ACCIDENT

Aircraft Type and Registration:	Boeing 767-324, G-OOBK
No & Type of Engines:	2 General Electric CO CF6-80C2B7F turbofan engines
Year of Manufacture:	1995
Date & Time (UTC):	3 October 2010 at 0536 hrs
Location:	Bristol Airport
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 12 Passengers - 258
Injuries:	Crew - None Passengers - None
Nature of Damage:	Significant structural damage to fuselage crown skins
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	49 years
Commander's Flying Experience:	14,433 hours (of which 1,355 were on type) Last 90 days - 225 hours Last 28 days - 92 hours
Information Source:	AAIB Field Investigation

Synopsis

The aircraft landed heavily on Runway 09 at Bristol Airport, having encountered rain, reduced visibility and turbulence during the approach. The de-rotation was rapid and damage occurred as a result of the force with which the nose landing gear met the runway. The investigation found that a high rate of hard landings on that runway had not been identified through flight data monitoring, and that training material produced by the manufacturer in response to previous, similar, events had not been presented to the flight crew. The cockpit voice recorder was not disabled after the accident and thus the recording was not available to investigators. A momentary longitudinal deceleration at touchdown was reported by the flight crew and recorded by the flight data recorder. Four safety recommendations were made.

History of flight

The flight crew were operating a three-day duty from their home base at Glasgow to Cancun and then Bristol. They reported at Glasgow at 0945 hrs on 1 October and flew to Cancun, arriving there at 2030 hrs (1530 hrs Cancun time). They took rest until 1745 hrs (1245 hrs Cancun time) on 2 October, when they reported to operate to Bristol. Each crew member stated that he rested quite well during the period in Cancun.

The flight crew examined the available weather forecasts for the trip. The forecast for their destination stated that at the time of their arrival the wind would be from 180° at 9 kt with visibility 10 km or more, scattered clouds at 2,000 ft aal, temporarily broken clouds at 700 ft aal, and no significant weather.

The flight crew decided to load 45,300 kg of fuel, the minimum required being 44,100 kg. This enabled them to consider an additional diversion aerodrome should they not land at Bristol and provided some holding fuel over the minimum required.

The aircraft was serviceable with one deferred defect relating to the co-pilot's yoke-mounted flight interphone switch, which did not function. To overcome this, the flight crew operated with their headsets displaced from one ear, to allow conversation across the flight deck, and the co-pilot used an alternative switch, on an audio selector panel, to select the interphone when he needed to use it.

Approaching the top of descent, the co-pilot carried out a briefing for the approach to Runway 09, referring to the operator's aerodrome-specific (category B aerodrome) briefing as he did so. He determined the runway in use from the available forecast, as the flight crew had been unable to obtain the actual weather at Bristol at this stage of the flight[1]. At the end of his brief, the commander emphasised points regarding the ILS glideslope on Runway 09[2] and its possible effects during the latter part of the approach, and the longitudinal profile of the runway. The flight crew planned to land with flap 30 and autobrake 4[3] because of the length of the runway.

Shortly after the top of descent, the flight crew obtained the ATIS which stated that Runway 09 was in use, the wind was from 100° at 10 kt, visibility 1,400 m in rain and mist, with RVR in excess of 1,500 m, and cloud scattered at 100 ft aal and broken at 400 ft aal.

Footnote

1 The aircraft was out of range of the Bristol ATIS transmission, and the available VOLMET (ground to air meteorological information broadcast) services did not carry weather information for Bristol; the aircraft was not equipped with ACARS.

2 The ILS glideslope is not usable below 200 ft aal.

3 Flap 30 is the maximum flap setting for landing; the maximum autobrake setting is Max Auto.

As the aircraft descended through FL300, the commander decided that, given the weather conditions at Bristol, he should carry out the landing himself, and took control. The flight crew were surprised at the poor weather reported at Bristol, as it was not consistent with the TAF presented to them at their briefing. An ATC report of "water patches" on the runway caused the second co-pilot to examine landing performance information for such conditions; he found the runway was sufficiently long for a landing to be attempted.

During the approach the commander commented that there was "a surprising amount of turbulence"; all three pilots wore their seat harnesses including shoulder straps, though they did not lock the shoulder straps' inertia reels. The commander configured the aircraft for landing earlier in the approach than usual, because of the challenging weather conditions. The aerodrome controller passed the latest weather conditions, including the surface wind which was from 120° at 12 kt, visibility 3,000 m in moderate rain, few clouds at 200 ft aal and broken clouds at 1,100 ft. The controller also reported that the runway surface was wet along its length. The co-pilot asked the controller to confirm that the water patches were no longer present, which she did.

The commander recalled that the FMC displayed a crosswind component of approximately 52 kt during the approach, with a considerable drift angle. The surface wind reports from ATC led the commander to expect the wind to change from a crosswind to a headwind during the approach, and he briefed that this might lead to a "balloon" or gain of energy. He asked the co-pilot to monitor the wind displayed on the FMC and report any substantial change.

At approximately 400 ft aal, the commander gained sight of the runway, although rain on the windscreen blurred his view. The windscreen wipers were selected ON. The co-pilot could not see the runway at this stage, as the aircraft's drift angle meant that the runway was obscured behind a windscreen pillar.

The commander disconnected the autopilot and autothrottle, and continued the approach. Two or three EGPWS 'glideslope' annunciations occurred below 200 ft; the pilots confirmed the PAPI indications were two white and two red. The pilots recalled that the automatic height callouts, made by the EGPWS computer, were in the sequence: 'FIFTY'; 'FORTY'; 'TWENTY'; 'TEN'. The 'THIRTY' callout was not made[4]. The commander recalled making a normal nose-up pitch input prior to touchdown, and that the touchdown was unusually hard. He commented that the profile of the runway meant that it was not possible to see the stop-end during the latter moments of the approach, and that the rain compromised his view.

Concerned that the hard touchdown had caused the aircraft to bounce, the commander recalled endeavouring to maintain a constant pitch attitude for a subsequent touchdown. However, both the commander and co-pilot reported that they were thrown forward during the touchdown, and that this resulted in the commander inadvertently moving the control column forward, to a nose down position. The aircraft then rapidly de-rotated before the nose gear contacted the runway.

The landing roll was completed uneventfully, and the aircraft was taxied to the apron and parked. The flight crew and cabin crew discussed the hard landing, the commander reported a suspected hard landing to the company's engineers, and an entry was made in the Tech Log.

