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Australian Transport Safety Bureau

Runway excursion involving Cessna 550, VH-FGK

Lismore Airport, New South Wales | 25 September 2015



Investigation

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Addendum

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Safety summary

What happened

On 25 September 2015, a Cessna 550 aircraft (Citation Bravo), registered VH-FGK, taxied at Lismore Airport for a private flight to Baryulgil, New South Wales. The flight crew consisted of a captain and copilot, who were the only occupants of the aircraft.

The flight crew did not detect anything abnormal during the taxi and take-off roll, until the captain attempted to rotate the aircraft to the take-off pitch attitude. When the aircraft had achieved the required rotate speed, the captain applied the normal backpressure on the control column to achieve a standard rate of rotation, and the aircraft did not rotate. The captain then applied full backpressure and reported that the controls felt very heavy. Neither the captain nor the copilot detected any change in the aircraft's pitch attitude or any indication of pitch-up on the attitude direction indicator.

The captain rejected the take-off, applied full braking and reverse thrust, but the aircraft overran the runway. The nose landing gear detached from the aircraft about 50 m beyond the end of the sealed runway, and the aircraft came to rest in long grass and mud. The aircraft sustained substantial damage, and the captain and copilot were uninjured.

Accident site



Source: Aircraft owner

What the ATSB found

The aircraft did not accelerate normally as the acceleration was retarded by drag associated with rolling friction. This was indicative of partial brake pressure remaining during the take-off run. The partial brake pressure was possibly due to the parking brake being selected on at the holding point with enough pressure to retard aircraft acceleration during the take-off, but not sufficient to prevent the aircraft reaching rotate speed.

Furthermore, the nose-down moment generated by the partial brake pressure probably prevented the aircraft rotating sufficiently to become airborne, despite normal nose-up elevator deflection.

Heat in the brakes due to partial pressure during the take-off run may have reduced their effectiveness when the captain rejected the take-off, contributing to the runway overrun.

What has been done as a result

The Australian Transport Safety Bureau issued a safety recommendation that Textron Aviation (Cessna) take safety action to address the fact that Citation aircraft do not have an annunciator light to show that the parking brake is engaged and the Cessna 'before take-off' checklist does not include a check to ensure the parking brake is disengaged.

Safety message

For pilots, this incident highlights the importance of attention to the configuration of the aircraft and cockpit settings at all stages of flight, but particularly during take-off. For manufacturers, this incident highlights the importance of systems that bring an irregular or abnormal configuration or cockpit setting to the attention of the crew, especially when that configuration has the potential to adversely affect aircraft performance or control.

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The occurrence

History of the flight

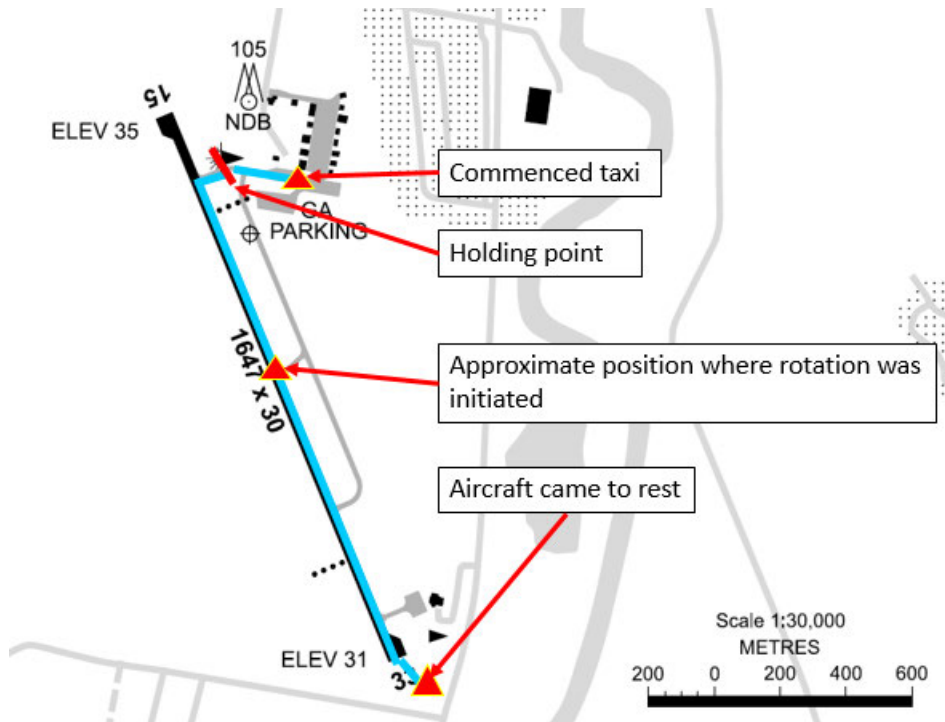
On the morning of 25 September 2015, the captain and copilot of a Cessna 550 aircraft (Citation Bravo), registered VH-FGK, prepared to conduct a private flight from Lismore Airport to Baryulgil, about 40 NM south-west of Lismore, New South Wales. The aircraft had been parked at the northern end of the airport overnight, with engine covers and control locks on.

After arriving at the airport, the flight crew conducted a pre-flight inspection, with no abnormalities identified. They then commenced the normal pre-start checks, which included the disengagement of the flight control locks.

The crew elected to use runway 15 for take-off, and used the Cessna simplified take-off performance criteria (see *Take-off performance simplified criteria*) to determine the thrust settings and take-off reference speeds. The resultant reference speeds were 105 kt for the decision speed (V_1)¹ and 108 kt for the rotation speed (V_R).²

At about 1300 Eastern Standard Time,³ the flight crew started the engines and performed the associated checks, with all indications normal. The crew reported that they completed the after-start checks, and the captain then taxied the aircraft to the holding point for runway 15, less than 200 m from where the aircraft was parked (Figure 1). While stopped at the holding point, the crew completed the taxi and pre-take-off checks, the copilot broadcast the standard calls on the common traffic advisory frequency, and the captain communicated with air traffic control (ATC).

Figure 1: Lismore Airport showing aircraft track



Source: Airservices Australia – annotated by ATSB

¹ V_1 is the critical engine failure speed or decision speed. Engine failure below this speed shall result in a rejected take-off; above this speed the take-off run should be continued.

² V_R is the speed at which the rotation of the aircraft is initiated to the take-off attitude. This speed cannot be less than V_1 , and takes into account a number of other critical speeds that relate to aircraft performance and handling.

³ Eastern Standard Time (EST) was Coordinated Universal Time (UTC) + 10 hours.

The captain taxied the aircraft onto the runway, and turned left onto the runway centreline to commence the take-off run from the intersection (Figure 1). While rolling along the runway, the captain advanced the thrust levers to the approximate take-off setting. The captain then called 'set thrust', and the copilot set the thrust levers to the more precise position needed to achieve the planned engine thrust for the take-off.

As the aircraft accelerated, the copilot called '80 knots' and crosschecked the two airspeed indicators were in agreement and reading 80 kt. The copilot called ' V_1 ' and the captain moved their hands from the thrust levers to the control column in accordance with the operator's normal procedure. A few seconds later, the copilot called 'rotate' and the captain initiated a normal rotate action on the control column.

The crew reported that the aircraft did not rotate and that they did not feel any indication that the aircraft would lift off. The copilot looked outside and did not detect any change in the aircraft's attitude as would normally occur at that stage. The captain stated to the copilot that the aircraft would not rotate, and pulled back harder on the control column. The copilot looked across and saw the captain had pulled the control column firmly into their stomach.

