INCIDENT

Aircraft Type and Registration:	Dornier 328-100, G-BWIR
No & Type of Engines:	2 Pratt & Whitney PW119B turboprop engines
Year of Manufacture:	1995
Date & Time (UTC):	20 February 2005 at 1536 hrs
Location:	London City Airport, London
Type of Flight:	Public Transport (Passenger)
Persons on Board:	Crew - 3 Passengers - 26
Injuries:	Crew - None Passengers - None
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	38 years
Commander's Flying Experience:	3,520 hours (of which 3,130 were on type) Last 90 days - 180 hours Last 28 days - 57 hours
Information Source:	AAIB Field Investigation

Synopsis

Shortly after touchdown at London City Airport (LCY), the aircraft veered to the right and departed the runway before the flight crew were able to bring it under directional control. The investigation revealed that a combination of crosswind and asymmetric reverse thrust caused the initial divergence. Because the aircraft was held in a slightly more nose-up attitude than normal, the nose wheel steering (NWS) system did not become enabled. The consequent unavailability of nose wheel steering resulted in the crew not acquiring directional control immediately. Directional control was only gained after the aircraft had departed the runway when differential braking and asymmetric reverse thrust were applied.

History of flight

The crew departed Edinburgh at 1423 hrs to operate the first of a series of four sectors between Edinburgh and LCY. After an uneventful cruise they flew an ILS approach to Runway 28 at LCY with the commander as the handling pilot. Runway 28 has an asphalt surface (which was dry), an LDA of 1,319 m and the ILS glidepath is set at 5.5º. During the final stages of the approach, the tower controller transmitted two consecutive wind checks of 330º/13 kt. Shortly after touching down on the centreline, the aircraft started a veer to the right which the commander could not correct, even with the application of full left rudder pedal. The aircraft departed the runway onto the grass before control was regained, using asymmetric braking and asymmetric reverse thrust. As the speed decayed, the aircraft was steered back onto the runway and taxied to its parking stand. The crew did not notice any Engine Indicating and Crew Alerting System (EICAS) status messages or warnings during the incident.

Following this excursion incident the aircraft was taken out of passenger service for inspection and functional tests. These included ground inspections and, on the following day, a number of crew training flights with particular attention being paid to the propeller controls and the nosewheel steering. Interrogation of the Integrated Avionics Computers showed a transient 'NWS' message but this did not appear to be linked to any mechanical or system failure.

No faults were found and the aircraft was returned to passenger service.

Flight data recorders

The aircraft was fitted with a Solid State Cockpit Voice Recorder (SSCVR) which recorded the last 30 minutes of flight crew speech and cockpit area microphone sounds. Unfortunately the CVR circuit breaker was not pulled after the landing so the CVR recording contained only post-landing cockpit sounds and crew speech.

The aircraft was also fitted with a Solid State Flight Data Recorder (SSFDR) which recorded a large number of flight data parameters and discretes. These included air data and engine parameters and control surface positions but no parameters related to the braking system or nosewheel steering. All of the available flight data was recovered successfully. Over 50 hours of data was recorded.

A time history of relevant flight data parameters for the landing at LCY is shown in Figure 1. The weight-on-mainwheels discretes (there was no weight-on wheels discrete for the nose wheel) were activated when the airspeed was about 93 kt, although it is possible that the aircraft may have touched down momentarily 4 seconds earlier, when there was a large increment in normal acceleration at an airspeed of about 102 kt.

There was a difference in engine torque of the order of 2% (right torque greater than left torque) just after touch-down. As soon as the aircraft touched down, the aircraft started to diverge to the right at a calculated rate of about 1°/sec. Despite the application of full left rudder 1 second after touch-down, the aircraft continued to diverge to the right. It is inferred from the normal acceleration and pitch attitude data that the aircraft left the paved runway about 9 seconds after touch-down. The airspeed at this time was about 48 kt. About 1 second later the turn to the right was arrested and the aircraft started to turn to the left. It is inferred, again from the normal acceleration and the pitch attitude data, that the aircraft regained the paved runway about 18 seconds after touch-down.

It can be seen from Figure 1 that, at about 5 seconds after touch-down, the difference in torque between the left and right engines was reversed (left torque greater than right torque). This difference was of the order of 4% and lasted for about 9 seconds. This is consistent with the crew attempting to control the yawing motion with differential propeller settings. Also, it can be seen that the pitch attitude remained at about 1° nose up during this part of the landing run and that the elevators remained slightly in the nose up sense until the turn to the right was arrested.

