Australian Government
Australian Transport Safety Bureau

Departure from controlled flight and collision with terrain involving Ayres Corp. S2R-G10 Thrush VH-WDD

36 km NW of Moree, New South Wales | 11 April 2012

Investigation

ATSB Transport Safety Report
Aviation Occurrence Investigation
AO-2012-049
Final – 23 October 2013

Australian Government

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ATSB TRANSPORT SAFETY REPORT

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SAFETY SUMMARY

What happened

At about 0910, on 11 April 2012, an Ayres Corporation S2R-G10 Thrush aircraft, registered VH-WDD, collided with terrain in a fallow wheat field about 36 km north-west of Moree, New South Wales while on a ferry flight from St George, Queensland to Moree. The owner-pilot was fatally injured and the aircraft was destroyed by impact forces and an intense fuel-fed fire.

What the ATSB found

The ATSB found that the aircraft departed controlled flight and the pilot was unable to recover before impact with the ground. On the basis of the evidence available to the ATSB, it was not possible to determine with any certainty the reasons for the loss of control.

There was no evidence of any mechanical fault with the aircraft that could have contributed to the accident, A number of other possible factors could not, however, be completely discounted: pilot incapacitation; aircraft handling, such as to avoid a bird or flock of birds or other deliberate manoeuvring by the pilot; or a mechanical problem which could not be identified during the post-accident site and aircraft examinations.

Although it did not contribute to the accident, an issue was identified with the potential to affect the safety of agricultural operations in S2R-G10 Thrush aircraft in Australia. The aircraft’s permitted load-carrying capability, based on its published maximum take-off weight, was very low in comparison with other agricultural aircraft types. The aircraft type’s operational history indicated that it could be operated at higher loads, but the absence of a more practical published weight limit increased the risk of pilots flying at weights where the aircraft had not been fully tested for safety.

What has been done as a result

In June 2012, Statewide Aviation, the Australian distributor for Ayres aircraft, in consultation with the Civil Aviation Safety Authority, commenced developing a Supplemental Type Certificate (STC) for some Ayres Thrush variants. This STC would permit an increase in the aircraft's maximum take-off weight, and is expected to be available to Thrush owners in October 2013.

Safety message

Although the investigation did not determine why the aircraft departed controlled flight, the potential for the operation of the emergency cut-off lever in Garrett-engined Thrush aircraft to prevent significant control difficulties in the event of a serious engine or propeller problem was highlighted.

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Prepared By

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THE AUSTRALIAN TRANSPORT SAFETY BUREAU

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

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

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

Purpose of safety investigations

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

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

Developing safety action

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

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

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

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

TERMINOLOGY USED IN THIS REPORT

Occurrence: accident or incident.

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

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

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

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

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

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

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

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

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

FACTUAL INFORMATION

History of the flight

On 11 April 2012, at about 0820 Eastern Standard Time,[1] an Ayres Corporation S2R-G10 Thrush, registered VH-WDD, departed from St George Airport, Queensland (Qld) on a ferry flight to Moree Airport, New South Wales (NSW). The owner-pilot was the sole occupant and was flying the aircraft to Moree for scheduled maintenance.

At about 0910, the aircraft impacted terrain in a fallow wheat field about 36 km north-west of Moree (Figure 1). The pilot was fatally injured and the aircraft was destroyed by the impact and an intense fuel-fed fire.

Figure 1: Accident location

Source: Google Earth

Witness information

Four witnesses saw the aircraft immediately prior to impact. The witnesses reported observing the aircraft in a steep, clockwise,[2] spiralling descent prior to impact with the ground.

One witness, who was about 1.8 km away, reported that he became aware of an unusual aircraft noise that was ‘not a steady drone, more like the sort of the noise that you would associate with acrobatics’ and described it as repeatedly rising and falling in pitch. He recalled seeing the aircraft descending vertically and rotating about its axis with the nose straight down.

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1 Eastern Standard Time (EST) was Coordinated Universal Time (UTC) + 10 hours.

2 In this report, ‘clockwise’ refers to the direction of rotation as viewed from above.

The other three witnesses were grouped about 3.2 km away from the accident and did not hear the aircraft. One of them reported seeing the aircraft prior to the descent heading south-east and rolling right through an inverted, slightly nose-down attitude. He looked away for a moment and when he looked back, saw the aircraft in a steep spiralling descent with the nose about 60° below horizontal. The two nearby witnesses described a similar steep, rotating descent, with one recalling a 60° nose-down angle and the other recalling a nearly vertical nose-down angle.

Aircraft information

General

The Ayers Corporation model S2R-G10 Thrush aircraft, serial number G10-123, was manufactured in the United States (US) in 1996 and was first registered in Australia on 3 July 1996. At the time of take-off, the aircraft had accumulated about 8,764.7 hours total time in service (TTIS). The aircraft was certified in the restricted category,[3] permitting agricultural work, and was fitted with spraying equipment (Figure 2).

