Aircraft Accident Report

Operator:	Sita Air Pvt. Ltd.
Aircraft Type and Model:	Dornier 228-202(K)
Registration:	9N-AHA
Location:	420 m south-east of the threshold of Runway 02 at Tribhuvan International Airport, Kathmandu, Nepal N 27° 40’ 51.8” E 085° 21’ 22.6’
Date and Time:	28 September 2012 at 0033 hrs All times in this report are UTC

Synopsis

On 28 September 2012 at 0032 hrs, a Dornier 228-202(K) aircraft, registration 9N-AHA, took off from Runway 20 at Tribhuvan International Airport, Nepal for a flight to Tensing/Hillary Airport, Nepal. It climbed approximately 100 ft before flying level during which time the speed decayed to stalling speed. The aircraft stalled, departed controlled flight and crashed 420 m South-East of the threshold of Runway 02 at 0033 hrs. The impact was not survivable.

The accident was notified to the International Civil Aviation Organization (ICAO), European Aviation Safety Agency (EASA), BFU Germany, RUAG Aerospace Services GmbH/RUAG Aviation, National Transportation Safety Board (NTSB), USA, Air Accidents Investigation Branch (AAIB), UK and Honeywell International Inc. on 28th September 2012 by Civil Aviation Authority of Nepal.

The Government of Nepal constituted an Aircraft Accident Investigation Commission to determine the cause and the circumstances of the accident. The Commission determined that there was more drag on the aircraft during level flight than thrust from the engines and the aircraft decelerated to stall speed. The Commission was unable to determine the reason for the lack of thrust. Fifteen Safety Recommendations are made including three interim safety recommendations for the advancement of aviation safety.

1 Factual Information

1.1 History of the flight

1.1.1 History of the flight

A Dornier 228 aircraft, registration 9N-AHA, was planned to operate a flight from Tribhuvan International Airport (TIA), Kathmandu, to Tensing/Hillary Airport, Lukla with 16 passengers and 3 crews. The Commander was the Pilot Flying (PF) which was in accordance with common practice for flight crews operating this route. The 0020Z METAR for TIA reported calm wind, 3,000 m visibility in mist, scattered cloud at 2,000 ft AAL, broken cloud at 10,000 ft AAL, a temperature of 19° C and a QNH of 1017 HPa. ATC broadcast a change in the QNH to 1018 HPa at 0029 hrs.

At 0028 hrs (0613 am), the Co-pilot asked ATC for taxi clearance and 9N-AHA taxied towards Intersection 2 for Runway 20. While taxiing towards the runway the flight crew carried out the before takeoff checklist during which the Commander confirmed that Flaps 1 was set and all four booster pumps were ON. There was no emergency brief or discussion about the reference speeds to be used during the takeoff. The flight crew changed frequency and contacted the tower controller who gave them clearance to enter Runway 20 from the intersection and wait for clearance to takeoff. The Commander asked for the line-up checks to be completed during which the Speed Lever was selected to HIGH.

After lining up, the Commander said "THERE IS A BIRD" and, three seconds later "I WILL TAKE FLAPS TWO" which was acknowledged by the co-pilot. The aircraft was cleared for departure and began its takeoff run at 0032 hrs. Two seconds after beginning the takeoff roll, the Commander said "WATCH OUT THE BIRD". The Co-pilot called "50 KNOTS[1]" as the aircraft approached 50 kt and the Commander replied "CHECK". Two seconds later, the co-pilot called "BIRD CLEAR SIR" as the aircraft accelerated through 58 kt. Approaching 70 kt, approximately 13 kt below V_1 and V_R[2], the first officer called "VEE ONE

[1] All speeds given in this section are in kt IAS (KIAS). See Section 1.11.1 for an explanation of how the speeds were obtained. All speeds and heights are approximate.

[2] V_1 (the takeoff decision speed) and V_R (the speed at which the aircraft should be rotated) were both 83 kt.

ROTATE". The aircraft began to rotate but did not lift off the ground and the nose was briefly lowered again. As the aircraft reached 86 kt, it lifted off the ground and the landing gear was raised immediately.