Although the aircraft's speed was then about 112 kt, and above V_R , the crew did not detect any movement of the attitude director indicator or the nose wheel lifting off the ground, so the captain rejected the take-off; applied full brakes, and set the thrust levers to idle and then into reverse thrust.

The aircraft continued to the end of the sealed runway and onto the grass in the runway end safety area (RESA), coming to rest slightly left of the extended centreline, about 100 m beyond the end of the runway (Figure 2).

Figure 2: Accident site



Source: Lismore City Council – annotated by ATSB

Injuries and damage

The aircraft sustained substantial damage and the flight crew, who were the only occupants of the aircraft, were uninjured. The nose landing gear separated from the aircraft during the overrun (Figure 2), and there was significant structural damage to the fuselage and wings. The right wheel tyre had deflated due to an apparent wheel lockup and flat spot, which had progressed to a point that a large hole had been worn in the tyre (Figure 3).

Figure 3: Right tyre



Source: ATSB

Context

Personnel information

Both flight crewmembers were appropriately trained and qualified for the flight, and reported feeling well rested and healthy.

Captain

The captain held an Airline Transport Pilot (Aeroplane) Licence, command instrument rating and a valid Class 1 medical certificate. The captain had a total aeronautical experience of 5,937.7 hours, including 800.6 hours on Citation aircraft, and also had check and training approval for the Citation.

Copilot

The copilot held a Commercial Pilot (Aeroplane) Licence, command instrument rating and a valid Class 1 medical certificate. The copilot had a total aeronautical experience of 377.8 hours, including 40.4 hours on Citation aircraft.

Aircraft information

Weight and balance

There were two crewmembers on board and no passengers. The crew reported that each pilot had a small bag stowed in the nose locker and there was no additional baggage on the aircraft. According to the loadsheets for the flight, there was about 4,000 lb (1,814 kg) of fuel on board (full fuel was 4,871 lb (2,214 kg)), and the take-off weight was about 13,518 lb (6,132 kg), below the maximum take-off weight of 14,800 lb (6,713 kg).

The crew reported they completed the weight and balance calculations prior to the flight, in accordance with their normal procedures. The loadsheet obtained by the ATSB showed that the centre of gravity was within the allowable range.

Aircraft examination

The operator's engineering manager inspected the aircraft on 1 October 2015, for any mechanical reason for the reported lack of response to elevator control input. The maintainer reported that the elevators were able to be operated to full deflection to the mechanical travel stops from the cockpit in the up and down sense. There was no binding or restrictions to travel noted in around the control yoke in the cockpit. There was no external evidence on or in the vicinity of the elevators to cause any restriction to travel.

The aircraft owner, who also inspected the accident site, reported that:

- the nose locker was filled with water and mud,
- the control lock could not be bypassed (that is, was working correctly),
- the weight and balance was towards the middle of the allowable envelope, and
- the elevator controls and surfaces had full deflection and were able to be moved in the correct sense.

The ATSB inspected the aircraft on 4 November 2015, after it had been moved to a hangar. The aircraft examination was limited to external general observations and a detailed examination of the flight control lock and elevator and trim systems, in an attempt to ascertain the reasons for an apparent lack of elevator response during the incident.

The control lock, elevator and trim system were in good mechanical order. All functional checks, tests and examinations did not find a fault that may have contributed to the runway overrun.

The left brake had been removed during the recovery of the aircraft as the brake had seized due to overheating (see *Brakes*).

Airspeed indications

The aircraft was equipped with three separate and independent pitot-static systems. The two primary systems served the captain's and copilot's systems. The third provided pitot and static air pressure to the standby flight display. Altitude and airspeed data was generated by micro air data computers, which transmitted the information to the primary flight displays. With two independent sources, and the copilot verifying at 80 kt that both airspeed indicators were in agreement, it is unlikely that they were both indicating the same but incorrect airspeed. Available evidence suggests that the airspeed indicating system was functioning normally during the take-off.

Thrust

The flight data and crew reports indicated that the thrust was set in accordance with the settings indicated in the simplified take-off performance reference. Both crew reported engine indications were normal. The flight data showed the engine RPM was consistent with four previous flights.

The flight data shows that the engines were delivering the expected amount of thrust during the take-off, and reverse thrust was not selected until after the captain rejected the take-off.

Elevator deflection and control movement

The captain checked the flight controls as part of the pre-take-off checks, and verified full and free movement, and normal feel of the control column. The crew were unable to see the elevator to assess whether control movement matched control surface deflection, however, normal deflection was evident in the recorded flight data.

The crew stated that the captain pulled the control column as far back as possible during the take-off roll, but that the aircraft did not rotate. The flight data showed that the elevator achieved normal deflection in the correct sense in response to the control input. The elevator was also operating correctly immediately after the accident when the operator's engineer inspected it, and when the ATSB subsequently inspected the full length of the elevator system.

Therefore, it can be concluded that the control input resulted in a correct and normal elevator deflection.

Aircraft configuration

From the available evidence, the following were configured correctly for the take-off:

- There was no evidence of any external securing articles still in place at the time of the accident. The post-accident inspection did not find any such articles. The crew reported having completed a normal pre-flight external inspection. There was no indication in the flight data of aerodynamic drag from, for example, an unsecured panel.
- The control lock was released. The aircraft will not start without the control lock being released, as it locks the thrust levers. The control lock mechanism was subsequently found to be working correctly and therefore would have prevented the pilot from starting the engines if it had been left in place.
- Based on the crew reports, cockpit voice recording and photo of the cockpit centre console immediately after the accident, the elevator trim was set correctly for take-off – in the take-off position marked on the trim indicator.
- The flight data showed that the speed brakes were not deployed.
- The flight data showed the autopilot was not engaged.
- The crew reported that the flaps were set in the 'take-off/approach' position marked on the flap indicator. The flight data was consistent with the flaps being set for take-off.

- Based on the cockpit voice recording, the crew completed all after-start, taxi and pre-flight checks in the sequence of the published aircraft checklist. The captain's response to the copilot's call of 'brakes' during the after-start checks was 'I'll check them'. There was no subsequent reference to the brake check on the CVR, however, the required action was to apply the toe brakes and ensure symmetrical retardation and positive pressure existed.

Aircraft parking brake

The parking brake was set by either pilot applying and holding footbrake pressure and the pilot in the left (captain's) seat pulling out the parking brake lever underneath the left instrument panel (Figure 4). The lever could be selected OFF or fully ON. There was no partial release position of the lever. When the lever was pushed forward from the ON position, pressure in the lever would continue to release the lever until it was in the OFF position. The position of the parking brake lever was not visible to the pilot in the right seat. There was no cockpit annunciation that the parking brake lever was in the ON position.

Figure 4: Parking brake lever in the ON position



Source: Aircraft owner

With the parking brake on, the applied pressure in the brake lines is trapped, and when the footbrake is released, the pressure at the brakes remains. If the parking brake handle is pulled with no footbrake pressure applied, no pressure will be present in the brakes. However, any subsequent footbrake pressure will be trapped and maintained, until the parking brake lever is returned to the OFF position. The park brake is certified to ensure that with full pressure applied, the wheels will remain locked even if full thrust is applied on both engines.

The parking brake was found engaged following the accident. However, the captain reported engaging it after the aircraft came to rest in the grass. The captain also reported that evacuation training always included setting the park brake as one of the first actions. The captain could not recall selecting the parking brake ON while at the holding point, where the aircraft was stationary for over 4 minutes.

Brakes

The aircraft brakes consisted of alternating discs connected to the wheel and axle. When the brakes are applied when the wheels are moving, their temperature will rise. If the brakes overheat, the disc pack will seize and the wheel will stop rotating. The brakes incorporated an anti-skid system. When a skid or impending locked wheel condition is sensed, a signal is sent to release the pressure in the affected brake.