Figure 2: VH-WDD spraying crops

The aircraft's maximum fuel load was 871 L, equivalent to about 697 kg. Its hopper could hold a maximum of 1,930 L by volume or 1,814 kg by weight and was fitted with a jettison system.

Certification

The aircraft was certified in accordance with US Federal Aviation Administration Airworthiness Advisory Circular AC21-25-1 in the restricted category, which exempted small, single-engine agricultural aeroplanes from spin testing. The aircraft manufacturer reported that no spin testing had been conducted on any

[3] In Australia, a restricted category aircraft was certified for designated special purpose operations as set out in Civil Aviation Safety Regulation 21.025(2). These included agricultural operations, such as spraying and livestock control, and fire fighting.

Thrush variant. The aircraft's type certificate data sheet required a placard to be displayed in view of the pilot stating 'No aerobatic manoeuvres including spins approved'.

Maintenance

A valid and current maintenance release was found among the wreckage. The aircraft maintenance release was valid for the flight and was issued on 5 March 2012 at 8,725.2 hours TTIS. It listed a scheduled maintenance requirement for an engine hot end inspection[4] at 8,807.2 hours and a lower wing spar cap replacement at 8,813.7 hours. According to the maintenance release, the aircraft's last flight prior to the accident was on 7 April 2012 with 0.6 hours recorded.

Engine and propeller

The aircraft was fitted with a Garrett 715 horsepower turboprop engine, model number TPE331-10-511M, serial number 3102180-2. The engine drove a four-bladed Hartzell, constant-speed, reversing, feathering[5] propeller, model HCB4TN-5NL-LT10890N.

At the time of take-off, the engine had accumulated 2,457.5 hours since overhaul (TSO) and 13,324.7 hours TTIS. It was last inspected on 5 May 2012 and overhauled on 20 September 2006. The engine gear case was repaired on 14 August 2009, with 1,206.9 hours TSO.

Propeller pitch control system

System description

In the S2R-G10, the aircraft's propeller pitch is continually and automatically adjusted to maintain a constant engine and propeller speed, and is primarily controlled by the use of oil pressure. A propeller governor adjusts oil pressure depending on engine speed. The oil pressure passes through a propeller pitch control (PPC), the position of which is determined by the position of the power lever in the cockpit, and then through a beta tube to the propeller hub where the oil pressure acts against springs to alter the blade pitch. The beta tube moves forwards and backwards in direct relation to the blade pitch. The relative positions of the PPC and beta tube determine the minimum pitch angle for a given power setting. Excess oil pressure is relieved by orifices in the beta tube, which become exposed when the beta tube moves too far relative to the PPC.

The cockpit power lever also controls propeller pitch indirectly: its position affects engine power, which affects engine speed, which in turn affects propeller pitch. The propeller pitch at any point in time is therefore normally determined by a combination of engine/propeller speed and power lever position. Furthermore, engine speed is affected by external forces on the propeller, produced by the relative airflow over the propeller blades.

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4 A hot end inspection is an inspection of the turbine section.

5 The term used to describe rotating the propeller blades to an edge-on angle to the airflow that minimises aircraft drag following an engine failure or shutdown in flight.

The system incorporates design features which, in the event of an engine failure, help prevent the propeller from ‘windmilling’ excessively, which would increase drag, disrupt the airflow over the aircraft’s tail surfaces and potentially result in control difficulties. For example, the engine’s negative torque sensing (NTS) system is designed to detect when torque is applied to the propeller by the airstream. The NTS system increases the blade angle to reduce these undesired effects but does not feather the propellers. If oil pressure to the propeller is completely lost or drops significantly, springs and counterweights force the blades towards the feather position.

Additionally, the S2R-G10 was fitted with an emergency cut-off lever which, when pulled to the cut-off detent, would shut down the engine by shutting off fuel flow and feather the propeller by relieving oil pressure to the propeller (Figure 3).

Figure 3: Emergency cut-off lever in the cut-off position (example aircraft)

The propeller pitch control could drive the propeller into beta mode,[6] the use of which was prohibited in flight. To put the propeller into beta mode the power lever would need to be lifted over a gate and then pulled further back.

Manuals and training

The operation of the NTS system and the emergency cut-off lever was reportedly included in the standard endorsement training syllabus for the Thrush. The aircraft

6 The two operating modes for the propeller are ‘propeller governing’ and ‘beta’. In normal flight, the propeller remains in the governing mode. Beta mode allows direct control of propeller blade angles below the normal flight range, normally to reduce the length of a landing run. The terms ‘beta’ and ‘reverse’ are often used interchangeably though reverse pitch is only part of the beta range.

flight manual (AFM) for VH-WDD included a procedure to test the NTS system prior to every flight or when a fault was suspected.

The emergency procedures section of the AFM stated that the emergency cut-off lever should be pulled in the case of an engine fire or during an in-flight engine shut down. The Australian Transport Safety Bureau (ATSB) received reports that some Thrush pilots were not aware of the dual functions of the emergency cut-off lever.