As the aircraft began to climb, it accelerated to 89 kt over approximately 2 seconds. It continued to climb to 100 ft above the runway over the next 11 seconds but, during this time, the speed decreased to 77 kt. The aircraft then flew level for 14 seconds during which time the following occurred: the speed decreased to 69 kt; the air traffic controller asked "ANY TECHNICAL?" to which the pilot replied "[uncertain]….DUE BIRD HIT"; it's heading changed slowly from 200 °M to approximately 173 °M; and the stall warning was triggered for three seconds as the aircraft decelerated through 71 kt.

Two seconds after the stall warning ended, it was triggered again for approximately six seconds with the airspeed at 69 kt. The aircraft began a gentle descent at 69 kt with the stall warning sounding and the rate of turn to the left increased rapidly. It departed controlled flight, most probably left wing low, and crashed into a small open area 420 m south-east of the end of Runway 20.

A runway inspection found the remains of a bird, identified as a "Black Kite", at a position 408 m from Intersection 2. No bird strike was reported in relation to any other departure.

1.1.2 Witness information

Witnesses in the ATC tower reported that the aircraft raised and then lowered its nose during the takeoff run. It left the ground near Intersection 5 and climbed straight ahead but the climb was not normal and the climb speed seemed to the witnesses to be very low.

A professional pilot was a passenger in a coach travelling across the airport towards an aircraft due to fly to Tensing/Hillary Airport and he observed 9N-AHA before, and during the first part of its takeoff run. When 9N-AHA was approximately 350 to 400 m into its takeoff run, he saw “an unsuccessful attempt to rotate the aircraft". The nose was raised from the ground quite suddenly and the tail almost hit the runway before the nose was lowered again.

This witness reported that his bag registered 15 kg when it was put on the scales at TIA at check-in. He stated that when the same bag containing the same contents was put on the scales at Tensing/Hillary Airport for the return flight the bag registered 11 kg. He also commented that there was no pre-flight emergency brief given to the passengers on either of his flights to or from Lukla.

A witness reported seeing the aircraft shortly after takeoff but he did not see the impact. He reported that both propellers were turning and that there were no flames from either of the engines.

A witness saw the aircraft pass over him in a left turn towards the crash site. The aircraft then became inverted with a very low nose attitude and hit the ground nose first. It toppled away from him and came to rest the right way up such that it pointed in the direction from which it had come.

1.1.3 CCTV recording from outside the domestic terminal

CCTV footage of the accident aircraft was available for a period of approximately 62 min before it taxied for departure. The front of the aircraft, including the forward baggage compartment, was hidden from view behind vehicles in the loading area. The rest of the aircraft, including the aft baggage compartment, was visible throughout this period although the quality of the image was poor.

Approximately four minutes before the aircraft began to taxi, a bus arrived at the rear of the aircraft and passengers transferred from the bus to the aircraft. One minute after the bus arrived, what appeared to be a baggage trolley was pulled to the rear of the aircraft. The baggage door was opened for 52 seconds and baggage appeared to be loaded into the baggage compartment. Once the baggage door was closed, it was not opened again before the aircraft began to taxi.

1.1.4 CCTV recording of the takeoff

A CCTV camera on an airport building recorded the flight from approximately 10 seconds before the aircraft left the ground until impact. Approximately 5 seconds before the aircraft left the ground, what appeared to be a flash appeared in the region of the right engine for one frame of video[3]. Following analysis, the flash was considered to represent a real event rather than being an artefact of the recording process (Figures 1.1-1 and 1.1-2).

Figure 1.1-1
CCTV image five seconds before the aircraft left the ground

[3] The video was recorded at 23.325 frames per second.

Figure 1.1-2
CCTV image five seconds before the aircraft left the ground –zoomed in

1.2 Injuries to persons

Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	3	16	–
Serious	–	–	–
Minor/None	–	–	–

1.3 Damage to the aircraft

The aircraft was destroyed on impact and large parts of the airframe were consumed by the post-impact fire.

1.4 Other damage

None.