Footnote

4 Previous experience suggested that the call was absent because the rate of change of radio altitude was greater than the relevant threshold for this callout to be made.

Definition of hard landing

The Aircraft Maintenance Manual (AMM) Chapter 05-51-01 states that a structural examination is required if the aircraft has experienced a hard landing. A hard landing is considered to have occurred if the pilot considers a hard landing has occurred or when an aircraft lands on its main landing gear and the peak recorded vertical acceleration exceeds 1.8 g, if recorded with at least eight samples per second However, for a hard nose landing, the peak recorded vertical acceleration can be significantly less than 1.8 g.

Examination of the aircraft

Phase one hard landing inspections were carried out by the operator in accordance with AMM 05-51-01. The most significant damage was to the crown skins between frames STA 610 and STA 632 and stringers 14 L and 14 R. See Figure 4.

Flight crew

All three pilots were rated on both Boeing 757 and 767 aircraft, although the operator's schedule meant that they flew the 767 less frequently than the 757. Their roster patterns meant they only operated to Bristol Airport approximately twice a year, and as the prevailing wind at Bristol favoured Runway 27, none of them had regular or recent experience of landings on Runway 09.

Meteorology

The Met Office supplied an aftercast of the weather conditions at Bristol at the time of the accident:

'In summary, the weather conditions at Bristol International Airport at 0541 UTC on 3rd October 2010 were characterised by periods of moderate (and sometimes) heavy rain, broken or overcast cloud cover and a moderate south easterly surface wind.

In greater detail, the radar and satellite information suggests some convective cells within the cloud structure. This would imply vertical motion of air and, in association with moderate or heavy rain, some downward motion of air. This is likely to have caused some turbulence on the approach into Bristol.'

The Met Office commented that '*relatively rapid*' changes of wind direction and speed with height suggested a potential for significant wind-shear induced turbulence and that:

'conditions were suitable (or very close to) for significant wind shear.'

Between the time of the flight crew's briefing at Cancun and their arrival at Bristol, the Bristol TAF was amended and more up-to-date forecasts were produced, indicating increasingly inclement conditions. These forecasts were not available to the flight crew by their normal means.

Final approach speed

The operator's operations manual stated:

'If the autothrottle is disengaged, or is planned to be disengaged prior to landing, the approach speed correction ("wind correction") is to add one half of the reported steady headwind component plus the full gust increment above the steady wind, to the reference speed.'

In light of the conditions at Bristol, the commander elected to use a final approach speed of 139 kt; the V_{REF} was 133 kt.

Landing technique

The operator's flight crew training manual for the Boeing 767 stated:

'When the threshold passes under the airplane nose and out of sight, shift the visual sighting point to the far end of the runway. Shifting the visual sighting point assists in controlling the pitch attitude during the flare. Maintaining a constant airspeed and descent rate assists in determining the flare point. Initiate the flare when the main gear is approximately 20 feet above the runway by increasing pitch attitude approximately 2° - 3°. This slows the rate of descent.

After the flare is initiated, smoothly retard the thrust levers to idle, and make small pitch attitude adjustments to maintain the desired descent rate to the runway. Ideally, main gear touchdown should occur simultaneously with thrust levers reaching idle. A smooth thrust reduction to idle also assists in controlling the natural nose-down pitch change associated with thrust reduction. Hold sufficient back pressure on the control column to keep the pitch attitude constant. A touchdown attitude as depicted in the figure below is normal with an airspeed of approximately VREF plus any gust correction.

Typically, the pitch attitude increases slightly during the actual landing, but avoid over-rotating. Do not increase the pitch attitude after touchdown; this could lead to a tail strike.

Shifting the visual sighting point down the runway assists in controlling the pitch attitude during the flare. A smooth thrust reduction to idle also assists in controlling the natural nose down pitch change *associated with thrust reduction. Hold sufficient back pressure on the control column to keep the pitch attitude constant.*

Avoid rapid control column movements during the flare. If the flare is too abrupt and thrust is excessive near touchdown, the airplane tends to float in ground effect. Do not allow the airplane to float; fly the airplane onto the runway. Do not extend the flare by increasing pitch attitude in an attempt to achieve a perfectly smooth touchdown. Do not attempt to hold the nose wheels off the runway.

After main gear touchdown, initiate the landing roll procedure. If the speedbrakes do not extend automatically move the speedbrake lever to the UP position without delay. Fly the nose wheels smoothly onto the runway without delay. Control column movement forward of neutral should not be required. Do not attempt to hold the nose wheels off the runway. Holding the nose up after touchdown for aerodynamic braking is not an effective braking technique and may result in high nose gear sink rates upon brake application.

To avoid possible airplane structural damage, do not make large nose down control column movements before the nose wheels are lowered to the runway.'

Regarding bounced landing recovery, it stated:

'If the airplane should bounce, hold or re-establish a normal landing attitude and add thrust as necessary to control the rate of descent. Thrust need not be added for a shallow bounce or skip.' [See Figure 1]

The manual did not make reference to locking of shoulder harness inertia reels. Examination of the flight deck showed that with inertia reels locked, it was not possible to reach some controls from one or both pilots' seats. Discussion with the flight crew and other pilots working for the operator suggested that the operator's pilots seldom locked their harnesses' inertia reels.

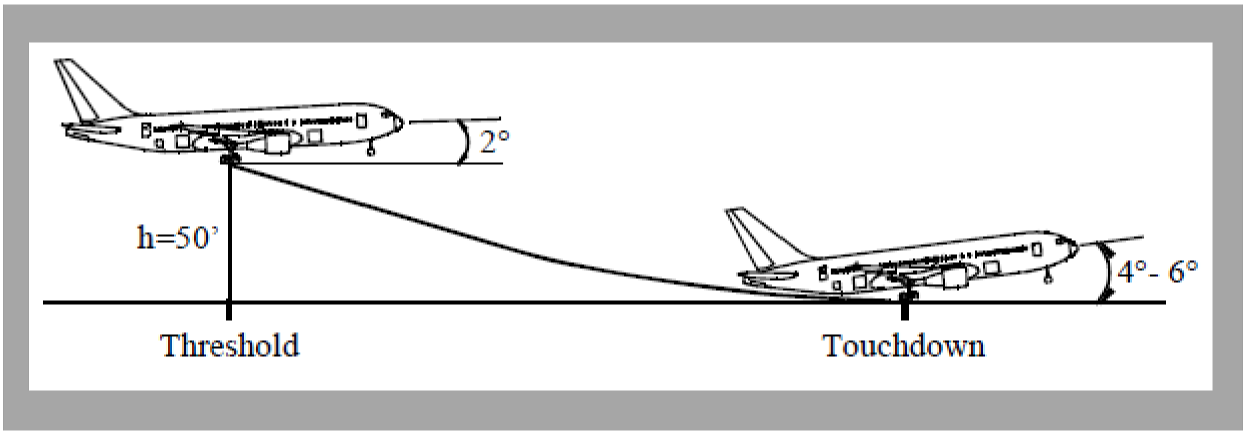

Figure 1

Graphic shown in Flight Crew Training Manual

Previous events and safety actions

In 1994, the US National Transportation Safety Board wrote to the US Federal Aviation Authority, making safety recommendations. The letter began:

