Runway Excursion - Darwin Airport, Boeing 737-376, VH-TJB, 19 February 2003

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Summary.

History of the flight

On 19 February 2003. a Boeing Company 737-376 (737) aircraft, registered VH-TJB. landed on runway 29 at Darwin. The aircraft touched down close to the right edge of the runway and ran off the sealed runway surface. The handling pilot returned the aircraft back to the runway during the landing roll. There were no reported injuries to either the passengers or crew. The aircraft sustained minor damage.

The aircraft was operating a scheduled public transport passenger service between Adelaide and Darwin, with six crew and 79 passengers. The approach was conducted at night and in conditions of reduced visibility due to rain. The automatic terminal information service[1] (ATIS) reported 6.000 m visibility at the aerodrome.

The runway was wet and the previous landing aircraft had reported that the braking action on the runway was good. The aerodrome controller had selected the high intensity approach lighting (HIAL) and high intensity runway lighting (HIRL) to Stage 6 (maximum intensity). The visual approach slope indicator system (T-VASIS) [2] was operating. Due to the weather conditions, the crew elected to perform a monitored approach[3] and configured the aircraft with flap[4] 40. and the autobrake[5] set to 3.

Initial approach

Consistent with company procedures, the copilot was the handling pilot for the initial stage of the monitored approach and provided input to the aircraft's automatic flight management system. The pilot in command monitored the progress of the approach and attempted to establish visual reference with the runway. The aircraft was flown with both autopilots engaged and coupled to the instrument landing system (ILS) for runway 29. The threshold reference speech (Vref)[6] for a flap 40 landing was 131 kts.

Analysis of data from the aircraft's flight data recorder (FDR) confirmed the aircraft was configured for landing prior to reaching the outer marker[7] (OM) and that the approach parameters were stable. The pilot in command recalled that the aircraft crossed the OM and was at an altitude of approximately 1.000 ft when the HIAL became visible. At the decision altitude[8] (DA) he could clearly see the approach lighting and runway lights and decided to continue the approach and land the aircraft. Consistent with company procedures for the monitored approach, the pilot in command became the handling pilot for the remainder of the approach and landing. The aircraft's landing lights were 'ON' during the final approach and landing.

Final approach

The FDR indicated that the autopilot was disengaged approximately 2 to 3 seconds after passing the DA and about 20 seconds prior to touchdown. At the time of autopilot disengagement, the aircraft was established on the localiser and glide slope, maintaining a heading of 283 degrees magnetic (deg M) and was about 200 ft above the height of the runway threshold (HAT). The aircraft's flight path deviated above glide path following disengagement of the autopilot.[9]

About 6 seconds after the autopilot was disengaged, the FDR recorded a control wheel input that resulted in a slightly right wing low bank attitude and then application of left rudder. The combined effect of those control inputs altered the aircraft's heading to the left, but introduced a sideslip to the right and a corresponding angle of drift. The localiser deviation recorded on the FDR indicated that the aircraft started to drift right of the extended runway centreline about 13 seconds before touchdown. Application of left rudder and roll attitude that was predominantly right wing low continued to the point of touchdown, by which time the aircraft's heading was about 7 degrees left of the aircraft's ground track and the localiser deviation indicated 0.57 dots fly left".[10] The control wheel inputs resulted in deployment of the right wing's flight spoilers[11] during the final 70 ft of descent.

The pilot in command recalled that during the final stages of the approach, he could see the runway lights along the full runway length and was satisfied that he had the required visual reference to continue the approach. He recalled that rain was streaming across the windscreen and that the wipers were operating. As the aircraft descended into the touchdown zone he observed that the runway surface was very dark and there was a lack of surface definition. He recalled shifting his gaze from the runway aim point to the cues available at the far end of the runway to judge the height for the landing flare. The pilot in command recalled hearing the synthesised calls of altitude from the aircraft's radar altimeter, which occurred at radar altitudes of 50 ft, 30 ft and 10 ft.