After the accident, the left brake had seized and both brakes appeared to have been exposed to very high temperatures.

If the brakes were partially engaged while the aircraft was moving throughout the take-off run, they would have been absorbing energy and increasing in temperature. In the event of a rejected take-off, the brakes would then be less effective than usual due to their elevated temperature.

The operator's engineering manager who inspected the accident site reported that they were unable to inspect the brakes as the brake and wheels were packed solid with grass and mud, and one tyre was fully deflated. The engineering inspection report provided to the ATSB (see *Aircraft examination* above) was limited to the elevator control functionality.

A failure of the parking brake valve could result in partial brake pressure. The brake valve was not inspected after the accident by the operator nor assessed during the ATSB's inspection of the aircraft. However, as the braking system was working during the taxi to the holding position, the short time between holding to enter the runway and taxiing onto the runway was the only opportunity for it to fail. Further, a senior air safety investigator from Textron Aviation (Cessna) was unaware of any other failures of the valve to operate correctly.

Airport information

Runway

Runway 15 at Lismore had an available take-off length of 1,647 m (5,403 ft). The runway sloped down by 0.1 per cent. The aircraft was taxied onto the runway at the northern taxiway intersection, about 152 m (500 ft) beyond the runway threshold (Figure 1). Although the take-off was commenced from the intersection, an additional 152 m of runway was available to the crew for the take-off.

Runway end safety area

The Civil Aviation Safety Authority Regulation (CASR) 139 *Manual of Standards requires* Code 3 and 4 runways⁴ like runway 15 at Lismore to have a runway strip extending 60 m beyond the runway end, and a runway end safety area (RESA) for 90 m beyond the runway strip. In addition, the International Civil Aviation Organization Annex 14 *recommends* that the RESA should extend (as far as is practicable) to a length of at least 240 m beyond the end of the runway strip.

Runway strips consist of a fully graded area surrounding the runway at both ends and beyond the side of the runway. Runway strips are required by CASR 139 to be free of all fixed objects and potential obstructions, other than visual aids for guiding aircraft or vehicles. These objects must be of low mass and frangible. The aim of this area is to reduce the risk of damage to aircraft running off the ends or sides of the runway.

RESAs are areas of graded flat ground beyond the end of a runway and runway strip, designed to enhance aircraft deceleration. These are symmetrical about the extended runway centreline, and are free from any non-frangible obstacles or obstructions.

By assisting aircraft to decelerate in a controlled manner, RESAs are designed to reduce the risk of damage to an aircraft that undershoots the runway, rejects a take-off and overruns the runway end, or overruns the runway end following a landing.

Using measurements from a Google Earth image of Lismore Airport taken in 2014, the overrun area beyond the sealed end of runway 15 at Lismore was about 180 m to the airport boundary fence, flat, grassed and free of obstacles.

⁴ Code 3 and 4 runways are 1,200 m (3,937 ft) or longer.

Accident site

Similarly, using measurements from Google Earth based on photos of the accident site, the aircraft came to rest about 150 m beyond the sealed runway and before the airport boundary fence. The RESA at Lismore may have assisted in decelerating the aircraft after the rejected take-off and reduced risk of injury and damage to the aircraft.

Distinctive marks on the end of runway 15 indicated that the right wheel tyre had deflated after the captain rejected the take-off and the wheel's rim was making contact with the runway. The position of the tyre witness marks on the runway showed that the aircraft remained just to the right of the centreline but moving towards the left as it exited the runway (Figure 5).

Figure 5: Southeast end of the runway showing right wheel contact marks on the runway and their position in relation to the runway centre line



Source: Aircraft owner

Operational information

Weather

According to the Meteorological Terminal Aviation Routine Weather Report (METAR) for Lismore Airport issued at 1230, the wind was from 190° at 10 kt, and the temperature was 18 °C. The runway was dry at the time of the accident.

Take-off performance simplified criteria

The Cessna 550 pilot operating handbook specified values for speeds and power settings for a reduced thrust take-off, known as simplified take-off performance criteria. The simplified criteria could only be used if the following conditions were met, including:

- flaps set to 15° (take-off and approach setting)
- available take-off field length of 5,200 ft (1,585 m) or longer
- no tailwind
- no runway gradient
- dry paved runway.

The crew used the reduced-thrust reference speeds and power setting based on an aircraft weight of 14,000 lb (6,350 kg) or less, airport altitude 3,000 ft or below, and the ambient temperature between -1 °C and 35 °C.

The aircraft weight, airport altitude and temperature met the required criteria, and the flaps were recorded in a position suitable for take-off and consistent with the simplified take-off criteria. In addition, by commencing the take-off run from the taxiway intersection, the runway length remaining (4,900 ft) was about 300 ft (91 m) less than that required.

Flight data

Accident flight

The ATSB analysis of the flight data recorder (FDR) showed:

- the control column input (to rotate the aircraft) started at about 105 kt (which was the calculated V_1 ; V_R was 108 kt)
- the maximum elevator position of 11° occurred at about 111 kt
- the maximum pitch attitude of 4.7° occurred at about 112 kt
- the aircraft took about 19 seconds to accelerate from 40 kt to 110 kt.

Flight data comparison

The accident flight data was compared with four previous flights. Although numerous variables would have differed for each of the previous flights, such as aircraft weight and balance and environmental conditions, the difference in the take-off run data between those flights was not significant compared with the evident differences in the data from the accident flight. Although the engine RPM was not significantly different from the previous flights, the accident flight differed to the others in the following ways:

- For the accident flight, the aircraft took about 19 seconds to accelerate from 40 to 110 kt, or almost twice that of the previous four flights, which took 10-12 seconds.
- While the rate of change of the elevator deflection after V_R was similar to four previous flight, the total deflection was greater.
- The rate of change of aircraft pitch after V_R was significantly lower (1.6° per second) than previous flights (3.6-4.8° per second). The maximum pitch angle was 4.7° whereas for the previous flights it was about 11°.

Analysis of flight data

During the take-off run, the aircraft accelerates against the aerodynamic drag of the aircraft and rolling resistance of the wheels. The variations of these with speed⁵ are different. The aerodynamic drag increases with the *square* of speed. In contrast, principal components of the rolling resistance are a *constant* force that varies with rolling speed. As shown in *Appendix A*, removing a component of aerodynamic drag to the accident flight speed profile does not result in a similar speed profile to the previous four flights throughout the take-off run. However, correcting the acceleration at a constant rate of 2.5 kt/sec does result in a closely correlated speed profile with the previous four flights. As such, it is evident the slow acceleration was a product of additional rolling resistance of the wheels rather than additional aerodynamic drag.

Appendix A also shows that an additional rolling resistance on the wheels, given the aircraft's thrust line (engine height) was above the main wheels contact point with the runway, would create a nose-down moment on the aircraft. Full elevator deflection, at the thrust setting and the airspeed when the captain attempted to rotate the aircraft, would have been insufficient to overcome this nose-down moment. (Aerodynamic drag would not produce the nose-down moment preventing rotation.)

⁵ The flight data includes airspeed rather than groundspeed. While the groundspeed of the aircraft would have differed from the airspeed by a number of factors including wind strength and direction, both speeds increase at effectively the same rate and the acceleration is comparable.