System examination and analysis

A propeller blade pitch angle higher than optimal results in decreased thrust, and if extreme could cause engine problems, but does not increase drag or severely disrupt airflow over the tail surfaces.

A pitch angle lower than optimal decreases thrust and increases drag, and could disrupt airflow over the tail surfaces and affect aircraft controllability. The engine manufacturer identified two potential failure modes that could result in a decreased pitch angle: a sticking metering valve in the governor or a blockage of the reset orifice/check valve. Both of these failure modes result in a likely decrease in propeller pitch to a point (known as the ‘beta followup’ pitch position) determined by the position of the power lever. The second failure mode would also result in failure of the NTS system.

In both cases, the engine overspeed governor would reduce fuel flow in an attempt to prevent overspeeding of the engine and propeller. The likely effect on an aircraft in level flight would be an initial reduction in thrust and an increase in drag, slowing the aircraft until the airspeed stabilises. The propeller would then behave as a variable pitch propeller and not a constant speed propeller, with the pitch directly controlled by the power lever. Ultimately, in the absence of other failures thrust would still be available but the aircraft’s maximum speed would be reduced. The propeller would only affect the airflow over the aircraft’s tail surfaces as the aircraft slowed, though the extent of the effect was not determined by the ATSB.

Though the possibility is remote, two or more concurrent failures could result in a greater reduction in propeller blade pitch. For example, if the propeller governor output oil pressure was excessively high and the beta tube oil orifices were blocked, the propeller pitch would not be limited by the position of the power lever and could decrease the pitch below the beta follow-up position. In such a situation the aircraft’s thrust, drag and controllability in pitch and yaw would be significantly affected, and could lead to a loss of control.

Propeller-related incidents

The ATSB conducted a search of Australian and US accidents and incidents to identify potential propeller faults that could have contributed to the accident. A significant proportion of events where engine or propeller problems resulted in a loss of control involved twin-engine aircraft, due to the effects of asymmetric thrust.

There were a number of reported occurrences[7] involving the inadvertent or deliberate use of the beta mode in flight, and at least two[8] involving inadvertent use

[7] For example, ATSB investigations AO-2012-005 and AO-2011-159.

[8] ATSB investigations 200404589 and BO/199600323.

of the ground start procedure in flight. This procedure locks the propeller in a ‘flat’ pitch position, generating significant drag and airflow disruption and likely leading to control difficulties in flight.

In addition, during the investigation, the ATSB was advised of a previously unreported occurrence where a pilot experienced control difficulties in a Thrush when the NTS did not operate correctly following an engine failure. The ‘discing’ (unfeathered) propeller generated significant drag and the pilot could feel the aircraft begin to ‘wobble’ almost to the point of losing control. The pilot was able to force the propeller to feather by pulling the emergency cut-off lever. This would have reduced the drag affecting the aircraft and the pilot was able to conduct a forced landing.

Other than those occurrences, there was no record of any instances in the previous 15 years where a propeller on a Garrett engine entered beta mode in flight. The propeller manufacturer advised the ATSB that it was not aware of any uncommanded reverse pitch events on a Garrett-engined aircraft.

Weight and balance

No aircraft weight and balance documents were found at the accident site. They had most likely burnt in the wreckage.

The aircraft documentation on record with the Civil Aviation Safety Authority (CASA) included a weighing conducted in the US in May 1996. That record listed the aircraft’s basic empty weight as 2,275 kg without spraying equipment. The aircraft’s maximum take-off weight (MTOW) listed on the type certificate data sheet and in the AFM was 2,721 kg.

It was reported that the aircraft was fully fuelled at St George on 7 April 2012 and that it had not flown since then. Using estimates for pilot weight, baggage weight and fuel burn during the flight, the ATSB estimated the aircraft’s weight at the time of the accident at around 2,963 kg, which was 242 kg in excess of the MTOW. The centre of gravity at this time was estimated to lie within the forward and aft limits at the published MTOW.

The ATSB calculated that with a pilot, half fuel load, and no load in the hopper, the aircraft weight would have been about 13 kg less than the MTOW. With no fuel on board, the aircraft would be at its MTOW with 20% of the hopper’s maximum weight uplifted.

Pilot information

The pilot held an Air Transport Pilot (Aeroplane) Licence and had a total flying experience of about 8,200 hours. This included 6,770 hours in aeroplanes and 3,200 hours in turbine-engine aircraft.

The pilot gained an aerobatic endorsement in 1992 for barrel rolls and loops, and demonstrated competence in recovering from spins in a Cessna 152 Aerobat.

In the 4 months prior to the accident, the pilot had used the aircraft to provide agricultural services under a contract to a local operator.

The pilot last conducted aerial work in the aircraft on 7 April 2013. He flew another aircraft to the Noosa, Qld area later that day and returned to St George on 10 April.

