INCIDENT

Aircraft Type and Registration:	Boeing 767-383, G-VKNI
No & Type of Engines:	2 Pratt & Whitney PW4060 turbofan engines
Year of Manufacture:	1989
Date & Time (UTC):	28 September 2006 at 1854 hrs
Location:	Royal Air Force Brize Norton, Oxfordshire
Type of Flight:	Public Transport
Persons on Board:	Crew - 12 Passengers - 136
Injuries:	Crew - None Passengers - None
Nature of Damage:	Abrasion damage to tailskid
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	42 years
Commander's Flying Experience:	8,700 hours (of which 2,300 were on type) Last 90 days - 210 hours Last 28 days - 70 hours
Information Source:	Aircraft Accident Report Form submitted by the commander, operator's reports, and flight data analysis by Boeing

Synopsis

Immediately after touchdown, the aircraft pitched nose-up and the tailskid came into contact with the runway, causing light abrasion damage. Recorded flight data showed that the pitch-up was probably caused by an 'up-elevator' control input by the handling pilot when the aircraft 'skipped' on landing. It may also have been aggravated by the simultaneous manual deployment of speed brakes by the non-handling pilot. The aircraft had touched down at less than the recommended speed, which resulted in an increased pitch attitude and therefore a reduced tail clearance margin. Additionally, a significant mass of baggage had been loaded in the rearmost hold, which the crew had not accounted for in their weight and balance calculations. Although centre of gravity limits were not exceeded, this served to make the aircraft more sensitive in pitch.

History of the flight

The aircraft was being flown under charter to the UK Ministry of Defence (MoD) and was landing at RAF Brize Norton when the incident occurred. The aircraft's crew had travelled by road from Gatwick Airport to RAF Brize Norton the previous day, reporting on the day of the incident at 1030 hrs. They were scheduled to operate a return flight to Zagreb, in the Republic of Croatia, and then to fly the aircraft empty to Gatwick.

Among the Acceptable Deferred Defects (ADDs) entered in the aircraft technical log was one concerning the automatic speed brake system (used to deploy the wing spoiler panels after landing). According to the log entry, the system was inoperative pending rectification. Although manual operation of the speed brakes was unaffected. The control lever on the flight deck was labelled "INOP". This was the only item of significance regarding the outbound flight to Zagreb.

The aircraft was subject to a longer than usual turn-round at Zagreb due to baggage handling problems. A Loading Instruction Report (LIR) was compiled and passed to the flight crew. The co-pilot used the LIR to complete a load sheet, which was then countersigned by the aircraft commander. The aircraft departed Zagreb at 1640 hrs with 136 passengers on board (maximum capacity 325), and with the co-pilot as the handling pilot.

The co-pilot later reported that, as the aircraft reached V_R during the takeoff run, it began to pitch up without any control column movement. The aircraft rotated to about eight degrees of pitch, after which control inputs were required to continue pitching to the target attitude. No excessive control inputs were required, and the commander was unaware that the co-pilot had experienced anything unusual with the rotation manoeuvre. The co-pilot reported that he raised the issue with the commander later in the climb but the commander did not pursue the matter. The commander reported that he did not recall the matter being raised.

During the co-pilot's approach and landing briefing the crew discussed the requirement for manual deployment of the speed brakes after landing. The weather for the approach was fine, with a reported visibility greater than 10 km and a surface wind from 200º(M) at 5 kt. The aircraft was vectored for an ILS approach to Runway 26, and the autopilot and autothrottle were disconnected at about 1,000 ft aal during the approach. At a late stage of the approach, the commander alerted the co-pilot to the fact that the airspeed was slightly low and the co-pilot applied engine power to correct the situation. The aircraft then deviated slightly above the glide slope, and the co-pilot made a control input to correct this. The resultant increased descent rate had been arrested by a height estimated to be 20 ft above the runway and, following the flare, an apparently normal main-gear touchdown was achieved.

The co-pilot selected reverse thrust at touchdown and the commander manually deployed the speed brakes. The co-pilot recalled that, as he relaxed the rearwards pressure on the control column in order to lower the nose gear to the runway, the aircraft unexpectedly pitched up. Both pilots pushed forwards on their control columns, and the co-pilot delayed further application of reverse thrust. A significant amount of forward control column movement was required to stop the pitch up and to return the aircraft to a normal attitude. Subsequent nose gear touchdown and the remainder of the landing roll were normal.