> *'the [NTSB] has been involved in the investigation of three similar accidents involving B-767 airplanes…All three of the accidents occurred during landing when the nose wheel struck the runway after normal touchdown on the main landing gear. In each case, the airplane fuselage structure and nose wheel wells were damaged.'*

As a result of these accidents, Boeing introduced production modifications to strengthen the upper crown skins on aircraft from serial number 563 onwards. In addition a modified metering pin was introduced into the nose landing gear to help reduce the peak maximum stroke. Both these modifications had been incorporated onto G-OOBK.

The NTSB recommended that the FAA should:

> *'Modify initial and recurrent Boeing 757/767 pilot training programs… to include discussion of de-rotation accidents'.*

The flight crew of G-OOBK had undertaken training to fly the B767 with UK operators; this training had not included discussion of de-rotation accidents. The aircraft manufacturer had produced a training video on the topic of hard nose gear touchdowns, but neither the pilots nor the operator's management were aware of the video.

The aircraft manufacturer published a regular magazine to operators of its aircraft. The April 2002 edition included an article entitled *'Preventing hard nosegear touchdowns'*. The preface stated:

> *'In recent years, there has been an increase in the incidence of significant structural damage to commercial airplanes from hard nosegear touchdowns. In most case, the main gear touchdowns were relatively normal. The damage resulted from high nose-down pitch rates generated by full or nearly full forward control column application before nosegear touchdown. Flight crews need to be aware of the potential for significant structural damage from hard nosegear contact and to know which actions to take to prevent such incidents.'*

The flight crew of G-OOBK, and the safety management team at the operator, were not aware of this article.

Bristol Airport

Several factors placed additional demands on pilots of Boeing 767 aircraft landing on Runway 09 at Bristol.

The operator's airfield brief for Bristol stated:

> *'The UK Air Pilot states "the quality of ILS Glideslope guidance to R/W 09 does not permit the use of ILS glideslope below 200 ft AAL". This coincides with Category I minima.'*

The undulating nature of the terrain upon which the runway was built might cause an unusual visual perspective on final approach. The runway profile did not meet standards recommended in Civil Air Publication (CAP) 168 – *'Licensing of aerodromes'*, and the airport operator was taking action, from time to time when significant runway engineering was carried out, to improve the profile towards the recommended values.

Because of the terrain, the ILS glideslope on Runway 09 was unusable below 200 ft aal. Correct tracking of the

PAPI glideslope caused nuisance 'glideslope' warnings to be triggered in aircraft fitted with GPWS or EGPWS.

The terrain around the airport and its exposed position caused turbulence in strong winds.

These factors meant that the operator categorised Bristol as category B, and were highlighted in the operator's brief for the aerodrome.

The operator's flight data monitoring programme

The operator had an established programme to capture and analyse data from recorders on board its aircraft to monitor and improve safety.

One of the parameters tracked was normal g on touchdown, which is an indicator of hard landings. The operator analysed this data for each airport to which it operated, and used three different g thresholds to identify light, moderate, and severe hard landings. The operator had identified that Bristol Airport had an unusually high rate of hard landings, with evidence of seven hard landings in 2,855 arrivals there. At the AAIB's suggestion, the data was re-examined for each runway rather than each airport. This revealed that there had been six hard landings in 709 arrivals on Runway 09 at Bristol, and only one on Runway 27; therefore one in 118 landings on Runway 09 had been classified as 'hard'. Neither the operator, nor any regulatory body, had defined an acceptable maximum rate for hard landings on a given runway.

The specific analysis of hard landing data by runway, rather than by airport, was discussed with the CAA. There was evidence that the analysis of such data by airport rather than runway was commonplace amongst operators.

Examination of data from the commander's previous landings did not reveal any history of abnormal technique.

Human factors

A specialist in human factors in aviation was briefed and asked to comment on the event. He offered the opinion that the operator's flight crew training manual gave a clear description of the desirable pitch control technique during landing and that there was no evidence that the commander's technique differed from this.

The commander's ability to respond effectively to an unexpected longitudinal deceleration sufficient to cause upper body movement (and therefore unintended movement of the control column) would have been influenced by the visual cues available, which were degraded by the rain and the runway profile, and a natural concern that over-compensation might lead to a tail strike or float.

The specialist commented that:

> *'the response time required to compensate for an unexpected longitudinal deceleration large enough to cause upper body movement was likely to be at least a significant fraction of a second.'*

Flight recorders

The aircraft was equipped with a 25-hour duration Flight Data Recorder (FDR) and a 120-minute Cockpit Voice Recorder (CVR). FDR data was available for the entire accident flight. However, due to the time elapsed before the operator identified that the aircraft had been damaged, the entire audio record of the accident had been overwritten.

Salient parameters from the FDR included the normal and longitudinal acceleration, which were measured by a tri-axial accelerometer mounted near to the aircraft's centre of gravity, the control column position and pitch attitude. The pitch attitude was recorded once per second, control column twice per second, longitudinal acceleration four times per second and normal acceleration eight times per second. Figure 2 provides a plot of the final approach and landing.

The aircraft was established on the ILS for Runway 09 with the autothrottle and autopilot engaged. The target approach speed was set to 139 kt on the Mode Control Panel (MCP) and at 1,600 ft above airfield level (aal), the aircraft was fully configured for landing, with flap set at 30° and autobrake four selected. The aircraft was stabilised on the glide path at an average descent rate of about 680 ft/min (~11 ft/s), although there were fluctuations in airspeed, angle of attack and normal acceleration, indicative of turbulence.