The pilot in command recalled that he did not detect any anomalies with the aircraft's approach path during the final stages of flight and was unaware that the aircraft had commenced to sideslip as it approached the runway. The copilot recalled that he did not detect any anomalies with the aircraft's flight path as he monitored the various flight instruments during the final stages of the approach.

The FDR recorded a backing of the wind direction and a gradual increase in wind speed during the 11 seconds prior to touchdown. Although this change in wind velocity represented an increasing left crosswind component as the aircraft approached the runway, this occurred after the aircraft had commenced the sideslipping manoeuvre.

Touchdown and landing roll

The pilot in command recalled that, due to the wet runway surface, he intended to make a firm touchdown on the runway. During the final stages of the flight, the aircraft's pitch attitude increased from about 2 to 3.2 degrees nose-up. Analysis of data from the FDR indicated that the aircraft touched down with a descent rate of approximately 600 ft/minute and a vertical deceleration of 2.3 g[12] Information contained in the operator's manuals indicated that the normal descent rate for touchdown should be about 150 ft/minute, with a nose-up pitch attitude of between 4 and 6 degrees.

The pilot in command recalled that immediately after touchdown, he brought his view back down the runway and saw that the runway edge lights were tracking down the windscreen centre frame. He immediately realised that they were close to the right edge of the runway and heard the aircraft wheels strike runway lights. Corrective control inputs returned the aircraft to the runway centreline and the aircraft completed the rollout.

Marks on the runway and data from the FDR provided further information on the touchdown and landing roll. Touchdown occurred approximately 520 m from the threshold of runway 29, at a computed airspeed of 127 kts (a ground speed[13] of about 128 kts). The right main landing gear was about 1.4 m inside the edge of the runway and the aircraft was sideslipping to the right. The right main landing gear departed the runway about 590 m from the threshold, at a ground speed of about 124 kts. The left main landing gear departed the runway about 760 m from the threshold, at a ground speed of about III kts. Corrective control inputs by the pilot had returned all wheels to the runway by about 1.130 m from the threshold. At the maximum point of excursion, the right main gear was about 7 m from the edge of the runway and the left main gear was about 2 m from the edge of the runway.

The pilot in command taxied the aircraft clear of the runway. Although there were no abnormal cockpit indications about the landing gear, he requested a precautionary inspection of the aircraft's landing gear by the airport's emergency rescue and fire fighting service before taxiing to the terminal.

Damage to the aircraft

During the landing roll, five runway edge lights were struck by the aircraft's landing gear. Examination of the aircraft revealed damage to the tyres and impact damage to the intakes and fan sections of each engine, mainly associated with the ingestion of runway light fragments. There was also minor damage to the surfaces of the wing flaps. Significant quantities of grass had accumulated in the vicinity of the main wheel brake packs and had also contaminated the wing flaps.

Runway 29 ILS

Runway 29 was equipped with a Category 1 ILS, which enabled pilots to make instrument approaches in conditions of low cloud and reduced visibility. The ILS consisted of a 3-degree glide slope and a localiser aligned on a track of 285 deg M. The relevant instrument approach procedure required the pilot to have visual reference with the runway threshold or approach lighting at the DA (290 ft pressure altitude, which was 209 ft HAT), with at least 800 m visibility. If the visibility subsequently reduced below landing minima, a missed approach was required. The aerodrome's ILS was operating normally at the time of the incident.

Runway 29 physical environment

Runway 29 was 3.354 m long and 60 m wide. The central 45 m of the runway was grooved to assist with wet-runway braking characteristics and tyre adhesion. The runway was not equipped with centreline lighting or touchdown zone lighting, nor was this required for runways equipped with a Category I ILS. However, the Manual of Standards (MOS) - Part 139 Aerodromes issued by the Civil Aviation Safety Authority (CASA) recommended provision of centreline lighting on runways where the width between runway edge lights was greater than 50 m.[14] The runway touchdown zone and centreline were marked on the runway. These markings were relatively well defined and provided contrast against the dark runway surface during daylight conditions and on a dry runway surface.