Witnesses reported that the pilot appeared to be in a good mood in the preceding days and that, on the morning of the accident, he was well rested. Acquaintances described him as fit and healthy and a fellow pilot described him as a 'very cautious and astute' pilot.

A review of the pilot's mobile phone records did not show any calls or text message activity during the flight.

Meteorological information

The Moree terminal area forecast was for a surface wind of 15 kt from a bearing of 140 ° and CAVOK.[9]

A Bureau of Meteorology observation at 0900 on the day of the accident indicated a temperature of 17 °C and a south-easterly wind at 11 kt at Moree Airport.

Witnesses reported that the weather conditions in the vicinity at the time of the accident were sunny and clear with a moderate southerly to south-south-easterly wind.

Medical and pathological information

A post-mortem examination of the pilot indicated that the pilot succumbed to multiple impact-related injuries. Based on the limited evidence available, the post-mortem could not assess the possibility of pre-existing medical conditions that may have contributed to the accident.

Toxicological testing confirmed a carbon monoxide level within the normal range and no traces of drugs or alcohol were found.

Wreckage and impact information

Wreckage examination

Examination of the wreckage indicated that the aircraft impacted terrain while inverted and rotating clockwise. The ground impact marks and aircraft damage were consistent with a near-vertical and low to moderate-speed impact, at a steep nose-down, inverted angle (Figure 4). The accident was not considered survivable.

The aircraft came to rest at the point of initial impact with the ground, facing approximately west. Most of the aircraft's forward structure and wings were subject to an intense post-impact, fuel-fed fire.

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9 Ceiling and visibility OK, meaning that the visibility, cloud and present weather are better than prescribed conditions. For an aerodrome weather report, those conditions are visibility 10 km or more, no significant cloud below 5,000 ft or cumulonimbus cloud and no other significant weather within 9 km of the aerodrome.

All of the major aircraft components were accounted for at the site with no evidence of pre-impact damage observed. There was no evidence of birdstrike or wirestrike. Flight control continuity was established from the cockpit section to the tail section and both wing control surfaces.

Control continuity within the cockpit section could not be established. The forward part of the fuselage up to the cockpit area was severely damaged by impact forces and fire, precluding any reliable determination of the positions and continuity of the cockpit flight controls, engine controls, aircraft trim, and cockpit switches. A correctly fastened, four-point harness buckle was located in the cockpit area, though the harness itself was destroyed by the fire.

Figure 4: Aircraft wreckage

The aircraft's instrument panel was heavily damaged during the impact sequence. The attitude indicator was captured[10] indicating an inverted, steep nose-down attitude.

On-site external examination of the aircraft's propeller and engine revealed no pre-impact anomalies (Figure 5). Two of the four propeller blades had broken off at their blade cuffs. On examination, all four propeller blades were found to be at a similar, mid-range pitch angle and exhibited minor bending. One blade's trailing edge had an impact puncture in a rearwards direction consistent with ground impact.

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10 An instrument's indicating mechanism can be rendered immobile or 'captured' due to impact damage. The captured position could be representative of the position at the time of impact, though it may also have moved during the impact sequence.

Figure 5: Aircraft engine and propeller

The engine was imbedded about 1 m into hard soil in an inverted position and was bent to the aircraft's right, consistent with left yaw at impact. There was no visible damage to the engine compressor first stage or last stage turbine blades and there was no evidence of an internal failure. The propeller and engine were removed from the site for later examination.

A substantial quantity of aviation turbine fuel was located in the wreckage and had soaked into the surrounding soil. There were no reported problems with other aircraft that had used fuel from the same source as used to refuel VH-WDD on 7 April 2013.

The fire projected about 12 m further forward of the aircraft's right wing than of the left wing. Small fragments of the left wingtip were found behind the left wing. The flap position could not be determined.

The rear part of the fuselage and empennage were almost entirely undamaged with the exception of the fin tip, which was bent to the aircraft's left.

Examination of recovered components

Propeller

The aircraft's propeller and propeller governor were examined at an approved maintenance facility under ATSB supervision. The propeller blades were confirmed to be in the governing range[11] and the start locks[12] were disengaged. There was no evidence of any pre-impact anomalies with the propeller or the governor.

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11 The propeller pitch range applicable to normal flight.

12 The start locks would engage when the propeller was below -1.4° pitch at low RPM.

Engine

The aircraft's engine was examined at an engine type-approved maintenance facility under ATSB supervision. The compressor and turbine blades and housings showed scoring consistent with engine rotation at impact. The reset orifice check valve, plenum housing, and torque sensor gear bearings were removed from the engine and taken to the ATSB's engineering facility in Canberra, Australian Capital Territory for detailed analysis.

The examinations did not identify any pre-existing damage or defects that would account for abnormal engine operation. Impact damage to the engine housing and internal blade scoring indicated that the engine impacted the ground inverted, with sufficient RPM to cause a severe propeller strike. Damage and carbon deposits indicated the presence of fuel in the turbine section after impact.