1.5 Personnel information

1.5.1 Commander/ Pilot-in-Command

Age:	42 years	
Licence:	Airline Transport Pilot's Licence	
Aircraft Rating:	DO-228	
Licence Proficiency Check:	Valid to March 2013	
Instrument Rating:	Valid to January 2013	
Operator's Line Check:	Valid to February 2013	
Medical Certificate:	Valid to March 2013	
Flying Experience:	Total all types	8,308 hours
	On Type:	7,112 hours
	Last 90 days:	81 hours
	Last 30 days:	52 hours
	Last 24 hours:	0 hours
Previous rest period:	60 hours	

1.5.1.1 Background of Pilot -in -Command

The Commander had been flying Do-228 aircraft since May 2003, having joined the operator as a Co-pilot, and he became a Commander in June 2006. Previously, he had flown Beech 1900-C and Y-12 as a Co-pilot for other operators. He held an appropriate and current service medical category, which was renewed in March 2012. The Commander's last flying duty before the accident was on 25 September 2012 when he flew three flights to Tensing/Hillary Airport. On the day of the accident, he reported to the Operations Department at 0000 hrs (0545 am) and appeared to staff there to be fit and well.

1.5.2 Co-pilot

Age:	24 years	
Licence:	Commercial Pilot's Licence	
Aircraft Rating:	DO-228	
Licence Proficiency Check:	Valid to June 2013	
Instrument Rating:	Valid to May 2013	
Operator's Line Check:	Valid to February 2012	
Medical Certificate:	Valid to November 2012	
Flying Experience:	Total all types	772 hours
	On Type:	519 hours
	Last 90 days:	56 hours
	Last 30 days:	25 hours
	Last 24 hours:	0 hours
Previous rest period:	36 hours	

1.5.2.1 Background of Co-pilot

The Co-pilot joined the operator in December 2009. His last flight before the accident was on 26 September 2012. On the day of the accident, he reported to the Operations Department at 0020 hrs (0605 am) and appeared to staff there to be fit and well.

1.6 Aircraft information

1.6.1 General Information

Manufacturer:	Dornier GmbH
Type:	Do 228-202K (RUAG is the Current TC holder)
Aircraft Serial Number:	8123
Year of manufacture:	1987
Number and type of engines:	Two TPE 331-10T-511D turboprop engines
Total airframe hours:	15,248 hours
Certificate of Registration:	Valid with no time limitation.
Certificate of Airworthiness:	Valid until 1 January 2013
Maintenance Release Certificate:	Valid until 31 October 2012 or 15,288 hours

1.6.2 Description of the aircraft

The Dornier Do 228-202K is a twin-turboprop aircraft with a maximum takeoff weight (MTOW) of 6,200 kg and can seat up to 18 passengers and 3 crews (Figure 1.6-1). It is of conventional aluminium construction with conventional cable and push-rod flight controls which are mechanically actuated apart from the horizontal stabilizer which is electrically actuated. The Fowler flaps fitted to each wing are electrically actuated and have four positions: UP (0°), 1 (5°), 2 (20°), and DN (30°). A hydraulic system provides hydraulic power for landing gear extension and retraction, wheel braking and nosewheel steering.

Figure 1.6-1
Dornier 228 aircraft, registration 9N-AHA (Copyright JETPHOTOS.NET)

1.6.3 Description of the powerplant

The aircraft 9N-AHA was fitted with two TPE 331-10T-511D turboprop engines. The left engine and propeller were installed on the aircraft on 25 February 2012, and the right engine and propeller were installed on 30 May 2011. The TPE 331 is a single-shaft turboprop engine with a two-stage centrifugal compressor and a three-stage axial turbine (Figure 1.6-2). The single shaft drives a reduction gearbox which drives the accessories and the propeller. The engine develops 715 shp and is flat-rated which means that it will continue to maintain its maximum power up to a certain altitude and temperature. For a pressure altitude of 4,300 feet[4], 715 shp can be maintained up to an ambient temperature of 30°C.