At 60 m wide, Runway 29 was significantly wider than other Australian runways[15] used by the operator's 737 fleet. As a consequence, the visual cues and runway perspective available to the pilot to complete an approach and landing on runway 29. were different from those normally available.

The average longitudinal slope of runway 29 was 0.2%, with two distinct crests along the runway. The runway crests obstructed portions of the runway and altered the pilot's view of the runway during the final stages of the approach and during the landing flare.

Runway 29 approach lighting

The intensity[16] of the runway's HIAL and HIRL was selected by the aerodrome controller. These had each been set to intensity setting Stage 6 at some point before the 737 crew commenced their approach. The 737 had crossed the OM when the controller transmitted that the HIAL was selected to the maximum setting. The pilot in command of the 737 acknowledged this transmission.

The Manual of Air Traffic Services (MATS) indicated that the initial intensity of the HIAL/HIRL should be set according to the prevailing visibility and ambient light conditions. At night and for the ATIS reported visibility of 6,000 m, MATS indicated an initial setting of Stage 1. Variations to these settings could then be made at the pilot's request. Stage 2 was to be set at night with visibility greater than 4,000 m, but less than 5.000 in. Stage 3 with visibility greater than 2,000 m, but less than 4.000 m and Stage 4 when the visibility was not greater than 2,000 m.

Stage 6 was the maximum intensity for the HIAL/HIRL and MATS indicated that setting should be made during the day when visibility was less than 2,000 m.

Both the pilot in command and copilot recalled the intensity of the lights as they approached and overflew the HIAL. The copilot reported glancing outside during the final approach while the autopilot was still engaged, but after the DA and recalled seeing bright HIAL lights with a black empty area behind and thinking that the HIAL was too bright during the later stages of the approach. The pilot in command reported that, although HIAL set to Stage 6 helped with the early acquisition of the runway environment during the approach, the HIAL appeared brighter as they got closer to the field and the intensity was slightly uncomfortable as they flew overhead. By the time he realised that the lights were too bright, the aircraft was passing overhead the HIAL and it was too late to request the controller to select a lower intensity setting.

Meteorological information

A monsoonal squall line had recently moved through the Darwin area from the west-south-west, but was clear of the airport at the time of the occurrence. There were no thunderstorms in the vicinity of the aerodrome.

While the 737 was on descent and manoeuvring to intercept the final approach, a heavy shower of rain passed overhead the aerodrome and the controller broadcast that the visibility at the aerodrome had reduced to 4,000 m. The pilot in command of the 737 reported his position at the OM and requested an update on the visibility at the aerodrome. The controller indicated that the visibility from the tower was approximately 5.000

m. After landing, the pilot in command reported to the controller that visibility around 3.000 m was experienced during the approach.

Data from the Bureau of Meteorology's (BOM) Low-Level Windshear Alerting System (LLWAS) did not record any significant wind gusts in the period immediately preceding the aircraft's arrival at the runway threshold. The anemometer closest to the threshold of runway 29 recorded westerly wind between 5 and 9 kts at the time the aircraft landed.

Data from the BOM's automatic weather station recorded various parameters on a minute by minute basis. During the minute that the aircraft touched down, the recorded average wind was 250 deg T at 7 kts and 0.2 mm of rainfall was recorded. No rainfall was recorded during each minute either side of the minute during which the aircraft was landed.

Monitored approach procedure

The operator required that a monitored approach be performed when visibility was below 5.000 m and/or low cloud existed at the destination aerodrome. The procedure required the copilot to fly the aircraft (or provide input to the automatic flight control system) with reference to the flight instruments during the initial part of the approach. The pilot in command was required to monitor the progress of the approach and assess the visual reference available to complete the landing.