Once the aircraft was parked, a normal unloading sequence was begun before the crew intervened. This prevented an accurate assessment of the mass distribution in the aircraft's holds, for comparison against the LIR. An aircraft inspection revealed that a tail strike had occurred, but that damage was light and confined to the tailskid friction pad; there had been no compression of the tailskid. It was also later established that the automatic speed brake system had actually been rectified two days before the flight, and was thus serviceable. Although an entry to this effect had been made in the technical log on a previous sector record page, the ADD page itself had not been amended, nor had the "INOP" placard been removed from the control lever. The aircraft was subsequently flown empty by the same crew to London Gatwick without further incident.

Loading and performance information

The loading operation at Zagreb was undertaken by the operator's local handling agents, and military personnel assisted with manual tasks. There were certain ground handling aspects of such MoD charter flights that were unusual, so a company representative from the operator's Airport Services department travelled on the aircraft and oversaw the turn-round process.

As the operator kept no stock of baggage containers at Zagreb, baggage had first to be unloaded from the containers off the inbound flight before they could be loaded with baggage for the return flight. It was agreed with the flight crew that the same container positions would be used for the return as were used on the outbound flight. However, on this occasion a greater volume of baggage necessitated that 2,339 kg of loose bags be loaded into the bulk hold (hold five) at the rear of the aircraft. The load figures were passed to the company representative, who then completed the LIR and gave it to the flight crew. The LIR accurately reflected the load distribution, including the bags in the bulk hold.

When the co-pilot compiled the load sheet, he did not notice the bags recorded on the LIR as being in the bulk hold, so they were not reflected on the load sheet. Nor was the error noticed by the commander, who countersigned the load sheet. The aircraft takeoff mass as stated on the load sheet was 129,868 kg, and the Centre of Gravity (CG) was calculated at 26% Mean Aerodynamic Chord (MAC). This represents a lightly loaded aircraft at a slightly aft CG. Using this information the crew determined a stabiliser trim position of 2.0 units and takeoff speeds of: V_R 139 kt, V_2 145 kt. With the additional 2,339 kg in the bulk hold, the takeoff mass was actually 132,207 kg and the CG was further aft, at 30.5% MAC. The aft CG limit at the actual takeoff mass was at 33.3% MAC. The stabiliser trim setting for the actual takeoff mass and CG would have been approximately 1.3 units, and the takeoff speeds would have been increased by between 1 and 2 kt. G-VKNI was re-weighed on 23 May 2007, and no change of any significance was found to the mass or indices used by the crew at the time of the incident.

The landing data card, completed by the crew in-flight, showed a landing mass of 119,500 kg. The flaps 30 V_{ref} speed for this mass was 131 kt, which the crew obtained from the Flight Management Computer (FMC). The actual landing mass was approximately 121,839 kg. The V_{ref} speed for 121,800 kg (the FMC displayed masses to the nearest 100 kg) would have been 132 kt.

Recorded information

Boeing's Air Safety Investigation Department conducted an analysis of the Flight Data Recorder (FDR) data for both the takeoff and landing events. However, several parameters were not valid during the period of the takeoff and initial climb. These parameters included the EPR and speeds for both engines, both elevator positions, and the stabilizer position. The stabilizer position remained invalid throughout the flight, while the elevator and engine data returned to normal after the initial climb period. The nature of the data anomalies suggested a maintenance issue existed, which the aircraft operator has been made aware of. The airspeed, groundspeed and vane angle data confirmed that the atmospheric conditions were relatively calm during the landing event. A simplified presentation of the relevant fight data is at Figure 1.