A comparison of the pitch parameters during the incident and during the previous landing is shown in Figure 2. It can be seen that the pitch attitude is about 0° during the previous landing and this was also the case for the other previous recorded landings.

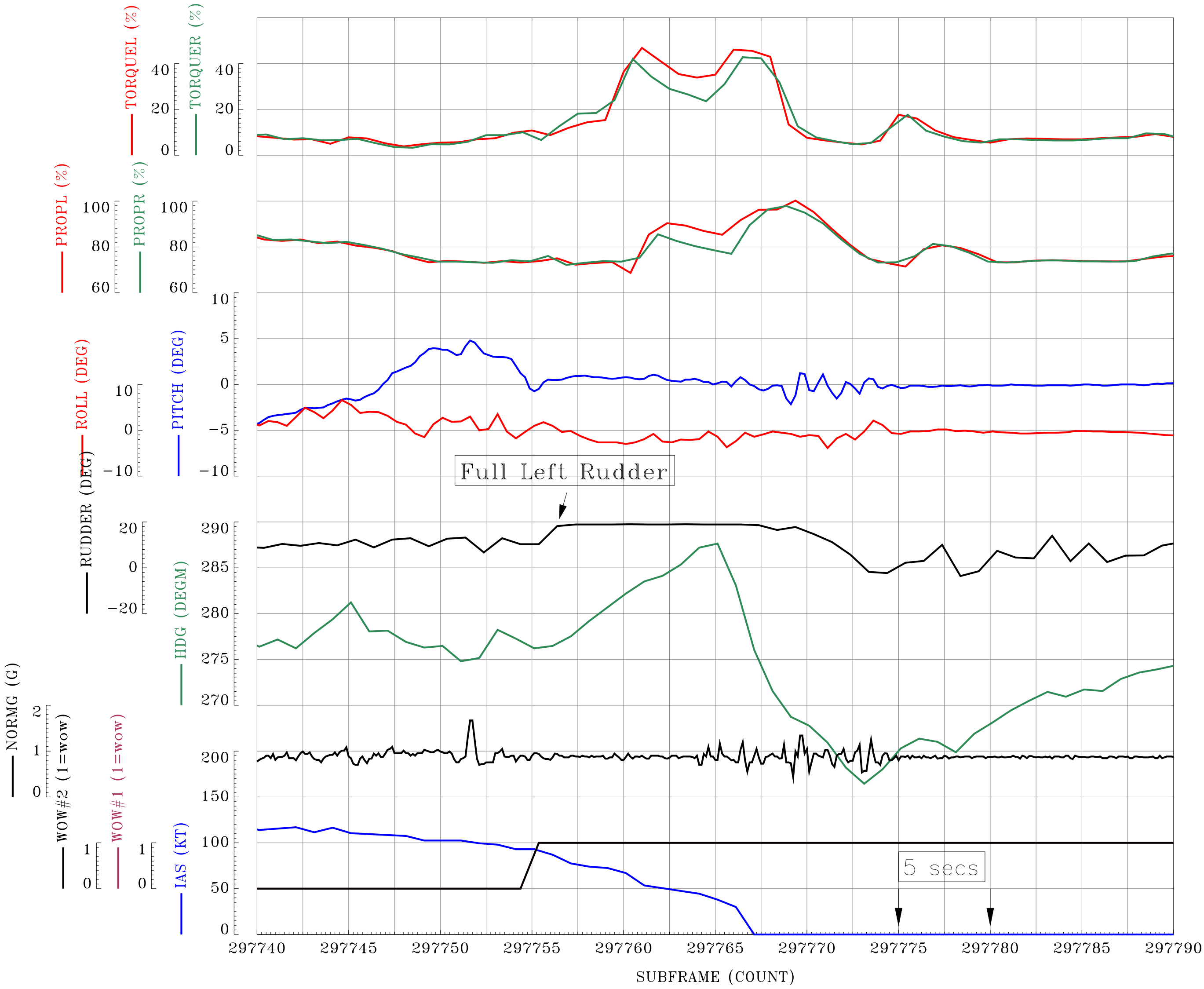

Figure 1

Salient Flight Data Parameters
Serious Incident to Dornier 328, G-BWIR, at London City Airport on 20 February 2005