Recorded data

There was no recorded data available to the investigation. The aircraft was fitted with a SATLOC agricultural navigation system; however, the unit did not have a memory card installed on the accident flight so no data was able to be stored. No Global Positioning System equipment was found in the wreckage.

Tests and research

Aerodynamic spins

An aerodynamic spin is a sustained spiral descent in which an aircraft's wings are in a stalled condition,[13] with one wing producing more lift than the other. This difference in lift sustains the rotation and keeps the aircraft in the spin. A spinning aircraft will descend more slowly than one in a vertical dive and it will also have a low airspeed, which may oscillate. The nose angle can also vary considerably.

In a fully-developed, upright, clockwise spin, an aircraft will simultaneously roll to the right while yawing to the right, making a vertical corkscrew path through the air. In an inverted, clockwise spin, an aircraft will take a similar path but in an inverted attitude, rolling to the right but yawing to the aircraft's left.

An aircraft may enter a spin if there is some yawing and/or rolling motion while the wings are in a stalled condition. This can be accomplished deliberately by applying rudder immediately before a stall. However, due to the dynamic nature of aircraft manoeuvres, there are many ways an aircraft can enter a spin depending on its attitude, rotating motion, power setting, and control inputs. For example, an aircraft can enter a spin in a low-speed, uncoordinated turn (slipping or skidding).

When entering a spin, an aircraft's motion through the air is irregular at first. This is known as the incipient phase of the spin. After a number of rotations and depending on the aircraft type, loading, and control inputs, an aircraft in an incipient spin may then settle into a regular rotating descent, known as a developed spin.

[13] Term used when a wing is no longer producing enough lift to support an aircraft's weight.

On the subject of inverted spins, Wood and Sweginnis[14] stated:

> If an airplane experiences an aggravated negative g[15] stall (the wings are at a negative angle of attack) and sufficient auto-rotational forces are present, the airplane can enter an inverted spin. The most probable reason for a non-aerobatic pilot to encounter a negative g stall is the use of excessive forward stick (yoke) while recovering from an erect spin. If the rudder is already being applied (as part of the erect spin recovery attempt) as the negative g stall is encountered, conditions are set for the inverted spin.

The first steps in recovering from a spin are to reduce power and apply rudder opposite to the direction of yaw. The principle applies similarly to both upright and inverted spins, but inverted spins can be deceptive since the direction of roll is opposite the direction of yaw. Because of this, unless accustomed to inverted spins, a pilot might mistake the direction of yaw in an inverted spin and apply rudder in the wrong direction.

Stalls and spins in Thrush aircraft

A test pilot who flew for the aircraft manufacturer advised that the Thrush aircraft type in general has 'very good' stall characteristics and does not tend to depart controlled flight in the stall. However, it had not been spin tested.

The test pilot had rolled an S2R-T34 Thrush[16] and stated that the aircraft had a rapid aileron response initially, but due to roll damping from the large wingspan it would actually roll quite slowly, dropping the nose significantly during roll manoeuvres. The test pilot hypothesised that with inappropriate control inputs while inverted, a Thrush could enter a spin, most likely an upright spin but that it might enter an inverted spin with 'forward stick' (down elevator).

Agricultural aircraft weights

Review of agricultural aircraft types

The ATSB compared the typical weight and power of 17 aeroplane types commonly used in agricultural operations, including the S2R-G10, to obtain an approximation of the useable load an aircraft was permitted to carry. In addition, the ATSB calculated the ratios of engine power to MTOW as an indication of each aircraft's potential take-off and climb performance at MTOW.

The methods and results are detailed in Appendix A. Of the aircraft examined, the S2R-G10 had the lowest proportion of useful load (about half that of the next lowest aircraft type), and the highest power to MTOW ratio.

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14 Wood, R. H. & Sweginnis, R. W., 2006. *Aircraft Accident Investigation*. 2nd ed. Wyoming, USA: Endeavour Books.

15 'g' is the nominal value for acceleration. In flight, g load values represent the combined effects of flight manoeuvring loads and turbulence. This can be a positive or negative value.

16 The S2R-T34 is similar to the S2R-G10, except it is fitted with a PT6 engine.

Aircraft type history and operation in the US

The Snow S2A aircraft type was certified in the US in 1959. Since then, the design evolved into a range of different aircraft types and variants, now commonly and collectively known as Thrush aircraft. The S2R-G10, first approved by the US Federal Aviation Administration (FAA) in 1993, is one of 17 variants certified under a single type certificate that was originally approved in 1965.

In the US, as in many countries, the rules that apply to an aircraft's design and (to some extent) its operation depend on the rules in force at the time of original certification. An aircraft's 'certification basis' is the set of rules applicable to that aircraft. The S2R-G10 certification basis was US Civil Air Regulation (CAR) 8, effective 11 October 1950, for restricted category aircraft.