Similar incidents

In 2010, a Cessna Citation CJ1, registered N646VP, overran the runway at Leeds Bradford Airport, West Yorkshire, UK. During the take-off run, the pilot assessed that the aircraft would not accelerate to V_1 and rejected the take-off. As the pilot braked, both brakes failed, the right brake caught fire and the aircraft overran the end of the runway. The accident investigation by the UK Air Accident Investigation Branch (AAIB), and reported in [AAIB bulletin 3/2011, concluded that the brakes were probably on, at least partially, during the take-off run.](#)

The US National Aeronautics and Space Administration (NASA) provided the ATSB with a report of *Cessna Citation parking brake engaged or partially engaged during takeoff roll incidents* from the Aviation Safety Reporting System (ASRS).⁶ This included the following two (of three) reports:

A Cessna 525 owner/pilot reports hiring a professional pilot to fly him to an airport due to a strong gusty wind forecast. The professional pilot forgets to release the parking brake prior to takeoff and this omission is not detected until airborne. Upon landing the right brake is locked and the right tire fails causing directional control problems.

On landing, a Cessna 550 blew both main tires which was caused by a partially engaged parking brake. There is no warning system or light that indicates the parking brake is still engaged.

A Senior Investigator from Textron Aviation (Cessna) indicated that there have been similar events where pilots have attempted to take off with the parking brake set and enough pressure to keep the aircraft rolling at idle thrust, resulting in similar incidents. This led to the publication of an article in Cessna's [Direct Approach](#) magazine issued in December 2008, which reminded operators to make sure to disengage the parking brake.

There is no parking brake indicator to alert the flight crew that the park brake handle is engaged. Flight crews should follow the procedures in the Airplane Flight Manual (AFM) and the Pilots' Abbreviated Checklist regarding the brake system operation. The pilot in command is the last set of eyes to make certain the brake system switch, circuit breaker, and park brake are all in the correct positions before taxi or takeoff.

⁶ Certain caveats apply to the use of ASRS data. All ASRS reports are voluntarily submitted, and thus cannot be considered a measured random sample of the full population of like events.

Safety analysis

Introduction

While the crew did not detect anything abnormal during the take-off run until rotation, the flight data showed a significantly reduced acceleration despite normal thrust and engine RPM, and normal aircraft configuration. When the captain attempted to rotate the aircraft, the aircraft did not rotate despite full elevator deflection. The captain rejected the take-off, applying full brakes and reverse thrust. Before the aircraft could stop, it overran the runway onto the grass over-run area, which minimised damage to the aircraft and prevented serious injuries occurring.

There was no evidence that the slow acceleration was related to aircraft weights or balance, weight and balance calculations, aircraft configuration or thrust settings, or inaccurate airspeed readings. There was also no evidence to suggest that the lack of rotation was related to insufficient elevator deflection or control column movement, external locks, control locks, inappropriate elevator trim, or inappropriate airspeed.

Flight data analysis showed that the slow acceleration and lack of rotation at V_R was consistent with a constant rolling resistance on the wheels. The analysis will consider the possibility that this rolling resistance was a result of partial brake pressure on the wheels as a result of an engaged parking brake. It will look at the limited opportunities the crew have to detect an engaged parking brake when it results in only a small amount of brake pressure. The analysis will also examine the implications of the captain's late take-off rejection and the intersection departure, and the runway end safety area, on the safety of flight.

Partial brake pressure during take-off

Rolling resistance on the wheels could be a result of a number of factors, such as soft ground, a wheel, tyre or brake failure, or partially applied braking pressure to the wheels.

The runway was a sealed hard surface, so it is not feasible the surface had any effect.

Neither crew member detected any tendency for the aircraft to yaw. Additionally, the position of the tyre witness marks on the runway showed that the aircraft remained on the runway centreline until after the captain rejected the take-off. This is indicative of equal resistance from both main wheels and not a failure of one wheel, brake or tyre.

Given that only one tyre was damaged (and that witness marks indicate it was damaged after the rejected take-off), it is therefore probable that the rolling resistance experienced by the aircraft was a result of partial brake pressure in both wheels. This affected both the slow acceleration rate and inability to rotate the aircraft at V_R .

Previous incidents have also shown that partial brake pressure in the wheels can lead to slow acceleration and an inability to rotate during take-off.

Parking brake not disengaged

The partial brake pressure to both wheels could have been a result of one of the flight crew applying toe braking throughout the take-off, a mechanical failure of the parking brake valve, or an engaged parking brake.

Both crew were sufficiently experienced to make it very unlikely that either was accidentally applying toe braking during the take-off run. Furthermore, the copilot (as pilot monitoring) reported having their feet flat on the floor during the take-off.

The possibility of mechanical failure of the parking brake valve was unlikely. The crew had been able to release the parking brake and commence taxiing to the holding point, and confirmed pressure was achievable in the toe brakes during the taxi. Although they were not inspected after

the accident, there was very limited opportunity for them to fail (after leaving the holding point), and there was no evidence of failure or history of failures of the park brake valve in other Cessna Citation aircraft.

In order for partial braking pressure to exist in the wheel as a result of the parking brake lever not being disengaged, a small amount of pressure from toe braking would also need to have been trapped.

The captain could not recall whether they selected the parking brake on while at the holding point. The aircraft was stationary at the holding point for over 4 minutes. The captain reported that only light pressure on the toe brakes would have been necessary to stop the aircraft at the holding point with the engine thrust at idle and after a short taxi. This would be consistent with enough partial pressure remaining in the brakes to affect acceleration but not sufficient to prevent the aircraft reaching V_R .

The parking brake was found engaged following the accident. The captain reported they engaged it after the aircraft came to rest in the grass. However, it is possible that having observed the parking brake engaged on returning to the aircraft after exiting following the accident, and expectations based on evacuation training, the captain may have assumed they engaged it during the shutdown process, influencing their subsequent memory. The flight crew reported being quite shocked and in a hurry to exit the aircraft in case of fire following the accident, and the CVR showed that the copilot needed to remind the captain to complete another pre-evacuation action (shutting down the engines). The copilot was unable to see the parking brake lever from their position.

The aircraft manufacturer was aware of a number of events where pilots have attempted to take off with the parking brake on and just enough pressure remaining in the brakes to permit the aircraft to roll even at idle thrust. These have resulted in similar incidents, including a runway overrun involving a Cessna Citation CJ1 (with the same braking system) in 2010 in the UK. Further, the captain, aircraft operator and owner, and Cessna, have all reported that it is not uncommon to attempt to taxi the Citation aircraft with the park brake engaged.

Therefore, although there is no direct indication that the parking brake was engaged resulting in a small amount of pressure being trapped in the brakes, the plausibility of it, past occurrences where it has occurred, and the absence of other explanations given the evidence suggests it is probable that the parking brake was still engaged during the take-off run.

No related cockpit annunciation or checklist item

The park brake lever was the only indication that the park brake was engaged in Cessna Citation aircraft. However, the lever is on the captain's side and is not visible from the copilot's seat. Further, it is outside the captain's normal line of sight during a routine instrument scan.

There was no cockpit annunciation on the instrument panel to show that the parking brake was on, and there was no check that the parking brake in the (manufacturer supplied) aircraft's pre-take-off checklist. The lack of one of either the annunciator light or a checklist item makes it difficult for any crew to realise when the parking brake is inadvertently left engaged when only partial brake pressure exists.

A representative from Textron Aviation (Cessna) advised that they were aware of similar events occurring due to pilots attempting to take off with the parking brake set, and only enough pressure to allow the aircraft to keep rolling at idle thrust. Cessna's *Direct Action* magazine had published a reminder to operators of Citation aircraft to ensure the parking brake was disengaged in response to a previous similar incident. The article stated 'There is no parking brake indicator to alert the flight crew that the park brake handle is engaged'.

Given the position of the park brake lever, the lack of annunciator light on the instrument panel, and no pre-take-off check, in addition to the fact that the slow acceleration was not perceivable to the crew, made it almost impossible for the crew to discover that the parking brake was engaged.