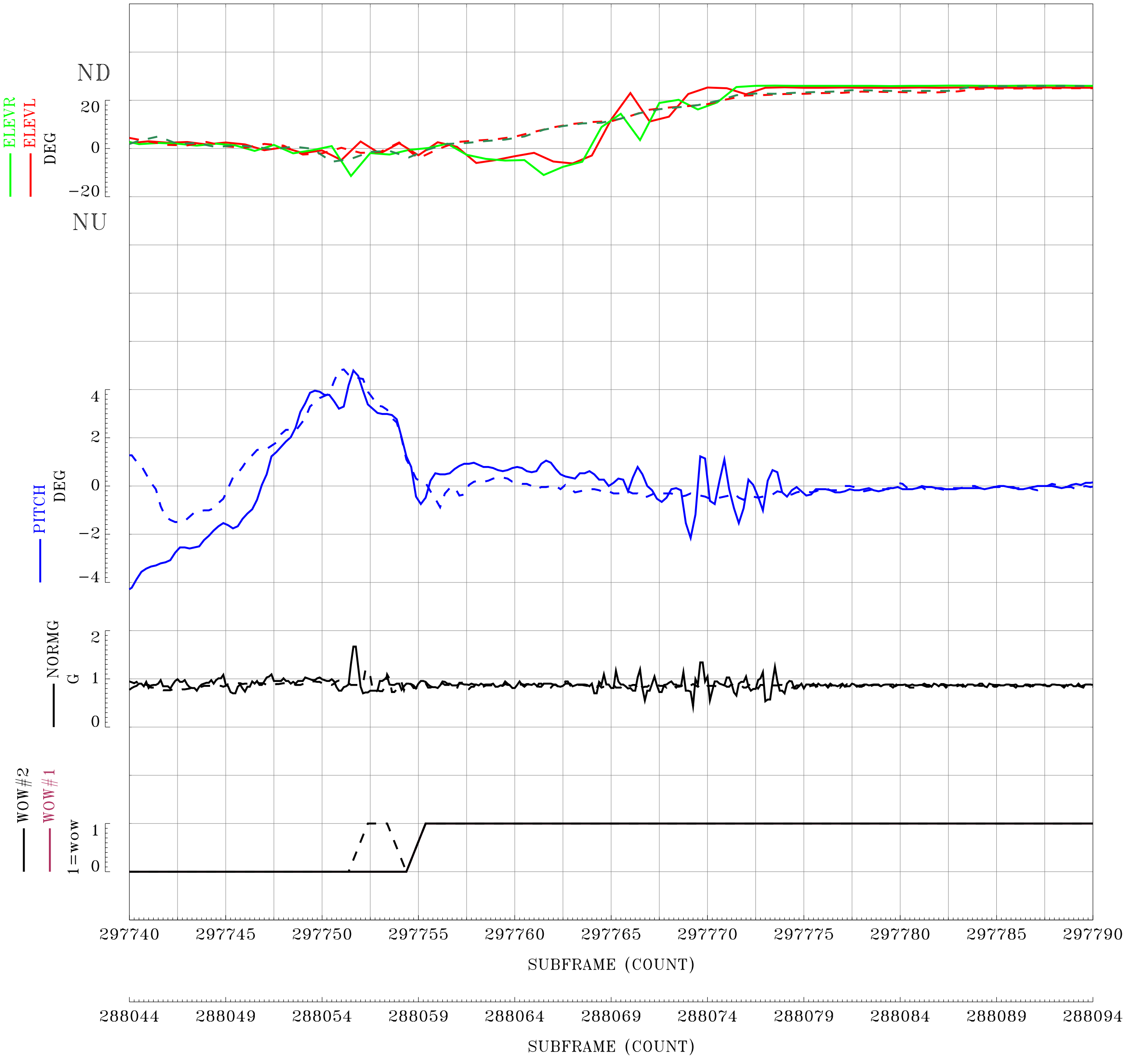

Figure 2

Comparison of Accident Pitch Parameters (solid) with Previous Landing (dotted)
Accident to Dornier 328, G-BWIR, at London City Airport on 20 February 2005

Systems description

On the ground, the Dornier 328 may be steered by a combination of differential braking, aerodynamic yaw control from the rudder and hydraulically actuated nosewheel steering.