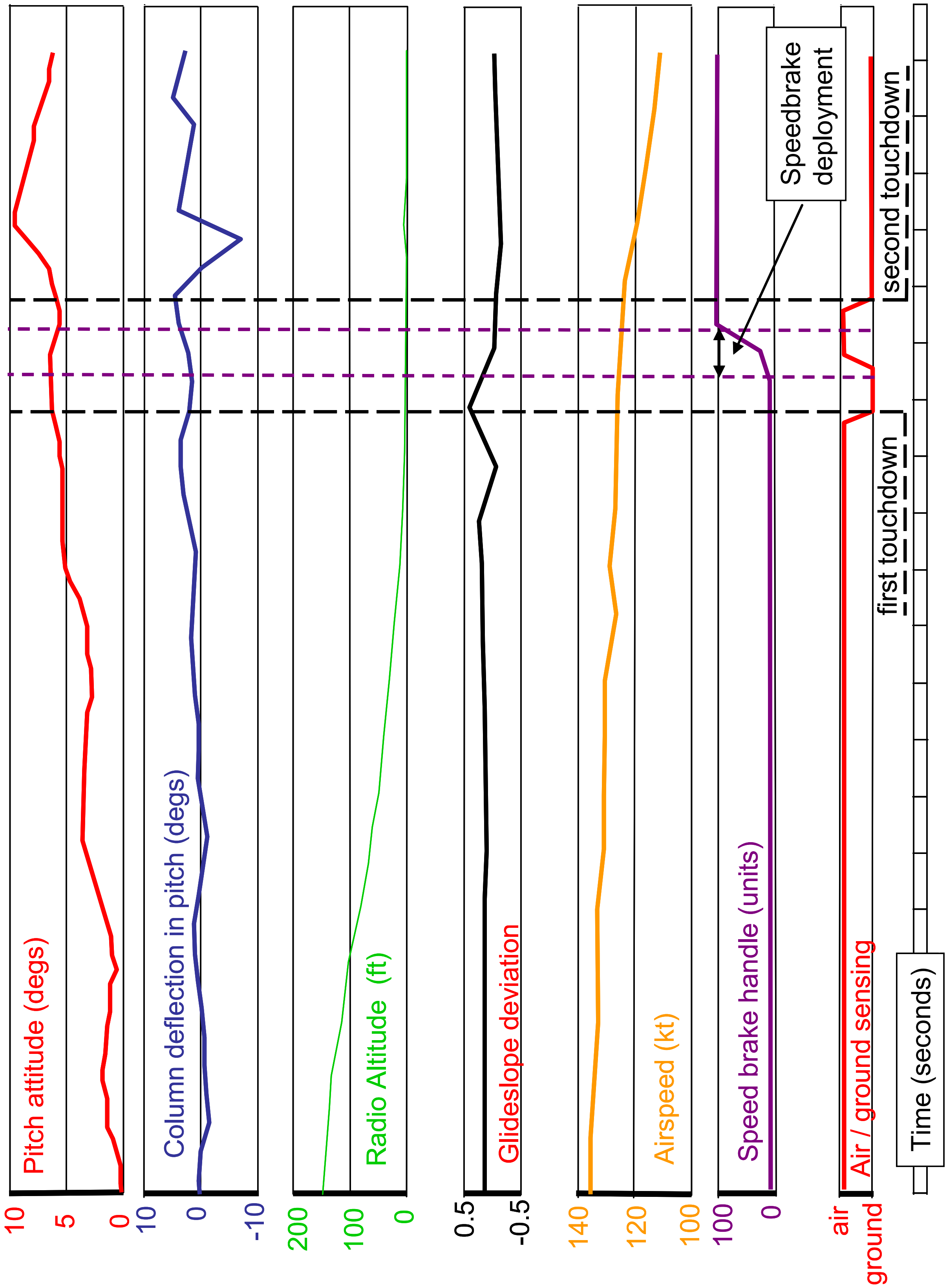

Figure 1

Relevant flight data (simplified)

Takeoff event

The recorded data showed an incremental nose-up control column input of 2.5º to 3º at 135 kt, which initiated aircraft rotation. This was compared with Boeing flight test data. It showed that 5º-6º of column movement was required at maximum takeoff thrust with the recommended stabilizer position set, at a similar mass and with the further-aft centre of gravity location of the incident aircraft. In order to validate the control column data, the column-elevator relationship implied by the recorded data for the subsequent landing was checked against values obtained in the simulator. This comparison showed that the column-elevator gearing was as expected.

Landing event

The data showed that the approach was stabilized as the aircraft descended through 700 ft radio altitude, and confirmed the crew's report that the aircraft began to deviate above the glideslope shortly before landing. At 40 ft radio altitude, a nose-up control input was made, to check the descent rate and subsequently flare the aircraft. A nose-down elevator input followed, which increased the descent rate. Initial touchdown occurred at 6.4º pitch attitude and at 126 kt (V_{ref}30-5). The descent rate was approximately 80 feet per minute, or 1.3 feet per second, with a load factor of 1.3g.

At touchdown, the main gear untilted (producing an 'on ground' signal) then tilted again, suggesting that the aircraft unloaded or 'skipped' before touching down again with a maximum recorded vertical acceleration of 1.55 g. An incremental 9º nose-up elevator command commenced with speed brake deployment, shortly before the main gear tilted again. There was a significant pitch-up after the second touchdown, which led to the pitch attitude increasing from the touchdown attitude of 6.4º to 9.5º in 1.5 seconds. The flight crew responded to this pitch-up with an incremental nose-down elevator input of 26º (from 16º nose up to 10º nose down).