Rejected take-off and overrun

Following the reduced acceleration during the take-off run, the aircraft accelerated to V_R but did not rotate, so the captain rejected the take-off.

When the aircraft reached V_R , the captain initiated rotation with normal backpressure (for a 3 degree per second rotation) on the controls. The captain reported that the controls felt heavy, and the aircraft did not rotate. The captain then applied full backpressure on the controls, and neither crew member detected any indication that the aircraft had pitched up, or that it would become airborne. The heavy feel of the control column and lack of rotation led the captain to assess that the aircraft was not capable of flight, and with the end of the runway looming, the captain rejected the take-off above critical speed.

The captain rejected the take-off, applying full brakes and reverse thrust. Partial pressure in the brakes during the take-off run would have overheated the brakes, reducing their effectiveness in the rejected take-off. Once the right tyre had blown, braking action would have been further compromised. The reduced acceleration during the take-off run meant the aircraft was further down the runway than normal when the aircraft reached V_R . Combined with the reduced braking effectiveness, the aircraft could not stop on the runway.

Rejecting the take-off despite the aircraft exceeding V_1 (after assessing the aircraft was not capable of flight) was in accordance with the operator's standard pre-take-off safety brief. The captain did not attempt to increase thrust (to try to get airborne) when the aircraft failed to rotate. If the captain had increased thrust, the aircraft may have achieved a sufficient speed to become airborne despite little or no rotation. However, the captain could not be certain of this. The decision to reject the take-off at this late stage resulted in the runway overrun, but reduced the overall risk to the flight compared to the potential for catastrophic damage and injury if the aircraft failed to achieve adequate lift, or achieved a successful take-off followed by a landing with partial brake pressure, ineffective brakes and a strong nose-down moment.

Intersection departure

The flight crew conducted an intersection departure with reduced thrust without realising the runway remaining was 300 ft (91 m) less than the 5,200 ft (1,584 m) stipulated in the simplified reduced thrust take-off criteria. The crew elected to commence the take-off from the taxiway intersection reducing the available runway length by about 500 ft (150 m).

Use of the full runway length may have reduced the distance the aircraft overran the runway by, however, the flight data indicated that the aircraft was still travelling at about 77 kt when it ran off the end of the sealed runway, and therefore that significant deceleration occurred due to the wet grass and mud in the runway overrun area. Therefore, it is unlikely that the use of the full runway would have prevented the runway overrun in this case.

By not realising the simplified criteria did not apply to the runway length available when using an intersection departure, the crew were increasing risk of a runway overrun if they rejected the take-off at about V_1 .

Runway end safety areas

The grass overrun area beyond the sealed end of runway 15 at Lismore was about 180 m to the airport boundary fence, longer than the required 150 m (90 m runway end safety area extending beyond the 60 m runway strip), and contained the aircraft which came to rest about 150 m beyond the end of the runway. The suitable overrun area restricted the aircraft damage and resulted in no injuries resulted from the accident.

Findings

From the evidence available, the following findings are made with respect to the runway excursion involving a Cessna 550, VH-FGK, at Lismore Airport, New South Wales, on 25 September 2015. These findings should not be read as apportioning blame or liability to any particular organisation or individual.

Safety issues, or system problems, are highlighted in bold to emphasise their importance.

A safety issue is an event or condition that increases safety risk and (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 operating environment at a specific point in time.

Contributing factors

- There was probably residual braking pressure in the wheel brakes during the take-off run.
- The aircraft's parking brake was probably applied while at the holding point and not disengaged before taxiing onto the runway for take-off.
- **The Citation aircraft did not have an annunciator light to show that the parking brake is engaged, and the manufacturer's before take-off checklist did not include a check to ensure the parking brake is disengaged. [Safety issue]**
- The aircraft experienced a retarded acceleration during the take-off run, and did not rotate as normal when the appropriate rotate speed was reached, resulting in a critical rejected take-off and a runway overrun.

Other factors that increased risk

- The flight crew conducted an intersection departure with reduced thrust without realising the runway remaining was 300 ft (91 m) less than the 5,200 ft (1,585 m) stipulated in the 'simplified reduced thrust take-off criteria'.

Other findings

- The captain did not increase thrust (to try to get airborne) when the aircraft failed to rotate as it was assessed that the aircraft was not capable of flight. Although increasing thrust and speed may have resulted in the aircraft taking off with little or no rotation, the captain could not be certain of this. The decision to reject the take-off at this late stage resulted in the runway overrun but reduced the overall risk to the flight.
- The grass runway strip and runway end overrun area at Lismore was about 180 m or more (longer than the required 150 m), which contained the aircraft which came to rest about 150 m beyond the end of the runway, resulted in no injuries and restricted aircraft damage.

Safety issues and actions

The safety issues identified during this investigation are listed in the Findings and Safety issues and 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.

The initial public version of these safety issues and actions are repeated separately on the ATSB website to facilitate monitoring by interested parties. Where relevant the safety issues and actions will be updated on the ATSB website as information comes to hand.

No cockpit annunciation or checklist item for parking brake status

Number:	AO-2015-114-SI-01
Issue owner:	Textron Aviation (Cessna)
Operation affected:	Aviation: General aviation
Who it affects:	All owners and operators of Cessna Citation aircraft.

Safety issue description:

The Citation aircraft did not have an annunciator light to show that the parking brake is engaged, and the manufacturer's before take-off checklist did not include a check to ensure the parking brake is disengaged.

Response to safety issue by Textron Aviation (Cessna)

Textron Aviation now has a formal team to address Continual Operational Safety (COS) issue with our fleet of aircraft. They will address any COS issues that comes in through the FAA safety recommendation system.

ATSB comment in response

The ATSB notes that Textron Aviation (Cessna) is willing to look at addressing safety recommendations so the ATSB is issuing the following safety recommendation.

ATSB safety recommendation to Textron Aviation (Cessna)

Action number: AO-2015-114-SR-002

Action status: Released

The Australian Transport Safety Bureau recommends that Textron Aviation (Cessna) take safety action to address the fact that Citation aircraft do not have an annunciator light to show that the parking brake is engaged and the Cessna 'before take-off' checklist does not include a check to ensure the parking brake is disengaged.

Current status of the safety issue

Issue status: Safety action pending

General details

Occurrence details

Date and time:	25 September 2015 – 1300 EST	
Occurrence category:	Accident	
Primary occurrence type:	Aircraft control	
Location:	Lismore Airport, New South Wales	
	Latitude: 28° 49.60' S	Latitude: 153° 15.45' E

Pilot details – captain

Licence details:	Airline Transport Pilot (Aeroplane) Licence
Endorsements:	Manual Propeller Pitch Control; Retractable Undercarriage; Single Engine Aeroplanes less than 5,700 kg Maximum Takeoff Weight; Pressurisation system; Gas turbine engine; Retractable undercarriage; Cessna 500/550/560
Ratings:	Multi-engine Command instrument rating
Medical certificate:	Class 1
Aeronautical experience:	5,937.7 hours
Last flight review:	10 July 2015

Pilot details – copilot

Licence details:	Commercial Pilot (Aeroplane) Licence
Endorsements:	Single Engine Aeroplanes less than 5,700 kg Maximum Take-off Weight; Manual propeller pitch control; Tailwheel; Pressurisation system; Gas turbine engine; Retractable undercarriage; Cessna 500/550/560
Ratings:	Multi-engine Command instrument rating
Medical certificate:	Class 1
Aeronautical experience:	377.8 hours
Last flight review:	12 September 2015

Aircraft details

Manufacturer and model:	Cessna Aircraft Company 550	
Year of manufacture:	1998	
Registration:	VH-FGK	
Serial number:	550-0852	
Total Time In Service	2,768.8 hours	
Type of operation:	Private – Test & ferry	
Persons on board:	Crew – 2	Passengers – Nil
Injuries:	Crew – Nil	Passengers – Nil
Damage:	Substantial	

Sources and submissions

Sources of information

The sources of information during the investigation included:

- the captain of VH-FGK
- the copilot of VH-FGK
- the owner of VH-FGK
- the operator of VH-FGK
- the licenced aircraft maintenance engineer for VH-FGK
- the aircraft's flight data recorder
- the aircraft's cockpit voice recorder
- Cessna (Textron Aviation)

References

Civil Aviation Safety Authority, 2008, *Manual of Standards Part 139 – Aerodromes* (v. 1.4). Canberra: CASA.