The pilot in command was responsible for deciding if sufficient visual reference was available to land the aircraft and became the handling pilot for the final phase of the approach and landing. The copilot was required to monitor the flight instruments and ensure that the parameters of the subsequent approach remained stable. He was also required to call out deviations outside approach tolerances until the point of touchdown. If visual reference with the landing runway was subsequently lost, the pilot in command was required to commence a missed approach.

The copilot reported that during the final stages of the approach, while monitoring the flight instruments, he did not detect any localiser deviation outside approach tolerances. He became aware of the aircraft's proximity to the runway's edge as he looked up from the instrument panel immediately following touchdown. The FDR indicated that the displacement of the localiser was about dot fly left' at the point of touchdown.

Use of autoland

The aircraft was equipped for autoland operations that permitted operations onto runways equipped with a Category 2 or Category 3 ILS. In addition, the operator permitted autoland operations on other approved runways when the weather conditions were above the minima for Category 1 operations. The operator had not approved autoland operations for runway 29 at Darwin.

Landing configuration

Due to the wet runway the crew had elected to perform a flap 40 landing. This reduced the threshold reference speed (Vref) and the possibility of the tyres dynamically hydroplaning!! on any standing water on the runway surface. A flap 40 landing required a slightly flatter attitude at touchdown when compared with the more routinely used flap 30 landing.

Technical crew information

The pilot in command was an experienced 737 check and training captain and had logged 17.906 hours aeronautical experience, which included 8.930 hours on the 737. The copilot had transferred from another aircraft type and had recently been endorsed on the 737. At the time of the incident, he was completing line training under the supervision of the check and training captain.

Both pilots held valid medical certificates. The pilot in command required reading glasses for near vision, but distance vision was reported to be normal. A post-incident ophthalmic examination revealed no other anomalies with the pilot in command's vision.

Both crew had signed on in Melbourne earlier on the day of the incident and had completed a sector to Adelaide. At the time of the incident, both had been on duty for about 6 hours 40 minutes and awake for approximately 16 hours. Both crew members had been free of duty for a period of 42 hours prior to signing on. They both reported being well rested prior to commencing duty.

Environmental conditions and relevant human factors

The investigation analysed the extent to which a number of environmental conditions could have altered the visual cues available for the pilot in command to complete the landing. This included an assessment of the available visual cues, the possible existence of visual illusions during the final stages of the approach and other factors such as rain on the windscreen, movement of the wipers and the effect of glare from the HIAL/HIRL.

The crew reported that they applied rain repellent to each windscreen during the approach. The copilot recalled that the pilot in command had requested the wipers to be set to 'high' during the final stages of the approach.

The analysis of the available visual cues during the final stages of the approach indicated:

- that the runway's HIAL lighting started to disappear from view (under the cockpit glare shield) about 23 seconds before touchdown
- the final bar of HIAL lights disappeared from view about 12 seconds prior to touchdown
- the runway threshold lights disappeared from the pilot's view about 10 seconds before touchdown and from this point of the approach, the pilot in command was required to judge the aircraft's lateral position over the runway surface using the runway edge lights
- a portion of runway lights would have disappeared behind the second crest of the runway about 4 seconds before touchdown and another portion of runway lights would have disappeared behind the first runway crest about 2 seconds before touchdown.[18]

The available visual cues were changing during the finals stages of flight and their salience depended on several factors. These included the extent to which individual runway lights may have glared on the wet windscreen and provided an indistinct reference set for judging the aircraft's increasing lateral displacement from the runway centreline. Other contributing factors may have included the action of the wiper blades across the windscreen and the effects of glare from the HIRL.

Data supplied by the operator

The investigation examined information from the operator's Flight Operations Quality Assurance (FOQA) database. This information was collected routinely from aircraft equipped with a quick access recorder and analysed for the purpose of monitoring the aircraft's performance during the landing approach. Around the time of the incident, this data was being expanded to monitor the accuracy of the aircraft touchdown.

A review of the available 737 data for approaches to runway 29 at Darwin from 2003 through to mid 2004. revealed that the mean average of daylight touchdowns was slightly further from the centreline when compared with night touchdowns, but that the standard deviation for these touchdowns was marginally larger at night.