Nose wheel steering commands are provided by a combination of pedal input, where full pedal deflections can provide ±10º of steering, and a hand control unit (tiller) located on the left-hand side console. Full deflection of this hand control unit can provide commands of ±60º to the nosewheel steering actuator but this requires the engine condition levers to be at or below the intermediate HIGH TAXI position. With the engine condition levers fully forward, the usual position immediately after landing, there should be no input to the steering actuator from the hand control unit.

The nosewheel steering system has a built-in monitoring function and steering is disabled when the landing gear is retracted after takeoff or if any of the components in the system fail. The system also provides status and failure messages for the crew on the EICAS system. At landing, nose wheel steering is enabled by a timing function 0.5 seconds after the nose leg weight-on-wheels (WOW) switch is closed. This delay of 0.5 seconds is reset each time the nose leg WOW switch becomes open, for instance during a bounce on touchdown.

In common with other turboprop types, the propellers may be operated on the ground in the Beta range, giving reverse thrust and enhanced retardation. Asymmetric application of Beta torque will produce a yawing moment. The effect of this was examined by the aircraft manufacturer during the original type certification tests, with full asymmetry (maximum Beta torque on one propeller and 'ground fine' pitch on the other) at 40 kt and 100 kt. In both tests the data shows that the test crew handled the asymmetry, with a brief yaw excursion of less than 10º, principally with prompt and effective input from the nosewheel steering system up to the 10º available on the pedals.

The primary flying controls of the Dornier 328 for pitch and yaw are simple mechanical systems with direct, unpowered linkages from the control columns to the elevators and from the pedals to the rudder (with assistance, at low speed, from a spring tab). For roll control, the control columns are linked directly to the ailerons and to hydraulically-powered roll spoiler panels outboard on the wing. One effect of the roll spoilers is, with large roll control inputs on the ground, to add a yaw effect in that direction.

Ground marks and tests

The marks from all three landing gears could be traced back to their initial departure from near the runway centreline. The marks showed a progressive departure from the runway heading which was not corrected until the aircraft had left the runway and there were no rubber deposits either to denote heavy differential braking or cycling of the anti-skid system. There were also no indications of nose wheel steering inputs to the left, which would have been expected with the full left pedal deflection shown on the FDR.

As a result of the lack of evidence of nose wheel steering on the runway and the FDR data showing a slight nose-up pitch attitude after touchdown, the AAIB and the operator conducted a series of tests on G-BWIR to examine the sensitivity and ranges of the WOW sensors on all three landing gear legs. This involved jacking the aircraft to unload the landing gear legs, while electronically monitoring the WOW sensors and measuring the pitch attitude with an accurate inclinometer.

The most significant result was that, with the main landing gear legs bearing their normal load, the nose leg WOW sensors became open at 0.6º nose-up. With the main landing gear legs progressively unloaded, the nose-up pitch attitude required to open the nose leg WOW sensors was reduced. The results of these tests fully supported the hypothesis that the lack of nosewheel steering effect during G-BWIR's runway excursion was due to the nose wheel steering system being disabled during this period because of the unloading of the noseleg, by aft control movement, to the extent that the WOW sensors did not detect that the nosewheel was in contact with the runway.

As part of the engineering investigation, the oleo strut from the nose leg assembly was removed and taken to an approved overhaul facility for test and examination. Before disassembly, the oleo strut was subjected to the functional testing normally performed as part of the post-maintenance acceptance test procedure. This showed it to perform within the specified values for a newly-overhauled unit and a strip examination showed no evidence of any unusual wear or other defect.

Company Standard Operational Procedures (SOPs)

The company Operations Manual Part B section 2.19.1 entitled 'Landing Technique' states

'When established on final the aircraft should be crabbed into wind as necessary to maintain the runway centreline. Crossing the threshold a transition to the wing down method should be made, touching down on the main wheel on the windward side, keeping the aircraft aligned with the runway centreline. The controls should be displaced to allow smooth contact with the runway as the speed decreases.'

When landing on a minimum length runway, strict adherence to the correct Vref speed and profile should be observed. Additionally, landing with minimum flare is recommended to make use of the available runway. Apply smooth constant brake pressure after touchdown to achieve the best performance. On slippery runways with the anti-skid functioning use full brake pedal after touchdown –DO NOT ATTEMPT TO MODULATE BRAKING ACTION THROUGH THE PEDALS.

Judicious use of reverse thrust will improve landing distance performance. Use reverse carefully on wet or slippery surface. Max thrust reverse should not be used below 60 kt to avoid ingestion. After the handling pilot has selected ground idle, the non-handling pilot should look for the beta lights and call '2 betas' once seen and '60 kt' at which point the handling pilot will call for 'condition levers minimum'.