International Civil Aviation Organization, 2004. *Annex 14 to the Convention on International Civil Aviation, Aerodromes, Volume 1, Aerodrome Design and Operations* (4th edition). Montreal: ICAO.

Kettle D.J. 1958, *Ground Performance at Take-off and Landing – A chart for the estimation of either unstick or landing roll distance*, Aircraft engineering.

Submissions

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

A draft of this report was provided to the captain and copilot, aircraft operator, aircraft owner, Cessna, NTSB, and CASA.

Submissions were received from the aircraft operator, owner, captain and copilot. The submissions were reviewed and where considered appropriate, the text of the report was amended accordingly.

Appendices

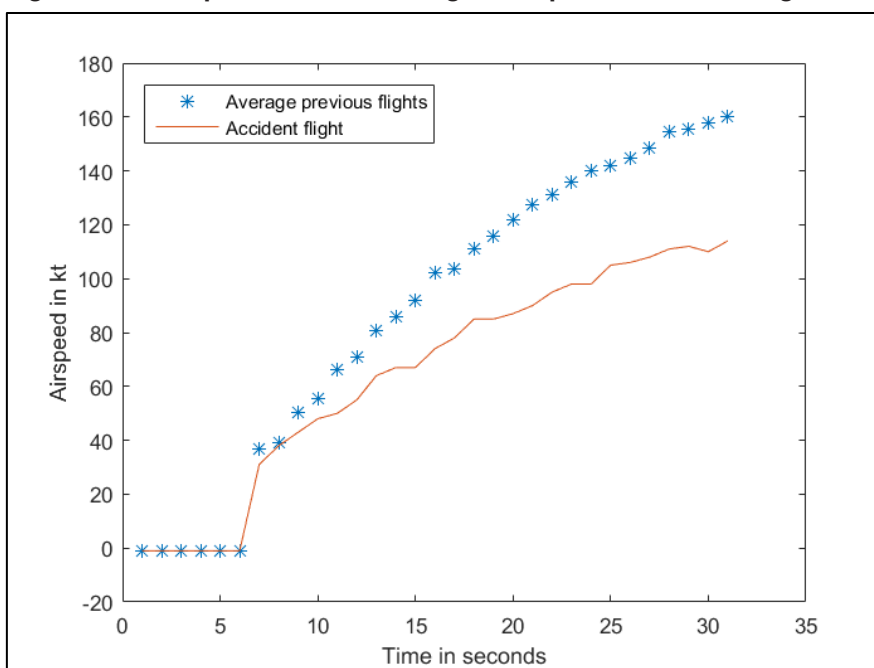
Appendix A – Analysis Report

Reduced acceleration

Interpretation of airspeed data during take-off run

The accident flight take-off data shows a reduced acceleration compared with the previous four flights, but a similar engine RPM. Figure A-1 shows the airspeed of the accident flight and the average of the four previous flights, which were not significantly different from each other.

Figure A-1: Airspeed of accident flight compared to the average of four previous flights



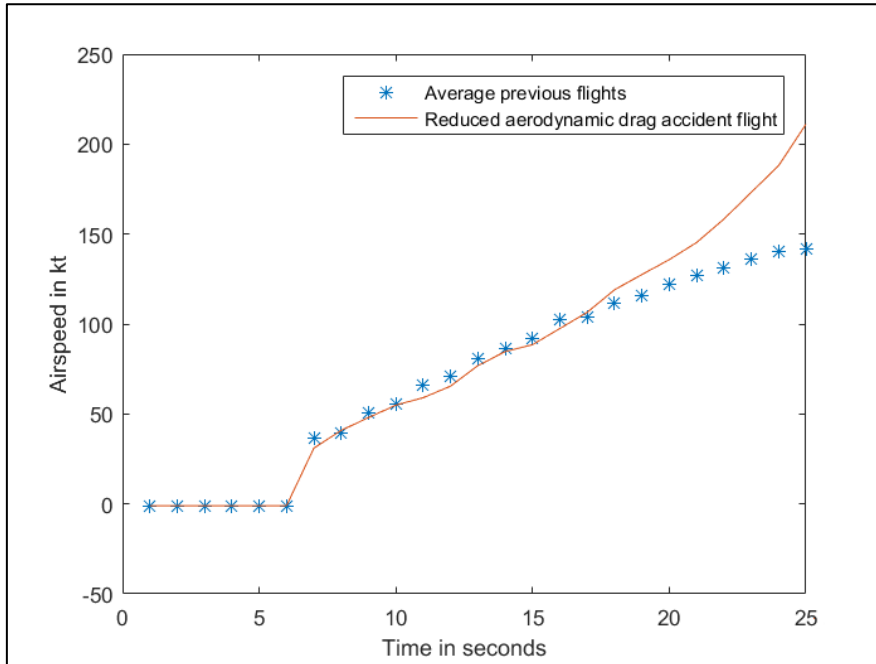
Source: Analysis of aircraft flight data conducted by ATSB

During the take-off run, the aircraft accelerates against rolling resistance of the wheels and aerodynamic drag of the aircraft. The variations of these with velocity are different. Note that the flight data includes airspeed rather than groundspeed. While the groundspeed of the aircraft would have differed from the airspeed, by a number of factors including wind strength and direction, both speeds increase at effectively the same rate and the acceleration is comparable.

Aerodynamic drag

The aerodynamic drag increases with the *square* of speed. If the increased drag was primarily aerodynamic, the effect on the airspeed curve would be an increase in the curvature (downwards) as speed increased, after being similar at lower airspeeds. Figure A-2 shows the airspeed from the accident flight with a component of aerodynamic drag removed, and compared to the average previous flights. As can be seen from the graph, this does not reflect a similar acceleration profile to the previous flights. The graph depicts the airspeed showing the commencement of the take-off run, to when the captain rejected the take-off in the accident flight.