As the aircraft descended through 200 ft aal, the autothrottle and autopilot were manually disconnected (Figure 2 point A). The airspeed was 141 kt at the time and the wind calculated by the FMC was from 138° at 25 kt. At approximately 120 ft aal, there was a slight increase in engine EPR and the airspeed also increased from 138 kt to 146 kt. At about the same time, the aircraft pitch attitude increased from 2.5° to just less than 4° nose up. This was followed by a momentary nose down input on the control column and a coincident reduction in engine EPR.

At a height of about 35 ft (just over three seconds before touchdown), the pitch attitude was just less than 1° nose up and airspeed was 142 kt. The descent rate was about 600 ft/min (10 ft/sec), with the wind, calculated by the FMC, from 116° at 20 kt. Aft control column was then applied and over the next three seconds the pitch attitude progressively increased to 3.5° nose up (Figure 2 point B). However, there was only a gradual reduction in the rate of descent before the aircraft touched down on the main landing gear, registering a peak normal load of 2.05g. The aircraft weight calculated by the FMC was 271,000 lb (~123,000 kg) and the airspeed was 141 kt.

Coincident with the touchdown of the main landing gear, a momentary longitudinal deceleration of -0.27g was recorded (Figure 2 point C). Less than 0.5 second later, the control column was recorded as having been moved rapidly to a nose down position (Figure 2 point D)[5]. The spoilers also started to deploy at this time. The aircraft then became 'light' on its main landing gear whilst also de-rotating in pitch at about three degrees per second. At a nose down pitch attitude of just less than 1°, a normal load of 2.05g was recorded as the nose gear contacted the runway. The aircraft then rapidly pitched up and down, from between 3° nose up to just less than 0.5° nose down (indicating bouncing of the nose gear), before the aircraft eventually settled on the landing gear.

Seven seconds after the initial touchdown, the thrust reversers were deployed, and the control column, which had remained in a forward nose down position since the initial touchdown, was progressively moved aft. Manual braking was then applied before the aircraft was taxied from the runway. There was no evidence from the FDR that the brakes had been applied during the initial touchdown phase.

Longitudinal deceleration at touchdown

To establish whether the momentary -0.27g longitudinal deceleration recorded during the accident flight

Footnote

[5] Due to the sample rate of the control column position, it was not possible to determine if the control column had been moved to a nose down position concurrent with the recording of a -0.27 g longitudinal deceleration.

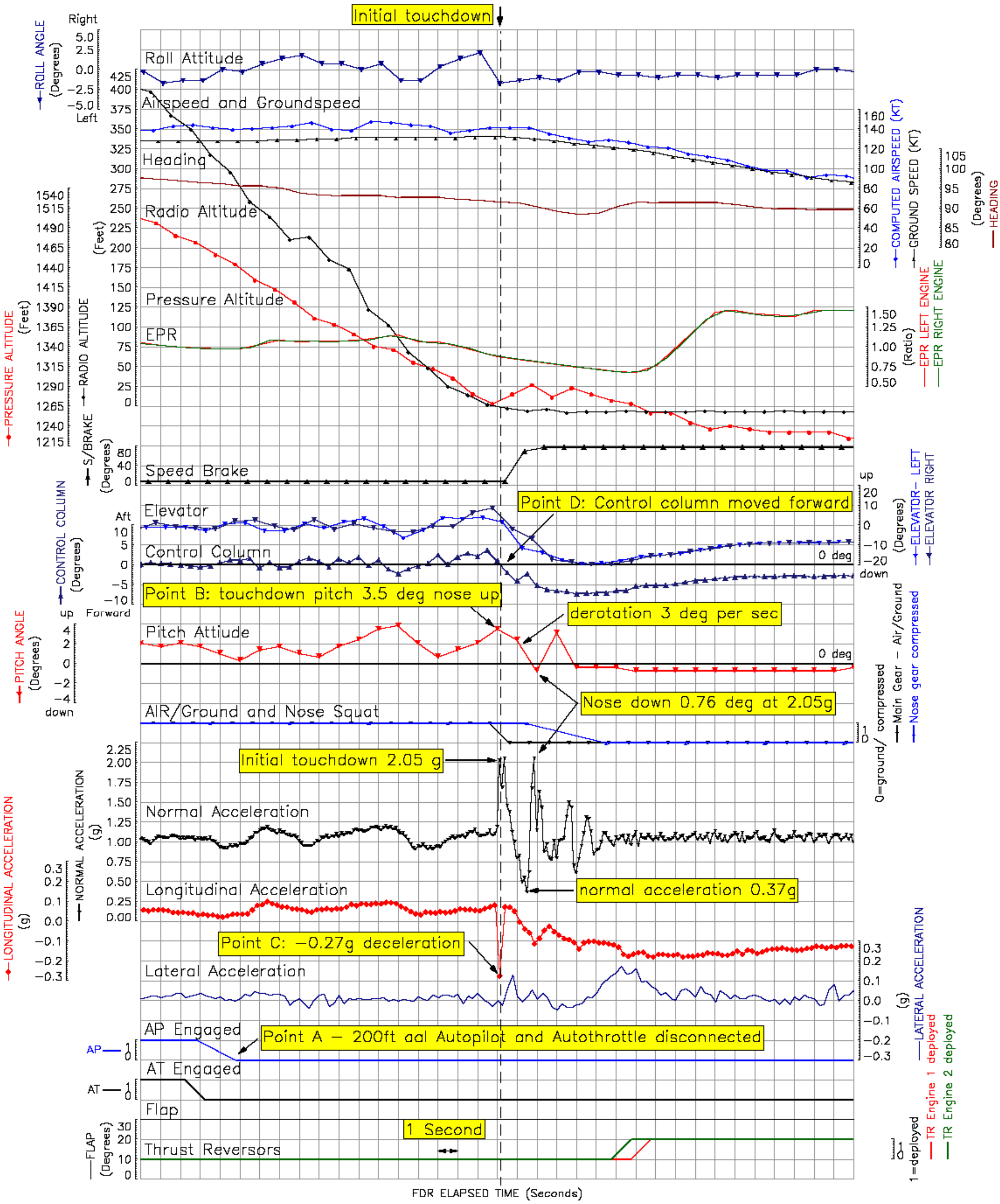

Figure 2

Final approach and landing at Bristol Airport Runway 09 touchdown was unique, the aircraft manufacturer was consulted and a review of the operator's FDM records conducted.