Handling information

The Boeing Flight Crew Training Manual (FCTM) for the B767-300 gives guidance and advice to flight crews regarding landing techniques. It recommends that the aircraft touchdown at no less than V_{ref} speed, producing in this case a pitch attitude of about 5.5º. Touchdown at a speed of V_{ref}-5 increases the touchdown pitch attitude, effectively reducing the tailskid clearance margin. Tailskid contact will occur at a pitch attitude of 7.9º with the main gear oleos compressed, and at 9.6º with the oleos extended. Tailskid contact during landing is therefore possible between these two values. According to the FCTM, touchdown in this instance would theoretically have occurred at a pitch attitude of 6.9º.

Some nose-up pitching moment is normal with speed brake deployment on landing and is caused by the resulting movement of the centre of lift. However, Boeing considers that this moment is negligible (with both manual and automatic deployment), provided that correct airspeeds and pitch attitudes are used, and that additional factors do not contribute to pitch-up. However, the pitching moment increases if touchdown is made at speeds less than V_{ref} with associated higher pitch attitudes.

When automatic speed brake deployment is used, some spoiler panels are delayed by 1.25 seconds, which reduces the initial pitch-up moment. If speed brakes are deployed manually, and if the rate of deployment is rapid, there may be reduced or zero delay in spoiler panel deployment. However, reviews of landing tail strike events by Boeing have indicated that manual speed brake deployment was not a factor in any of the cases studied.

Discussion

Although the loading operation in Zagreb was protracted, it was completed in accordance with the operator's instructions and the LIR was accurate, as far as could be ascertained. The co-pilot's error in compiling the load sheet (and the likely reason why the commander did not detect it) probably occurred because of an expectation of how the aircraft would be loaded. The flight crew was asked about the loading configuration, and had indicated that the same container positions should be used for the return as were used on the outbound flight. Thus, with a relatively small passenger load, the crew would not have anticipated a need for the bulk hold to be loaded. As the bulk hold was not commonly used during routine operations, it may have been prudent for the company's Airport Services representative to bring its use to the flight crew's attention.

Takeoff speed errors (which resulted from the load sheet error) were small, and fell within the natural tolerances experienced during line operations. The effect of the error on aircraft trim was more significant, as it resulted in the stabilizer trim being mis-set for takeoff, although the CG limitations were not exceeded. The co-pilot's recollection was that the aircraft started rotation without control input, but data analysis confirmed that a control input had been made which was sufficient, given the loading configuration and mis-set stabilizer trim, to initiate rotation, albeit at some 5 kt below V_R. Additionally, the more aft CG would have resulted in lighter than normal control forces to initiate rotation. The lack of valid recorded engine and stabilizer position data during the takeoff made it difficult to draw further conclusions.

There is a discrepancy in the crew's reports concerning whether the aircraft's behaviour during takeoff was discussed later in the flight. The principles of good Crew Resource Management require that other crew members be made aware of any unusual handling characteristic as soon as possible. If the matter had been raised, it would be expected that the loading paperwork would have been reviewed during the flight, which should have revealed the load sheet error. If, as the co-pilot reports, the commander chose not to investigate his comments, there should have been nothing to prevent the co-pilot from reviewing the paperwork independently.

As with the takeoff speeds, the landing V_{ref} speed error was small and should not have been significant during a normal landing. However, in this case it did serve to increase the pitch attitude, albeit by a small amount. If the aircraft had touched down at V_{ref} speed, the pitch attitude would have been about 5.5º. When the extra mass in the bulk hold is considered, the touchdown speed was actually V_{ref}-6. The reduced touchdown speed lead to an increased pitch attitude and thus a reduced tail skid clearance margin. The nose-up elevator command may have been a reaction to the lack of lift resulting from speed brake deployment, which would have been evident during the landing 'skip'. Alternatively, it may have been in anticipation of an expected input to prevent the nose-gear making too firm a contact with the runway; some aft control column pressure is normally required during landing as the aircraft 'de-rotates'.

As the pitch attitude increased after landing, the aircraft quickly entered the pitch band at which a tail strike was possible, almost reaching the upper limit at which a tail strike would occur even with the main gear oleos fully extended. It is probable that the nose-up elevator command, combined with the speed brake deployment and aft CG, produced the significant pitch-up after the second gear tilt, which resulted in tailskid contact.