Figure A-2: Airspeed of accident flight without an aerodynamic drag component, compared to the average of four previous flights



Source: Analysis of aircraft flight data conducted by ATSB

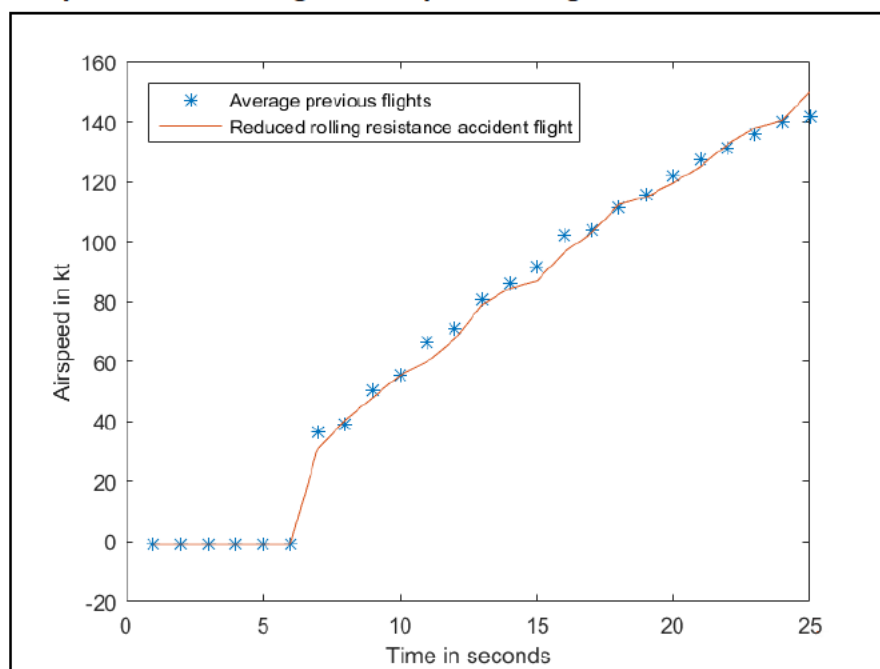
Rolling resistance

The principal components of the rolling resistance are a constant force and a force that varies with rolling speed. If the acceleration was retarded by an increase in rolling resistance, the effect on the airspeed curve would be a general reduction over all airspeeds. This would show a more linear relationship (as depicted in Figure A-3 rather than the curve in Figure A-2).

Assuming, as was evident from the flight data, that the thrust was similar to previous flights, some of the thrust was required to overcome the additional rolling resistance, therefore effectively less thrust was available to accelerate the aircraft.

A correction of an acceleration of 2.5 kt/second as a constant applied to the accident flight is depicted in Figure A-3. As can be seen, the corrected line correlates closely with the average take-off acceleration from the previous four flights. Adding an acceleration component equates to a deceleration (or rolling resistance) component present in the accident flight data. A deceleration component of 2.5 kt/second is 0.13 g.

Figure A-3: Airspeed of accident flight with a reduced rolling resistance component, compared to the average of four previous flights



Source: Analysis of aircraft flight data conducted by ATSB

Rolling coefficient of friction

The rolling coefficient of friction is assumed to be constant with speed and independent of wheel load. The following values (g) have been suggested:⁷

Table 1: Suggested values for rolling coefficient of friction (g)

Runway surface	Rolling coefficient of friction (g)
Hard surface	0.03
Hard turf	0.04
Short grass	0.05
Long grass	0.10
Soft ground	0.10-0.30

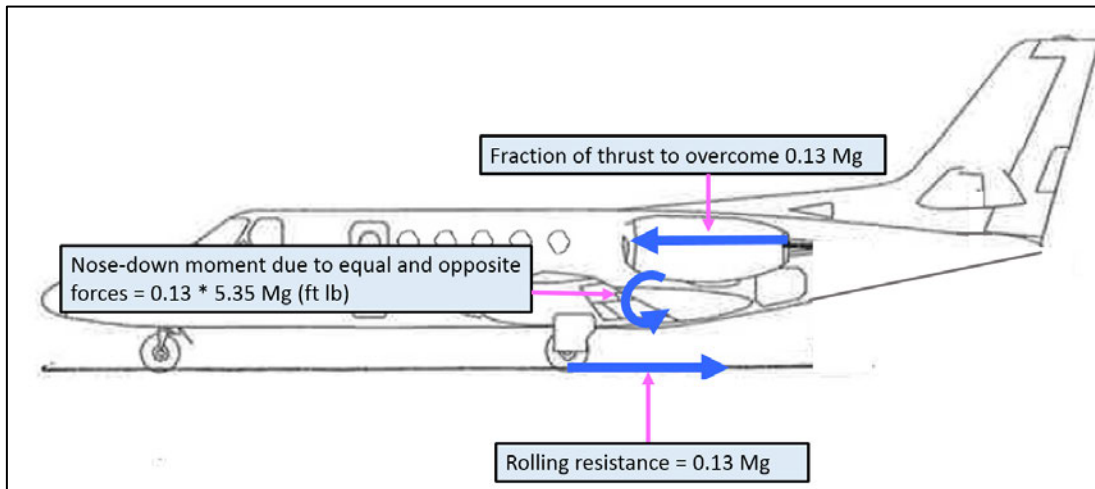
From the data in Table 1, a deceleration component of 0.13 g plus the constant for a hard dry runway of 0.03 g equates to a rolling coefficient of friction of about 0.16 g. Therefore, the effect of the rolling resistance force was equivalent to taking off on soft ground.

Failure to rotate

During a normal take-off run, a portion of the thrust equals the rolling resistance. The rolling resistance occurs at the point of contact between the wheels and the runway. The engine thrust occurs through a line parallel to the rolling resistance, at the height of the centre of the engines; the height of the thrust line above the ground for this aircraft is 5.35 ft. An acceleration of 0.13 g on an aircraft of mass M requires a force of $0.13 Mg$ (Figure A-4). As the thrust line is 5.35 ft above the wheel contact point, it creates a nose-down moment on the aircraft.

⁷ Kettle D.J. 1958, *Ground Performance at Take-off and Landing – A chart for the estimation of either unstick or landing roll distance*.

Figure A-4: Representation of thrust, rolling resistance and nose-down moment



Source: Aircraft owner – annotated by ATSB

The nose-down moment of the thrust force required to counteract the additional rolling resistance of 0.13 g, is $0.13 \text{ Mg} \times 5.35 \text{ (ft lb)}$.⁸

Centre of gravity (CG)

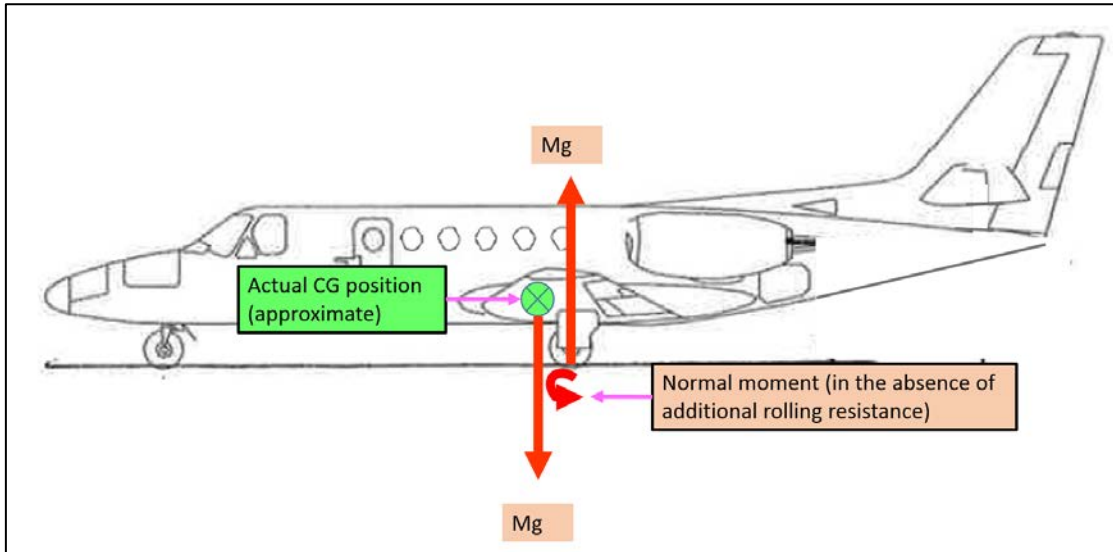
In order for an aircraft to be stable on the ground, the CG is designed to be forward of the main landing gear (otherwise it would tip on its tail). At rotation, a downward force on the tailplane rotates the aircraft about the wheel contact point, raising the aircraft nose and increasing the wing angle of attack. The downward force on the tailplane is produced by an upward deflection of the elevator.