CAR 8 did not require manufacturers to set the MTOW for a restricted category aircraft used for agricultural purposes in the US. Rather, operators needed to formally develop operating weights for each aircraft using procedures set out in US Civil Aeronautics Manual (CAM) 8, which included design analysis and flight test methods. As a result, there was no fixed MTOW for certain aircraft types certified under CAR 8 in the US, including the S2R-G10.

Some aircraft manufacturers provided a recommended MTOW and an operator could then use that MTOW directly or as a basis for determining an alternate operating weight under CAM 8. The manufacturer of the S2R-G10 set a recommended MTOW of 6,000 lb (2,721 kg).

Post July 1981, CAM 8 could not be used for certificating new restricted category agricultural aircraft in the US. However, aircraft originally certified under CAR 8 could continue to operate under the older rules.

Aircraft type operation in Australia

Subregulation 137.190 (1) of the Australian Civil Aviation Safety Regulations 1998 states that the pilot in command of an aeroplane engaged in an application operation must not commence a take-off if the aeroplane's gross weight exceeds:

> (a) the maximum gross weight shown in the aeroplane's flight manual; or
>
> (b) any maximum gross weight that:
>
> > (i) has been established for that type of aeroplane by a flight test supervised by CASA; and
> >
> > (ii) is shown on a placard, approved by CASA and displayed in the aeroplane's cockpit; or
>
> (c) the maximum gross weight shown on the type certificate, or type certificate data sheet, that is issued for the aeroplane by the NAA of the State of Design (within the meaning given in Annex 8 to the Chicago Convention) of the aeroplane.

This rule prohibited flight at weights exceeding the maximum weight shown on the type certificate data sheet, which in the case of the S2R-G10 Thrush was 2,721 kg. However, prior to February 2012, CASA exemption EX38/11[17] permitted operators

[17] Several other related exemptions were in force at various times prior to 2011.

of agricultural or restricted category aircraft to operate above the MTOW contained in ‘a flight manual or a placard or another document’. This exemption was predicated on the complying aircraft having an appropriate jettison system installed (as most agricultural spraying aircraft do).

In February 2012, CASA revoked EX38/11 and introduced EX01/12. This exemption permitted operators to fly at take-off weights up to the maximum listed in the AFM, type certificate, or type certificate data sheet, or to any maximum gross weight established by a flight test that was supervised by CASA and is shown on an in-aircraft placard.

In July 2012 CASA reported that ‘there [were] no instruments or other documents that would allow a Thrush to operate at a MTOW higher than those allowed by CASA Instrument EX01/12’.

ANALYSIS

Background

During a ferry flight in benign weather conditions, the aircraft departed controlled flight and the pilot was unable to recover before impact with the ground. The site evidence was consistent with a near-vertical ground impact at relatively low speed, with the aircraft in a steep nose-down attitude with significant right roll and left yaw.

The reasons for the departure from controlled flight could not be determined to the level of certainty applied by the Australian Transport Safety Bureau (ATSB). However, the ATSB considered several possibilities as discussed in the following section.

Potential reasons for the departure from controlled flight

Medical incapacitation

The pilot did not have any known pre-existing medical conditions and the post-mortem examination did not detect any conditions that may have contributed to the accident. In addition, acquaintances described the pilot as being fit and healthy and witnesses that interacted with the pilot in the days previous, and on the day of the accident indicated that he was in a good mood and well rested.

However, the possibility of an incapacitating medical event occurring during the flight, although considered minimal, could not be completely excluded.

Structural or flight control problems

There was no evidence of an in-flight break-up or other significant pre-existing mechanical problem with the aircraft. However, some of the control components were seriously damaged or destroyed in the post-impact fire, precluding their examination and confirmation of their serviceability in the lead-up to the accident. In this context, the possibility of a control problem contributing to the accident could not be completely excluded.

Wirestrike or birdstrike

There were no wires in the immediate vicinity of the accident and no evidence of a wirestrike on the remaining wreckage. Similarly, there was no evidence of a birdstrike in the wreckage.

A very heavy impact with a large bird could deform the wing enough to cause significant asymmetric lift and subsequent control difficulties, although no bird remains were found. However, any potential evidence of wing impact, or presence of bird remains, could have been destroyed by the ground impact and subsequent fire.

It is also possible that the pilot lost control of the aircraft while attempting to avoid a large bird or flock of birds. However, none of the witnesses reported seeing any birds in the area, although they were probably too far away to see or notice them, and the witnesses were likely to have been focusing their attention on the aircraft itself.

Engine or propeller problems

A very serious engine and/or propeller problem, such as uncommanded propeller blade pitch reversal, could have resulted in a loss of control. However, the ATSB found no mechanical faults with the aircraft or engine likely to have contributed to the accident.