Significant aileron inputs are required in a crosswind even with the aircraft on the ground, due to the relatively narrow wheel track of this aircraft. Into-wind aileron activates the roll spoilers on the upwind wing which will aggravate the aircraft's potential to weathercock. After touchdown the nosewheel is lowered and symmetric reverse thrust applied, using the rudder pedals to keep straight. At 60 kt, reducing the condition levers to the HIGH TAXI position activates the tiller (positioned on the commander's side only) which may then be used to steer the aircraft. Although the commander was relatively new in the left-hand seat, he had flown many landings into LCY from the right-hand seat. The company regards both runways at LCY as 'minimum length runways'.

Analysis

The investigation identified four means of directional control on the ground available to pilots on this aircraft; asymmetric thrust, differential braking, nose wheel steering and rudder and these are discussed in turn.

1. The investigation initially focussed on the asymmetric application of torque in the Beta range, there being slightly more reverse torque on the right-hand engine. However, analysis of the FDR data showed that the initial yaw to the right ***preceded*** this application and the manufacturer's certification tests had shown that this asymmetry could be countered by the nosewheel steering system. At about the time that the aircraft left the runway, the commander deliberately set opposite asymmetric power to assist with regaining directional control (more left reverse thrust than right) and this is reflected by the aircraft regaining runway heading. Therefore, whilst the initial reverse thrust asymmetry would have exacerbated the heading divergence, it should not by itself have led to loss of directional control.
2. Differential braking was reportedly used by the commander after the aircraft had departed from the runway and enabled directional control to be established with the aircraft on the grass. It would only be usual to use differential braking after having applied full rudder pedal deflection. At high speeds, differential braking would normally be used only when other directional control means had been exhausted as it can lead to steering overcontrol and can generate high lateral forces.
3. Data from the manufacturer's certification tests show that the initial asymmetric torque could be countered by an effective nosewheel steering system. Therefore a serviceable nose wheel steering system should have enabled directional control, even taking into account the weathercocking effect of the crosswind. That full rudder pedal deflection (and therefore an expected 10º of nose wheel steering) was applied without any consequent directional correction, suggested that the nose wheel steering system had not been activated. This was almost certainly as a result of the noseleg WOW switch not being closed. The results of the WOW sensor test support this conclusion and the recorded flight data suggests that the unusual aircraft nose-up elevator input led to the nose wheel steering not being available.
4. Although full left rudder pedal deflection was attained almost immediately after the aircraft began its right swing, it had no effect on the rate of change of the aircraft's heading for a further 7 seconds. Notwithstanding the ineffectiveness of the nose wheel steering, the lack of aerodynamic effect from the rudder was also surprising, particularly at initial application with the aircraft at relatively high speed. However, anecdotal evidence suggests that this is not uncommon with engines in reverse thrust, as the disrupted airflow across the rudder can significantly reduce its authority.

Although the manufacturer considers that the normal pilot action, after touchdown, would be to relax elevator control, thereby ensuring activation of the nose wheel steering, there is no guidance in the Dornier 328 operator's or manufacturer's literature concerning elevator handling after touchdown. The Bombardier DHC-8-400 uses a similar noseleg WOW switch to enable nose wheel steering activation and that aircraft's flight manual includes the following note in Section 4.4 entitled 'Landing Procedures', *'The nosewheel should be promptly brought into contact with the ground following mainwheel contact'.* Given the implications of the noseleg WOW switch not being closed, the AAIB recommends that similar guidance on post-touchdown elevator handling be promulgated to Dornier 328 operators.

Conclusion

This investigation concluded that, after touchdown, the aircraft veered to the right as a result of the weathercocking effect of the crosswind, exacerbated by a slight asymmetry of the reverse thrust which was initially applied. The failure to gain directional control, immediately, most likely occurred as a result of the non-availability of the nose wheel steering system. The nose-up elevator position during the landing rollout appears to have prevented the noseleg WOW switch being closed, which is a prerequisite for nose wheel steering activation. Directional control was only gained after the aircraft had departed the runway when differential braking and asymmetric reverse thrust were applied.

Safety Recommendation 2005-139

It is recommended that AvCraft, the Dornier 328 type certificate holder, produce guidance to all Dornier 328 operators regarding post-touchdown elevator handling and the implications of the noseleg weight-on-wheels switch not being activated.