The elevator control power limits the forward CG position of the aircraft. The CG position is conventionally expressed as a per cent mean aerodynamic chord (MAC). According to the [Type Certificate Data Sheet](#) for the 550 Bravo, the MAC was 80.98 inches. If the centre of gravity is too far forward, and beyond the design limitation, the elevator will not have sufficient moment to rotate the aircraft.

Figure A-5 depicts the normal nose-down moment of the aircraft, in the absence of additional rolling resistance, and the approximate actual CG position for the accident flight.

⁸ A foot-pound (ft lb) is a unit of torque equal to the force of 1 pound acting perpendicularly to an axis of rotation at a distance of 1 foot.

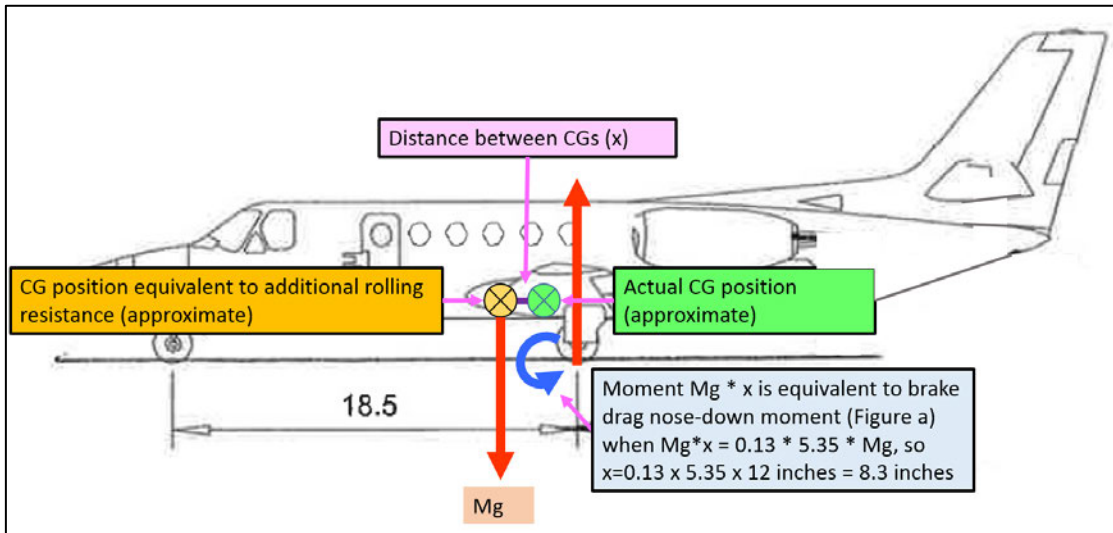
Figure A-5: Representation of normal nose-down moment and centre of gravity (in the absence of additional rolling resistance)



Source: Aircraft owner – annotated by ATSB

The nose-down moment due to the additional rolling resistance, depicted in Figure A-4, is equivalent to the nose-down moment due to the vertical force (Mg) through a more forward centre of gravity position (Figure A-6). So that $0.13 Mg * 5.35 \text{ (ft)} * 12 \text{ (inches per foot)} = Mg * x$, where x is the effective forward movement of the CG. Therefore, x is 8.35 inches, which is 10.3% MAC.

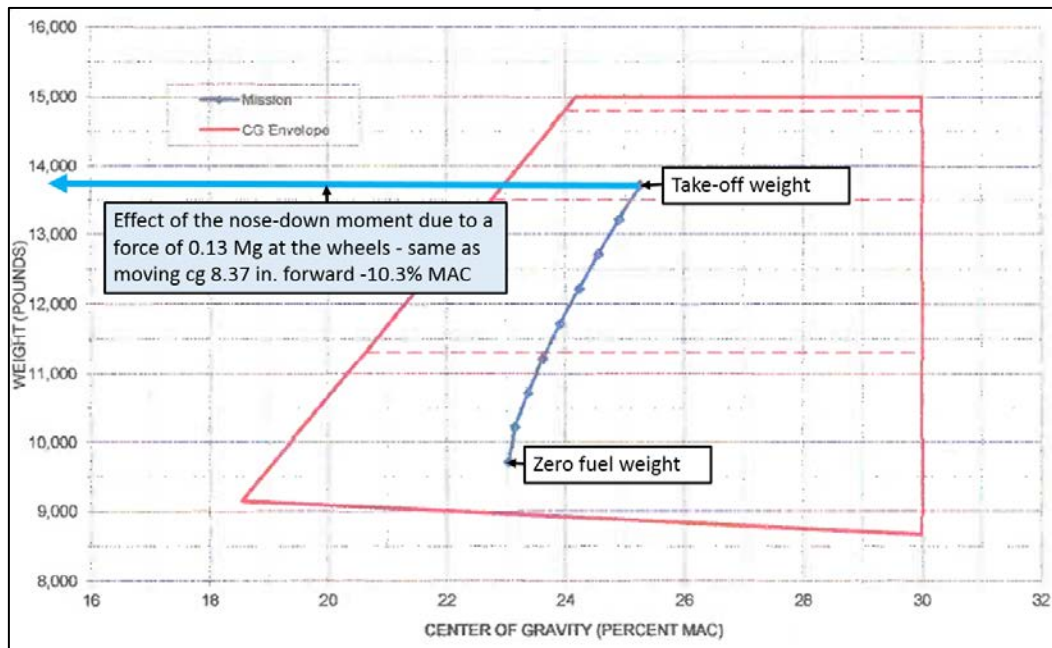
Figure A-6: Representation of nose-down moment with additional rolling resistance equivalent to more forward centre of gravity



Source: Aircraft owner – annotated by ATSB

The aircraft's load sheet the flight crew prepared for the flight is depicted in Figure A-7. The computed CG was 25.1% MAC at take-off. The most forward allowable at that weight was 22% MAC. Moving the centre of gravity forwards 8.35 inches, or 10.3% MAC, would place the effective centre of gravity over 5 inches forward of the allowable range (and off the chart). In that condition it should be impossible to raise the nose of the aircraft – to rotate on take-off.

Figure A-7: Load sheet for VH-FGK showing the accident flight computation of weight and balance from take-off to landing, and the effect of moving the centre of gravity 8.35 inches forward



Source: Aircraft owner – annotated by ATSB

Despite achieving full elevator deflection, at the thrust setting and the airspeed when the captain attempted to rotate the aircraft, it was insufficient to overcome the nose-down moment caused by the additional rolling resistance.

If sufficient rotation could have occurred for the speed that the aircraft achieved (to the necessary angle of attack), the aircraft would have flown (and the wheel rolling resistance would no longer be a factor until landing). In addition, if there were sufficient thrust to continue accelerating the aircraft, at some airspeed it would have lifted off in the ground run attitude, without rotation.

Note that an increase in aerodynamic drag is not only inconsistent with the form of the airspeed curve, but would also not produce the nose-down moment preventing rotation.

Australian Transport Safety Bureau

The Australian Transport Safety Bureau (ATSB) is an independent Commonwealth Government statutory agency. The ATSB 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 operations involving the travelling public.

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 factors related to the transport safety matter being investigated.

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

Developing safety action

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

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

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

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

Australian Transport Safety Bureau

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Investigation

ATSB Transport Safety Report Aviation Occurrence Investigation

Runway excursion involving Cessna 550, VH-FGK, Lismore Airport,
New South Wales, 25 September 2015

AO-2015-114

Final – 25 July 2016