FDR analysis by the aircraft manufacturer

At the request of the Australian Transport Safety Bureau, the aircraft manufacturer provided additional analysis of the data from the FDR. The manufacturer confirmed that the aircraft was cross-controlled!! during the manual portion of flight and that this had resulted in the development of a sideslip. Of particular significance, the manufacturer noted that the environmental wind data recorded by the FDR was not reliable during sideslipping flight. Kinematic!! analysis of various FDR parameters indicated that the environmental crosswind component remained near zero during the final stages of flight and did not indicate any significant increase in crosswind component as recorded by the raw FDR data. The kinematic analysis also indicated a 5 kt reduction in headwind component during the final stages of flight.

Footnotes:

1 An automated transmission indicating the prevailing weather conditions at the aerodrome and other relevant operational information for arriving and departing aircraft.

2 The T-VASIS consisted of high intensity lights on either side of the runway, in proximity to where the glide path for the instrument landing system intersects the runway. That provided visual approach slope guidance for pilots, and included a transverse bar of four lights on either side of the runway.

3 A monitored approach is a reduced visibility procedure where one pilot will fly the aircraft with reference to flight instruments, while the other pilot monitors the approach and assesses the visibility conditions. The procedure is fully explained later in this report.

A Flap 40 is the maximum flap extension, which results in a lower approach/touchdown speed. This reduces the required landing distance and also the possibility of aircraft tyres dynamic hydroplaning on runways affected by standing water.

5 The autobrake system has four landing settings. 1. 2. 3 and Max. and selects the desired deceleration rate for landing.

6 The threshold reference speed is for a specific landing weight and flap configuration and is published by the aircraft manufacturer.

7 The outer marker is a navigation aid associated with the final approach fix for the runway 29 ILS approach procedure and is on the extended runway centreline, approximately 3.8 NM from the threshold.

8 The decision altitude for the runway 29 ILS procedure was 290 ft. This was 209 ft above the height of the threshold of runway 29.

9 This was probably a consequence of nose-up trim applied by the autopilot during the final stages of automatic flight.

10 Localiser deviation is indicated on a display marked with dots. An indication of dot fly left' represents the aircraft displaced to the right of the runway centreline.

" Roll control for the aircraft was provided by ailerons and flight spoilers on each wing. The flight spoilers would begin to deploy at about 10 degrees rotation of the control wheel.

12 g - Acceleration due to Earth gravity, international standard value being 9.80665 nVs2, assumed at standard sea level.

13 Ground speed is the aircraft speed relative to the ground, whereas airspeed is a relative velocity between an aircraft and the surrounding air.

M That was consistent with the recommended practices of the International Civil Aviation Organization (ICAO).

15 Most runways used by the operator's 737 fleet were 45 m wide.

16 Intensity of the HIAL/HIRL for 6-stage lighting, was 100% (Stage 6). 30% (Stage 5). 10% (Stage 4), 3% (Stage 3), 1% (Stage 2) and 0.3% (Stage 1) of the maximum lighting intensity. Changes of these magnitudes were required for the human eye to detect that a change in intensity had occurred.

17 Dynamic hydroplaning is a condition where standing water prevents tyre contact with the runway surface and results in a lack of traction between the tyre and the runway surface.

18 These lights normally provide visual cues to assist the pilot judge the landing flare.

19 Application of flight control movements in the opposite sense to those in normal turns or manoeuvres.

20 A branch of physics that deals with the motion of a body without reference to force and mass.

Analysis

Standard company procedures required a monitored approach in the weather conditions prevailing at Darwin for the aircraft's approach and landing. The approach was conducted at night and in conditions of rain and reduced visibility.

The aerodrome controller had selected the runway 29 HIAL and HIRL to a higher intensity than recommended in MATS for the initial setting given the prevailing weather conditions. Although this selection assisted the crew to acquire the HIAL and HIRL at an earlier stage of the approach, the apparent intensity of those lights increased significantly as the aircraft approached the runway. The crew did not realise that the lights were too bright until the aircraft was passing overhead the HIAL and consequently, did not request a lower intensity selection.

