. However, human factors research shows that time pressure increases the risk of stress and performance errors. Given the number of events, such as delayed aircraft departures or extended flight time enroute, that can produce time pressure, it is important that pilots and operators have contingency plans to reduce pilot exposure to time pressure.

The flight assessment conducted by the investigation highlighted the risk to controllability that abnormal trim tab settings can present during the early stages of a flight. As the main trim tab setting risk control for operation of aircraft below 5,700 kg is the pre-takeoff check, it is imperative that it is completed before each flight. Increased emphasis on trim tab settings during daily or pre-flight inspections as recommended in the Cessna 310R *Pilots Operating Handbook* (POH), would reduce the risk of takeoffs with abnormal trim tab settings.

Flight control difficulties can be difficult to diagnose and rectify, especially when the aircraft is close to the ground. In that situation, the pilot has a high workload controlling the aircraft and has limited cognitive resources to apply to troubleshooting. Incorporation of the POH-supplement autopilot and electric trim procedures as memory/recall items in operator's checklists would enhance the ability of pilots to manage flight control difficulties. Development of a procedure to assist pilots in the diagnosis and management of flight control difficulties generally may also be valuable.

At the time of the accident, the *Day VFR Syllabus – Aeroplanes* produced by the Civil Aviation Safety Authority (CASA) did not specifically require that training for private or commercial pilot licences include management of flight control difficulties. An important part of any training or guidance given to pilots would be a discussion of possible factors in the development of flight control problems and the importance of airspeed in regard to aircraft controllability.

Given multi-engine aircraft systems are generally more complex than single-engine aircraft systems, the inclusion in the draft Civil Aviation Advisory Publication titled *Multi-engine Aeroplane Operations and Training* of autopilot and electric trim related issues is an important development.

The ATSB research report showed that flight control difficulties did not contribute to a high number of fatal uncontrolled flight into terrain accidents. However, the search of the database for all reported occurrences during the same 10 year period showed that there were 190 occurrences where there were reportedly problems related to flight control. That number of occurrences suggests that pilots are exposed to a significant number of flight control anomalies and would benefit from training and guidance in that area.

2.8 Maintenance safety issues

There was no specific requirement for the maintenance provider to return the aircraft to a flight-ready or neutral configuration after maintenance. That was a pilot in command pre-flight responsibility. Nevertheless, the risk of pilots taking off with abnormal trim tab settings or other mis-configurations would be reduced if aircraft maintenance procedures included an appropriate configuration check of the aircraft at the completion of maintenance.

Although the investigation considered that the tool found in the wreckage was not implicated in the accident, the presence of foreign objects in the internal parts of aircraft increases the risk of interference in flight control systems and other systems within aircraft. Aircraft maintainers need to be vigilant in the inspection of internal aircraft areas prior to them being covered and in the location-tracking of equipment used for maintenance.

3 FINDINGS

3.1 Contributing safety factors

1. Before taxi, the rudder trim tab was in the full right position (nose left tendency) and the aileron trim tab was probably at, or close to the 12 degrees down position (left roll tendency).
2. The pilot probably overlooked the rudder and aileron trim tab settings during the pre-takeoff phase of the flight due to significant time pressure and the relatively obscure location of the rudder and aileron trim tab indicators.
3. The pilot experienced a flight control difficulty during, or shortly after takeoff from runway 30 Right (30R) at Tamworth Airport and was not able to identify the source of the difficulty.
4. The pilot lost control of the aircraft at a position corresponding to an early left downwind for runway 30R, probably as a result of heavy control loads produced by a combination of abnormal trim tab position and increasing airspeed.
5. The aircraft impacted the ground in a nearly wings-level attitude at high speed and at a nose-down angle of between 35 and 40 degrees.

3.2 Other safety factors

1. The *Day (VFR) Syllabus Aeroplanes* did not require that flight control difficulty be specifically addressed and the S*yllabus of training initial issue of multi-engine aeroplane type endorsement (rating)* did not specifically address autopilot/electric trim emergency procedures.
2. The Cessna 310 cockpit checklists that were produced by the regular operator of the aircraft and the operator that tasked the pilot did not include any normal and emergency procedures, such as autopilot and electric trim procedures, which were contained in the supplement section of the aircraft flight manual.
3. The aircraft's maintenance schedule and the maintenance provider's procedures did not include return of the aircraft's configuration to normal, including a trim neutrals check at the completion of maintenance, nor was there any regulatory requirement or formal guidance to do so.
4. The maintenance provider did not have a system to track the location of tools and equipment during aircraft maintenance, nor was there any regulatory requirement or formal guidance to do so.

3.3 Other key findings

1. There was no evidence that a bent hand tool found in the wreckage was implicated in the development of the accident.

4 SAFETY ACTIONS

4.1.1 Tamworth-based operator

The operator advised that it had incorporated the emergency procedures related to autopilot and electric trim contained in the flight manual supplements into their aircraft-specific operating procedures. Those procedures were included as Phase 1 or memory recall checks. As a precautionary measure, the operator included a note for the pilot to pull the associated circuit breaker after the applicable checklist was completed.

4.1.2 Maintenance provider

The maintenance provider advised that it had incorporated the use of shadow boards for more effective control of 'shop' tools. The maintenance provider's policy and practice regarding individual tool control was amended such that individual tools were required to be placed in foam cut outs within tool trays to allow for quick and positive identification that an individual's tool set was complete or otherwise.

4.1.3 Civil Aviation Safety Authority

As a result of the accident, the investigation briefed the Civil Aviation Safety Authority (CASA) on the 'Other safety factors' identified in the findings section of the report. In response to the briefing and draft report, CASA advised that:

- In relation to the *Day (VFR) Syllabus Aeroplanes* and the S*yllabus of training initial issue of multi-engine aeroplane type endorsement (rating)*, that the final version of the Civil Aviation Advisory Publication titled *Multi-engine Aeroplane Operations and Training* was due for release by the end of July 2007.
- In relation to the aircraft operating procedures and cockpit checklists produced by aircraft operators, that certain low risk operators are exempt from the requirements of Civil Aviation Regulation (CAR) 232 with respect to CASA approval of flight check systems. Other operators have approved systems that should cover all requirements including autopilot or electric trim procedures. CASA Flying Operations Inspectors (FOIs) conduct surveillance on operator compliance with CAR 232. CASA will ensure that the safety action in the report is passed to field FOIs for their attention. The matter has also been referred to the Aviation Safety Promotion Branch for consideration as the basis for articles in *Flight Safety Australia* and for discussion with Field Safety Advisors.
- In relation to the return of the aircraft's configuration to normal at the completion of maintenance, that setting the correct trim position is an essential pre-takeoff check for all pilots irrespective of whether the aircraft has been returned to service from maintenance or flown by another pilot who could leave the aircraft configured for touchdown. However, returning the aircraft configuration to normal is a housekeeping matter that is good practice for all maintenance organisations. CASA has referred the matter to the Aviation Safety Promotion Branch for addressing with maintenance organisations by Field Safety Advisors. CASA is also addressing the matters with maintenance organisations in the course of normal business.

- In relation to tool and equipment control, that it is also a housekeeping matter that is good practice for all maintenance organisations. CASA has referred the matter to the Aviation Safety Promotion Branch for addressing with maintenance organisations by Field Safety Advisors. CASA is also addressing the matter with maintenance organisations in the course of normal business.