The evidence of fuel supply and engine rotation at impact indicate that the engine was producing power at that time, and the position of the propeller blades as found indicates that they were most likely in the normal operating range at impact. The witness that reported hearing the aircraft did not report a sudden or dramatic change in aircraft sound that might have characterised over speeding, discing or reverse-pitch propeller or of a complete loss of power. No recent maintenance work had been conducted on the aircraft, so any propeller pitch control rigging issues would probably have been evident prior to the flight. In addition, there was sufficient space for a forced landing in the event of a manageable mechanical problem.

Based on the evidence available, the likelihood of an engine and/or propeller pitch control issue seriously affecting the aircraft's controllability was considered to be very low. However, the possibility of an otherwise minor engine and/or propeller problem or failure being handled incorrectly, or two or more failures in the propeller control system occurring concurrently and resulting in propeller discing or entry into reverse pitch (though no such previous events were reported to the ATSB) could not be completely excluded.

In general, a severe loss or reversal of thrust could have led to difficulty controlling the aircraft as the result of increased drag and disrupted airflow over the tail surfaces. Though it did not appear to be an issue in this case, pilots are reminded that operation of the emergency cut-off lever feathers the propeller, reducing both drag and airflow disruption and improving aircraft controllability in the event of a serious engine or propeller problem.

Aircraft handling

General

Together with the witness observations, the physical evidence was consistent with the aircraft being in a spin, possibly inverted, at impact. The ATSB could not determine what might have initiated a spin.

The pilot was experienced on the aircraft type in demanding agricultural operations and there were no prior indications of problems with regard to his handling an agricultural aircraft. In addition, there were no indications of problems with the aircraft that might have sufficiently distracted an experienced agricultural pilot to the extent that he lost control of the aircraft.

There was no apparent reason for the pilot to conduct any manoeuvres at that point in the ferry flight. Although the need for the pilot to manoeuvre or react abruptly to avoid a large bird or flock of birds could not be totally discounted, the pilot's extensive experience in agricultural operations could be expected to mitigate the risk of his losing control during such manoeuvres.

Recovery from a spin

The Thrush aircraft was not certified or tested for spinning and there was no assurance that it could easily recover from a spin. In combination with the time since the pilot had experienced any spin training, this increased the likelihood that the pilot would be unable to recover from a spin before the aircraft impacted the ground.

It was unlikely that the pilot had experienced an inverted spin before, and such a manoeuvre is not usually performed other than by professional aerobatic pilots. If the aircraft inadvertently entered a spin and was inverted, its movement would have been extremely disorienting and the pilot would have experienced great difficulty in identifying the direction of the spin and, subsequently, the correct recovery technique. This would have further delayed any recovery effort by the pilot.

Aircraft maximum weight limit

Although the aircraft was above its published MTOW by about 242 kg at the time of the accident, this was not considered to have led to the departure from controlled flight. The aircraft had probably flown at similar weights and balance on previous occasions, was heavier at take-off than at the time of the accident, and had completed approximately 50 minutes of flight from St George. In addition, there were no indications of structural failure, a failure type that can occur as a result of operating above MTOW. However, the extent to which the aircraft's weight and balance might have affected recovery from the loss of control could not be determined.

In general, VH-WDD would have been very close to its MTOW with half of its maximum fuel load, and no load in the hopper. Furthermore, it could nominally carry less than a quarter of its maximum hopper load even with no fuel on board. Therefore, it was likely to have been operated well above its MTOW when conducting previous agricultural flights.

The investigation considered how the aircraft's MTOW might impact agricultural operations. A review of agricultural aircraft in Australia found that the S2R-G10 Thrush had the lowest ratio of useable load to aircraft empty weight and the highest ratio of engine power to MTOW of the 17 aeroplane types examined (Appendix A).

In the United States, it was likely that operators would use the aircraft at higher weights by applying the provisions of US Civil Aviation Regulation 8, possibly with more stringent operational restrictions in each case. There were no similar provisions for operations at higher weights in VH-WDD at the time of the accident. The combination of a relatively high power-to-weight ratio and low nominal load-carrying capability could lead a pilot to operate above the published MTOW during agricultural flights, particularly if take-off and climb performance were used as the major factor in determining the effect of weight on the safety of flight.

In this context, although experience might suggest that the aircraft type can 'safely' operate at weights above its published MTOW, the absence of a more practical published weight limit in Australia led to the risk of pilots flying at weights where the aircraft was not proven to be safe. Alternatively, pilots might unknowingly exceed additional operating restrictions that should apply at those higher weights.

Summary

The reasons for the departure from controlled flight could not be determined to the level of confidence required by the ATSB. However, the possibility that pilot incapacitation, aircraft handling, such as to avoid a bird or flock of birds, or a mechanical problem that could not be identified during the post-accident site and aircraft examinations were a factor could not be discounted.

The lack of a practical, published aircraft weight limit in Australia increased the risk that pilots might fly the S2R-G10 Thrush at weights where the aircraft was not proven to be safe. This increases the underlying safety risk of agricultural operations in this aircraft type and is cause for concern.