Aircraft manufacturer assessment

The aircraft manufacturer was provided with a copy of the FDR data for analysis. The aircraft manufacturer advised that the momentary longitudinal deceleration of -0.27g during the accident landing was both normal and not unique to the Boeing 767 aircraft.

At touchdown, the aircraft will experience a short duration longitudinal deceleration impulse as a function of tyre spin-up and subsequent landing gear assembly spring-back. During flight testing of the Boeing 767, longitudinal acceleration was recorded at fifty times per second from a sensor installed in the forward equipment bay, which is near to the cockpit. Each of the landings contained a longitudinal impulse coincident with main landing gear touchdown. Further, the manufacturer had observed similar records of a longitudinal impulse during analysis of lower sample rate FDR data. From a sample of five flight test landings, the maximum longitudinal deceleration impulse was approximately -0.27 g, which was recorded during a touchdown measuring a peak normal acceleration of about 2.1g. The lowest amplitude impulse was about 0.15 g, which occurred during a touchdown having a peak normal acceleration of approximately 1.3 g. The total duration of the impulse was typically 0.4 seconds, with 0.2 seconds being attributed to wheel spin-up and 0.2 seconds landing gear assembly spring-back. Figure 3 depicts the general shape of the longitudinal impulse based on the five flights provided to the AAIB. The manufacturer further advised:

'The amplitude and duration of the longitudinal deceleration impulse will be different for each landing due to a number of variables, including gross weight, sink rate, landing speed and staggered main gear touch down. Analysis has indicated though, that for a given gross weight and a wings level touchdown, the amplitude of the impulse will increase as a function of increasing sink rate at touchdown.

The amplitude of the longitudinal deceleration impulse may be slightly increased when landing on an up-sloping runway.

The amplitude of the longitudinal deceleration impulse will be reduced by approximately half when landing on a wet runway. The duration of the impulse will not be effected by runway friction.

The FDR recording rate of four samples per second is such that it is unlikely to capture the peak amplitude of the longitudinal deceleration impulse at touchdown. The probability of capturing within 10% of the peak is about 20%.'

The manufacturer stated that it had no record of pilots having inadvertently moved the control column to a nose down position as a consequence of being thrown forward following a heavy landing.'

The aircraft manufacturer considered that the longitudinal deceleration impulse at touchdown was of:

'insufficient magnitude and duration to cause a pilot to be thrown forward with sufficient force so that the control column would be inadvertently held in a nose down position.'

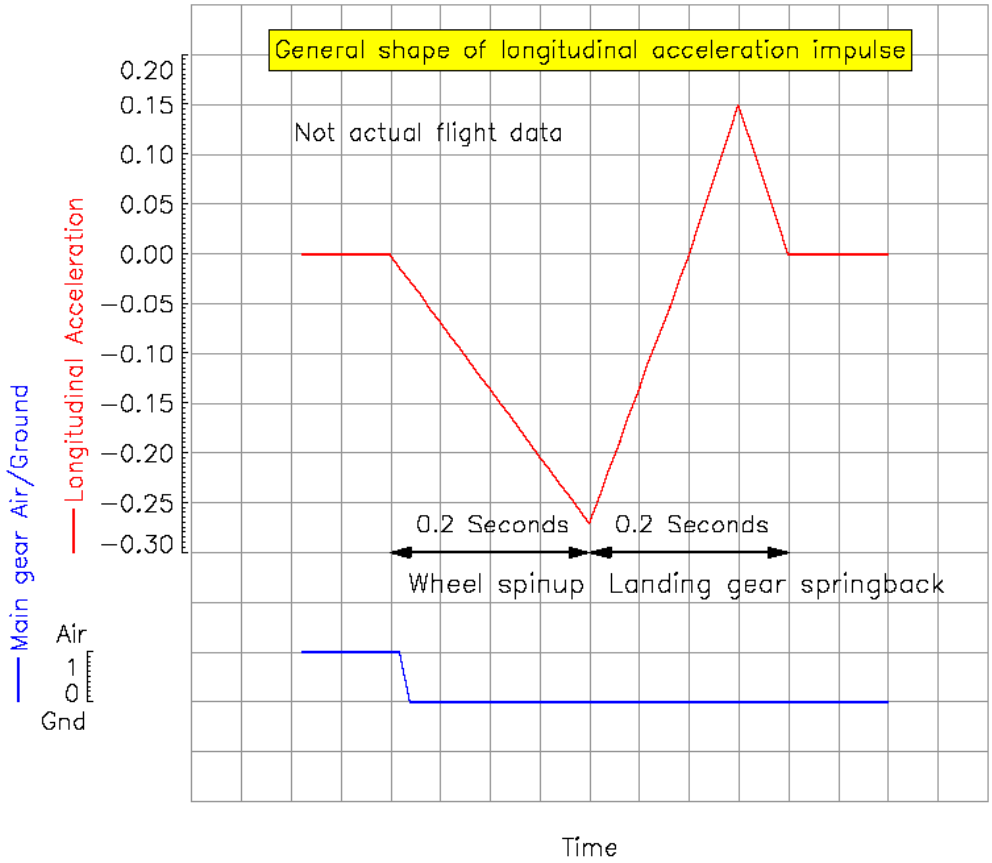

Figure 3

General shape of longitudinal acceleration impulse at touchdown

Assessment of additional Boeing 767 FDR data for the presence of longitudinal deceleration impulses at touchdown

A combination of FDR data from seven hard landings[6] and the 11 previous landings of G-OOBK were analysed. Six of the seven hard landings and four of the previous flights contained rapid, short duration changes in longitudinal acceleration at touchdown, indicative of the recording of an impulse. Excluding the accident flight, the maximum deceleration at touchdown was -0.26 g, which was recorded during a landing measuring a peak normal acceleration of 1.85g. From the small sample size, there was no apparent relationship between peak longitudinal deceleration at touchdown and runway gradient, although the three highest recorded values of longitudinal deceleration all occurred during landings at Bristol Airport (Figure 4). None of the hard landings, except that on the accident flight, exhibited rapid de-rotations after the initial touchdown.

Preservation of flight recordings (CVR)

Regulations require that the CVR starts to record prior to the aircraft being able to move under its own power and that it continues to record until the end of the flight, when the engines have been shut down. Some aircraft are equipped with automatic interlocks, with the intent of preventing unnecessary operation of the CVR after the engines have been shut down. However, many aircraft, including G-OOBK, operate the CVR

Footnote

[6] Peak normal acceleration at touchdown, ranged from 1.81g to 2.14 g.