The aircraft commenced deviating from the extended runway centreline about 7 seconds after the autopilot was disengaged and as the HIAL was starting to disappear from the pilot's view. Associated with this deviation were control inputs by the pilot in command, including a left rudder pedal command and a right wing down control wheel input that resulted in the aircraft entering a cross-controlled sideslip to the right as the aircraft approached the runway. These control inputs were not conventional for the environmental conditions.

The control inputs made by the pilot in command during the final stages of flight altered the aircraft's flight path across the ground and directly contributed to the aircraft's deviation from the runway centreline. The control wheel inputs for right roll resulted in the deployment of the right wing's flight spoilers during the final 70 ft of the descent. This increased the drag on the right wing, reduced the lift produced by that part of the aerofoil section and consequently, increased the rate of descent. The investigation could not determine the reason for the rudder and aileron inputs made by the pilot in command.

The data derived by kinematic analysis by the aircraft manufacturer was consistent with other available sources of environmental wind data.

The pilot in command did not detect the aircraft's increasing lateral displacement from the runway centreline. He considered that he had sufficient visual reference to complete the landing. However, during the final seconds prior to touchdown, it was possible that he encountered an abnormal situation where few reliable visual cues were available for determining the aircraft's position relative to the centreline of the runway.

The nature of the available visual cues increased the difficulty for the pilot in command to detect the aircraft's increasing displacement from the runway centreline. This included a wet runway surface with a probable lack of surface definition, painted runway markings that were less conspicuous on a wet runway at night, a lack of touchdown zone lighting/centreline lighting on a runway that was wider than normal and the possibility that the HIRL was glaring on the wet windscreen. The investigation concluded that the presence of centreline lighting would have increased significantly the nature of the visual cues available and would have assisted the pilot to recognise the developing sideslip and lateral deviation from the runway centreline.

The lack of a positive flare, a marginal reduction in headwind component and deployment of the right wing's flight spoilers during the final stages of the approach contributed to the high rate of descent at touchdown. The wider runway would have provided an unfamiliar set of cues for judging the flare height. The lack of runway surface definition would have increased the difficulty for the pilot to estimate the height of the aircraft above the runway and possibly had contributed to the lack of a positive landing flare. This was also coupled with a different flap setting from that routinely used during landing.

The aircraft was sideslipping to the right at the point of touchdown. The excursion from the runway was not preventable due to the sideslip and the proximity of the aircraft to the edge of the runway. There was no evidence to indicate that standing water, or adhesion of tyres on the wet runway surface, were factors in the excursion from the runway.

During the final stages of the approach, the copilot was monitoring various parameters. He did not detect the increasing displacement of the localiser. or make any call for correction prior to touchdown. The size of indicated deviation, together with the other instruments being monitored, made this an unlikely deviation to detect.

The investigation concluded that the presence of runway centreline lighting would have increased the visual cues available to the pilot and assisted with his recognition of the developing sideslip and lateral deviation from the centreline.

Safety Action

Operator

Following this incident, the aircraft operator standardised approach procedures across all aircraft types in their mainline fleet.

Recommendation

The aircraft's deviation from the runway centreline during the final stages of the flight was undetected and uncorrected by the pilot. This could indicate that the visual cues available during the final stages of flight were insufficient for the pilot to safely land the aircraft. Significantly, the pilot did not recognise that those visual cues had diminished to such a point where he was unable to control the lateral position of the aircraft over the landing runway.

Accordingly, the Australian Transport Safety Bureau makes the following recommendation.

R20040090

The Australian Transport Safety Bureau recommends that the Department of Defence (airport infrastructure owner) and Darwin International Airport Pty Ltd (civilian facilities operator) consider installation of centreline lighting and touchdown zone lighting, consistent with CASA recommended practices on runways wider than 50 in.