FINDINGS

From the evidence available, the following findings are made with respect to the departure from controlled flight and collision with terrain of Ayres Corporation S2R-G10 Thrush, registered VH-WDD, 36 km north-west of Moree, New South Wales on 11 April 2012 and should not be read as apportioning blame or liability to any particular organisation or individual.

Contributing safety factors

- While on a ferry flight, and for reasons which could not be determined, the aircraft departed controlled flight and the pilot was unable to recover before impacting the ground.

Other safety factors

- The Ayers Corporation S2R-G10 Thrush aircraft type had a published maximum take-off weight which was not practical for agricultural use, increasing the risk that pilots would operate the aircraft above the published maximum weight and potentially at unsafe weights. *[Safety issue]*

Other key findings

- The aircraft was about 242 kg above its published maximum take-off weight at the time of the accident.

SAFETY ACTION

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

All of the directly involved parties were provided with a draft report and invited to provide submissions. As part of that process, each organisation was asked to communicate what safety actions, if any, they had carried out or were planning to carry out in relation to each safety issue relevant to their organisation. Maximum take-off weight requirements

Safety issue

The Ayers Corporation S2R-G10 Thrush aircraft type had a published maximum take-off weight that was not practical for agricultural use, increasing the risk that pilots would operate the aircraft above the published maximum weight and potentially at unsafe weights.

Action taken by Statewide Aviation

In June 2012, Statewide Aviation, the Australian distributor for Ayres aircraft, in consultation with the Civil Aviation Safety Authority, commenced developing a Supplemental Type Certificate to permit an increase in the maximum take-off weight of a number of Thrush variants, including the S2R-G10, to 10,500 lb (4,673 kg). This certificate is expected to be available to Thrush owners in October 2013.

ATSB comment/action in response

The ATSB is satisfied that the action taken by Statewide Aviation will, when implemented, adequately address this safety issue.

APPENDIX A: AGRICULTURAL AIRCRAFT LOAD AND POWER COMPARISON

The ATSB conducted a comparison of 17 aeroplane types commonly used in agricultural operations to determine the relative loads that each aircraft could carry compared with its basic empty weight (BEW). An approximation of the useable load an aircraft could carry, including the weight of the pilot, fuel, oil, baggage and hopper payload was obtained by subtracting the typical empty weight from the approved maximum take-off weight (MTOW). The ratios of typical engine power to MTOW were also compared as an indication of the aircraft's potential take-off and climb performance at MTOW. The results are shown in Table 1. Actual aircraft weights and power may vary from those provided.

Table 1: Agricultural aircraft load and power comparison

Aircraft type	Typical MTOW (kg)	Typical BEW (kg)	Max. load (MTOW minus BEW) (kg)	Max. load proportion of MTOW (MTOW ÷ Max. load) %	Typical rated cont. engine power hp	Power to weight ratio at MTOW (hp/kg)
S2R-G10 Thrush	2,721	2,275	446	16%	900	0.331
AT-502	2,948	1,949	999	34%	750	0.254
M18A (TPE331)	4,200	2,627	1,573	37%	1,000	0.238
S2R-T34 Thrush	3,856	2,268	1,588	41%	750	0.276
AT-402	3,175	1,860	1,315	41%	680	0.214
PA-36-375	1,977	1,118	859	43%	375	0.190
Agtruck	1,909	1,062	847	44%	300	0.157
Agwagon	1,724	987	827	46%	230	0.127
AT-401	3,565	1,925	1,640	46%	600	0.168
PA-25-235	1,315	703	612	47%	235	0.179
Thrush 400	3,629	1,928	1,701	47%	600	0.165
FU-24	2,463	1,188	1,275	52%	400	0.162
S2RHG-T65 Thrush	4,763	2,268	2,495	52%	1,300	0.273
AT-602	5,670	2,581	3,089	54%	1,300	0.229
Ag Cat	3,184	1,429	1,755	55%	750	0.236
AT-802	7,257	2,951	4,306	59%	1,300	0.179
Cresco 08-600	3,742	1,438*	2,304	62%	750	0.200

* includes 100kg estimate for spray equipment.

APPENDIX B: SOURCES AND SUBMISSIONS

Sources of information

The sources of information during the investigation included the:

- aircraft manufacturer
- engine manufacturer
- propeller manufacturer
- Bureau of Meteorology
- Civil Aviation Safety Authority (CASA)
- United States National Transportation Safety Board (NTSB)
- Australian distributor for Thrush aircraft.

Submissions

A draft of this report was provided to CASA, the NTSB, the aircraft manufacturer, the engine manufacturer and the Australian distributor for Thrush aircraft.

Submissions were received from the Australian distributor for Thrush aircraft. The submissions were reviewed and where considered appropriate, the text of the report was amended accordingly.

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Investigation

ATSB Transport Safety Report
Departure from controlled flight and collision with terrain involving Ayres Corporation S2R-G10 Thrush, VH-WDD
36 km NW of Moree, New South Wales, 11 April 2012

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