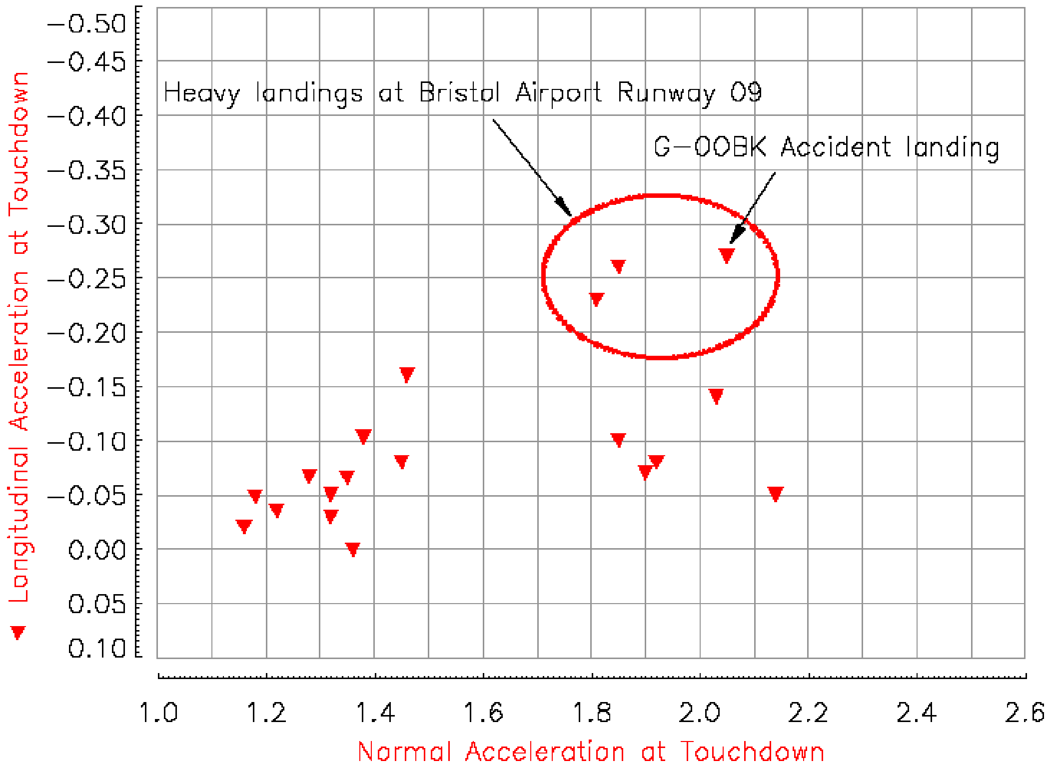

Figure 4

Peak normal and longitudinal acceleration at touchdown

whenever aircraft electrical power is on. Unlike the FDR, which is required to retain a minimum of 25 hours of data, the CVR retains only the last 30 or 120 minutes of audio, dependent upon type. It is therefore especially important that electrical power is quickly removed from a CVR if its information is to be preserved.

Commission Regulation (EC) 859/2008, referred to as EU-OPS, provides common technical requirements and administrative procedures applicable to commercial transportation by aeroplane. EU-OPS 1.160 '*Preservation, production and use of flight recorder recordings*', states:

> '*(2) Unless prior permission has been granted by the Authority, following an incident that is subject to mandatory reporting, the operator of an aeroplane on which a flight recorder is carried shall, to the extent possible, preserve the original recorded data pertaining to that incident, as retained by the recorder for a period of 60 days unless otherwise directed by the investigating authority.*'

EU-OPS 1.085 '*Crew Responsibilities*' states:

> *('f) The commander shall: (10) Not permit:*
>
> *(i) A flight data recorder to be disabled, switched off or erased during flight nor permit recorded data to be erased after flight in the event of an accident or an incident subject to mandatory reporting;*

> *(ii) A cockpit voice recorder to be disabled or switched off during flight unless he/she believes that the recorded data, which otherwise would be erased automatically, should be preserved for incident or accident investigation nor permit recorded data to be manually erased during or after flight in the event of an accident or an incident subject to mandatory reporting;[7]'*

Both EU-OPS 1.160 and EU-OPS 1.085 refer to the preservation of the FDR and CVR following an incident or accident that is subject to mandatory reporting. EU-OPS 1.420 *'Occurrence reporting'* defines:

> *'(1) Incident. An occurrence, other than an accident, associated with the operation of an aircraft which affects or could affect the safety of operation.*
>
> *(2) Serious Incident. An incident involving circumstances indicating that an accident nearly occurred.*
>
> *(3) Accident…..*
>
> *(ii) the aircraft sustains damage or structural failure which adversely affects the structural strength, performance or flight characteristics of the aircraft, and would normally require major repair or replacement of the affected component, except for engine failure or damage, when the damage is limited to the engine, its cowlings or accessories; or for damage limited to propellers, wing tips, antennas, tyres, brakes, fairings, small dents or puncture holes in the aircraft skin;…'*

The flight crew of the aircraft were aware that the landing had been heavier than normal and made an entry in the aircraft technical log *'Suspected hard landing. Check required'*. Unaware of the severity of the damage, the flight crew left the aircraft. During the following maintenance activities, the CVR continued to operate and by the time the damage was identified and the circuit breakers pulled, the entire CVR record of the accident had been overwritten.

The circumstances of this CVR overrun are not new to the AAIB. In 2009, a review of previous AAIB investigations identified that from 99 CVRs, 19 had been overwritten due to delays in removing electrical power, with seven CVRs being of 120 minute duration. Report EW/C2009/07/09, published in June 2010, concluded that operator's procedures concerning CVR preservation were ineffective, and the following safety recommendation was made to the UK CAA.

> **Safety Recommendation 2010-012**
>
> It is recommended that the Civil Aviation Authority review the relevant procedures and training for UK operators, to ensure the timely preservation of Cockpit Voice Recorder recordings of a reportable occurrence is achieved in accordance with the requirements of ICAO Annex 6 Part I, 11.6 and EU- OPS 1.160.

Footnote

7 There currently exists a discrepancy between ICAO Annex 6, Part 1 and EU-OPS 1.085. ICAO Annex 6, Part 1, which is the internationally-accepted Standard, states that flight recorders should not be switched off during flight, however, EU-OPS 1.085 states that a CVR may be disabled in flight under certain circumstances. This is due to be corrected, with the replacement of EU-OPS by EASA-OPS. In its draft form, EASA-OPS CAT.GEN.AH.105 (Responsibilities of the commander) states that flight recorders are not to be disabled or switched off in flight, and that they are to be deactivated immediately after the flight is completed.

In August 2010, the CAA responded, publishing Airworthiness Communication (AIRCOM) 2010/10. In addition to reminding UK operators of their responsibilities under EU-OPS 1.160, the AIRCOM made the following recommendations:

> *'4.1 Operators and continuing airworthiness management organisations should ensure that robust procedures are in place and prescribed in the relevant Operations Manuals and Expositions to ensure that CVR/FDR recordings that may assist in the investigation of an accident or incident are appropriately preserved. This should include raising awareness of Flight Crew and Maintenance staff to minimise the possibility of loss of any recorded data on both the CVR and FDR.*
>
> *4.2 When appropriate, the relevant circuit breakers should be pulled and collared/tagged and an entry made in the aircraft technical log to make clear to any airline personnel that an investigation is progressing. Furthermore, conformation from the investigating authority/operator is required to be obtained before systems are reactivated and power is restored.*
>
> *4.3 Operators who contract their maintenance or ground handling to a third party should ensure that the contracted organisation is made aware of all their relevant procedures.'*

Considering the relatively short recording duration of the CVR, it is often the commander, rather than an operator's safety or engineering department, who is best placed to ensure the timely preservation of the CVR and FDR. This has been reflected by an Irish registered operator, which has issued its flight crew with comprehensive guidance concerning the types of incident or accident that may require the preservation of the CVR and FDR, with instructions to isolate the relevant circuit breakers as necessary. To ensure that the preservation of the CVR and FDR is recorded and that an aircraft is not returned to service with inoperative recorders, the flight crew are required to make an entry in the technical log. In a recent AAIB investigation it was determined that that procedure proved effective.

At the time of this accident, the operator's CVR and FDR preservation procedures referred to the regulatory requirement within EU-OPS, but they provided no formal guidance or instructions of how to ensure compliance. As such, the operator failed to preserve the CVR record of the accident. Since the accident, the operator has taken a number of steps to address this: to assist in the prompt identification of CVR circuit breakers, identification tags have been fitted; a notice has been issued to flight crew, prior to amendment of its operations manual, providing similar guidance and instructions as those of the aforementioned Irish operator. In light of this remedial action, the AAIB considers that a further Safety Recommendation on this subject to this operator is unnecessary.

A recent review of UK-based operators' preservation procedures has identified that instructions and guidance is varied, or in some cases, not available at all. Discussion with the UK CAA has also highlighted that when auditing an operator, it is difficult for National Aviation Authorities (NAA) to determine if an operator's procedures are likely to be effective as there is no regulatory guidance material. Although the publication of AIRCOM 2010/10 has raised awareness of UK operators' responsibilities, there remains no official guidance, when formalising or reviewing their procedures with NAAs. Until such guidance becomes available, it remains likely that accident investigators will continue to be faced with the loss of CVR information due to ineffective procedures. In order that effective safety investigations can be conducted it is essential that accident investigators have access to CVR recordings. Therefore, the following Safety Recommendation is made:

Safety Recommendation 2012–013

It is recommended that the European Aviation Safety Agency publishes guidance information that assists operators and National Aviation Authorities in the production and auditing of procedures to prevent the loss of Cockpit Voice Recorder recordings in accordance with the requirements of EU-OPS 1.160 and EU-OPS 1.085.

Examination of the aircraft

Phase one hard landing inspections were carried out by the Operator in accordance with AMM 05-51-01. The most significant damage was to the crown skins between frames STA 610 and STA 632 and stringers 14 L and 14 R. See Figure 5.

All the stringers in this area were cracked, bent or deformed and the skin was creased and wrinkled. Five frame segments were twisted and deformed, and the frame segment at STA 632 was cracked between stringer 13L and 14L. The intercostal was buckled at STA 645, stringer 1R. See Figure 6.

There was light creasing in the skin above and below the nose jacking point, though it was not possible to establish if this damage had occurred during this

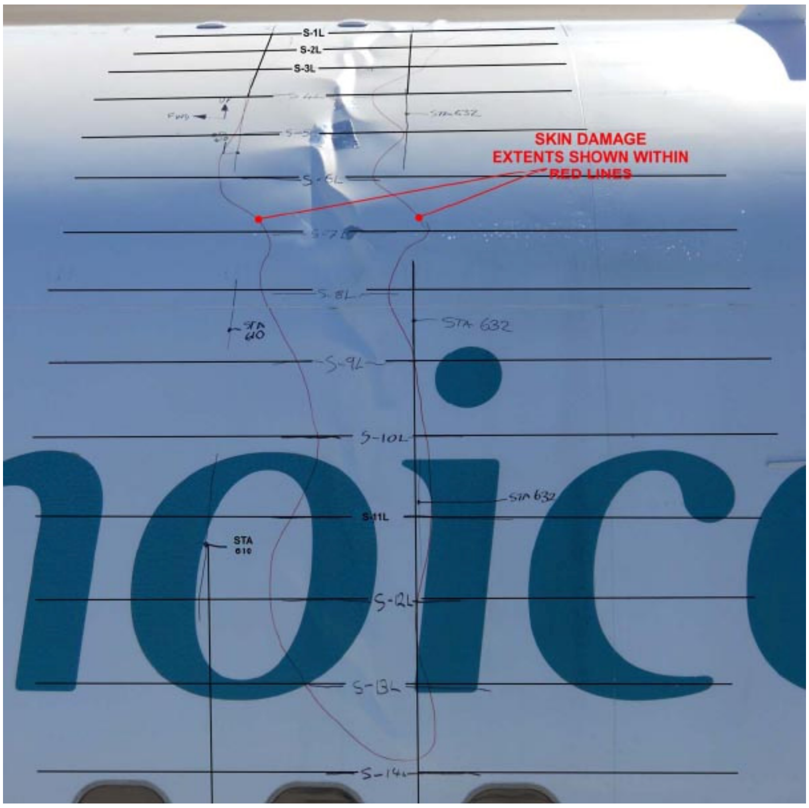

Figure 5

Buckling of skin between STA 610 and STA 632

Figure 6

Buckling of intercostal and cracking of frame

landing. The skin in the area of the nose landing gear was also found to be wrinkled between STA 276 and 303, stringer 28R to 30R, and stringer 25R-26R. See Figure 7. There was evidence of an oil leak from the lower seal on the nose oleo and the trunnion bushings showed signs of having been displaced.

The aircraft tyres exhibited normal wear and there was no physical evidence of heavy braking, or the wheel brakes having locked on landing. The operator advised that no significant faults other than the hard landing had been reported at the end of this flight.

After reviewing the flight data, the aircraft manufacturer determined that the damage to the aircraft was consistent with the aircraft either landing on the nose wheel or the nose wheel making contact with the runway following a rapid de-rotation.

Figure 7

Damage adjacent to nose jacking point

Previous damage and repair

On the 19 September 2000, when the aircraft was previously registered as S7-RGV and operated by another airline, it sustained similar damage to the upper crown skins. It was not possible to establish the circumstances of this accident. The repair was carried out by a team from Boeing. See Figure 8. The maintenance records revealed that since the operator had taken delivery of the aircraft in December 2004 and there had only been one other report of a hard landing that occurred on 16 March 2010.

The operator's actions following the accident

Both co-pilots continued their flying duties following the accident. The commander carried out a small number of flights in the Boeing 767 aircraft with training captains, in order to ensure his confidence in continuing to operate the aircraft; no abnormal techniques were apparent during these flights and the commander returned to his normal flying duties.

Safety actions taken by the operator included:

- revision of advice in the flight crew training manual relating to flare height and landing technique
- a recommendation that pilot flying should lock inertia reel shoulder straps during landing
- additional text in the aerodrome brief for Bristol airport stating that some automatic radio altitude call-outs may be omitted during approaches to Runway 09 and highlighting the runway's profile and increased risk of hard landings
- action to prevent loss of recorded data following a reportable occurrence, including providing tags to enable CVR and FDR circuit breakers to be identified more easily
- action to improve the company's efficiency in reporting accidents and incidents.

Figure 8

Previous damage to the crown skins

The operator's training management reviewed the training material previously produced by the manufacturer on the topic of rapid de-rotations, but considered it was somewhat out of date. Having also concluded that there was no evidence of a significant frequency of rapid de-rotation events in the company's operation, the training management decided not to issue the training material.

Analysis

The flight was unremarkable until the approach and landing at Bristol, where a number of factors made the pilots' task more challenging than usual.

Historical data was available to the operator, which indicated that the rate of hard landings involving Boeing767 aircraft landing on Runway 09 at Bristol was unusually high, but the operator's method of analysis (which was common in the industry) had not highlighted this. It is probable that other similar opportunities to identify unusual rates of events may similarly be lost, and therefore, the following Safety Recommendation is made:

Safety Recommendation 2012–014

It is recommended that the Civil Aviation Authority should advise operators of the benefits of analysing recorded flight data relating to landings not only by airport, but also by runway.

This accident might have been avoided if the unusually high rate of hard landings by Boeing 767 aircraft on Runway 09 had triggered safety action to reduce the rate or stop operations of the type onto that runway. No threshold value, at which action should be taken to reduce the rate of hard landings, had been established by the operator. Without a threshold value at which action is required, opportunities for safety improvement may be lost. Therefore, the following safety recommendation is made:

Safety Recommendation 2012–015

It is recommended that the Civil Aviation Authority should advise operators of the benefits of establishing, in conjunction with aircraft manufacturers, acceptable maximum rates within their flight data monitoring schemes for events such as hard landings, beyond which action should be taken to reduce the rate.

Despite the turbulence, the approach itself was stable and within normal parameters. The absence of a usable glideslope indication below 200 ft aal, the EGPWS 'glideslope' alerts, and the absence of an automatic height call-out at 30 ft aal were unhelpful. The profile of the runway deprived the commander of sight of the full length of the runway as the aircraft approached the flare, and probably contributed to the high rate of hard landings (the flight crew training manual emphasised the importance of shifting the visual sighting point to the end of the runway).

Touchdown on the main landing gear, at 2.05g, was classified by the aircraft manufacturer as a heavy landing. However the structural damage to the crown of the fuselage occurred as a result of the rapid de-rotation of the nose wheel onto the runway following the main wheel touchdown. There is no evidence to suggest that the repair following the previous occurrence contributed to the damage seen on the aircraft.

The sampling rate of the flight recorder meant that the longitudinal deceleration recorded (-0.27g) was probably not the peak value. However this value was the maximum recorded during flight testing using a sampling rate of 50 times per second, during a touchdown measuring a peak normal acceleration of about 2.1g. The aircraft manufacturer considered that the longitudinal deceleration impulse at touchdown was of insufficient magnitude and duration to cause a pilot to be thrown forward with sufficient force so that the control column would be inadvertently held in a nose down position.

The commander's stated action, in attempting to maintain a constant pitch attitude after this touchdown, was in accordance with the operator's guidance. His report, and those of the other flight crew members, of being thrown forward in their seats, offered a possible explanation for the nose-down pitch input which followed the main landing gear touchdown.

The flight crew could have locked the inertia reels of their shoulder harnesses, but did not. Had the shoulder harnesses been locked, it is possible that the degree to which they were thrown forward would have been reduced, and in the commander's case, any consequent movement of the control column would have been lessened.

There was a history of damage to Boeing 767 aircraft similar to that to G-OOBK following hard nose gear touchdowns, and the manufacturer had produced training and awareness material on the topic, but the operator was not aware of this material and it had not been made available to flight crew. The material was published outside the normal suite of operational information (it had not for example been included in the flight crew training manual), it was effectively uncontrolled, and no processes existed to ensure its continuing distribution throughout the remaining operational life of the aircraft type.

It is possible that this material regarding hard nose landing gear touchdowns is not the only material relevant to flight safety which has been lost from the 'corporate memory', and therefore, the following Safety Recommendation is made:

Safety Recommendation 2012–016

It is recommended that Boeing Commercial Airplanes review archived training and safety information, to ensure that relevant safety information is promulgated, and continues to be promulgated, to operators.

Conclusion

Damage to the fuselage occurred as a result of rapid de-rotation of the aircraft following a hard landing on the main landing gear. The runway profile, nuisance GPWS alerts and the meteorological conditions may have influenced the landing.