The engine drives a four-bladed constant speed Hartzell HC-B4TN-5ML propeller with feathering and reversing capability. Oil pressure from the propeller governor is used to drive the blades towards a low pitch angle while blade mounted counterweights and a feathering spring act to move the blades towards the high pitch/feather position in the absence of governor oil pressure. The propeller incorporates a start lock mechanism that holds the blades at a low blade angle during engine start. The blades are of aluminum construction and propeller rotation is anti-clockwise as viewed from the rear. The blade angles for the different conditions are as follows (angle reference is at the 30-inch station):

Flight Idle:	15.0° ± 0.2°
Reverse Pitch:	-16.0° ± 0.5°
Start Lock:	-8.0° ± 0.2°
Feather:	76.0° ± 0.5°

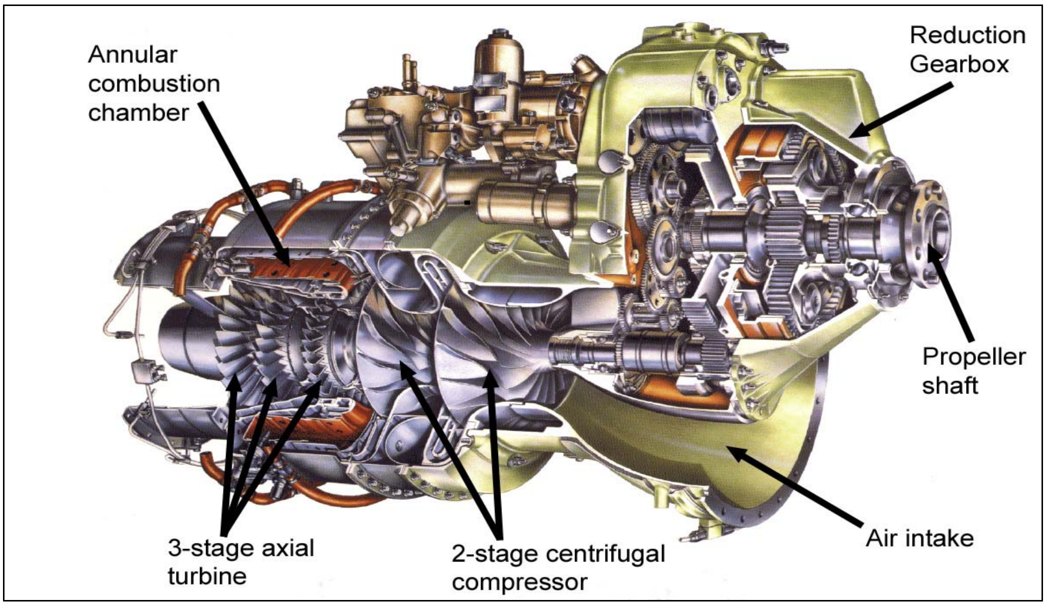

Figure 1.6-2
TPE 331 engine schematic

[4] Pressure altitude at the runway at the time of the accident – temperature was 19°C

The engine and propeller are controlled by the pilot via a power lever and a speed lever (sometimes referred to as the condition lever or rpm lever). The power lever increases the fuel flow to the engine when it is moved forward of the flight idle gate. This is accomplished by a mechanical link between the power lever and the Fuel Control Unit (FCU). When the fuel flow is increased the torque and power delivered to the propeller increase. The propeller governor maintains a set engine and propeller speed by automatically varying the propeller blade pitch angle when the power changes. When power is increased the propeller blade pitch angle increases until the rotational forces are in balance.

The speed lever controls the set engine speed (rpm). Moving the speed lever full forward selects the high position which sets the speed at 100% which is equivalent to 1,591 rpm of the propeller - this speed is used for takeoff and landing. The speed lever is normally pulled aft to select about 96% to 97% rpm for cruise, but there is no cruise gate. A 'low' position is used for engine start and ground taxi which selects about 68% to 72% rpm. If 'low' is selected in flight (power lever forward of flight idle) then the minimum rpm is 96% (assuming the idle fuel flow has been set correctly). The speed lever is also used to shut down the engine and feather the propeller. When the speed lever is lifted above the 'low' gate and pulled aft against increasing spring pressure, the fuel flow to the engine is shut off. If the speed lever is moved further aft and pushed inwards into the feather gate, the propeller will be commanded to feather.

On the ground the power lever can be retarded behind the flight idle gate and this changes the lever's operation from controlling fuel flow to directly controlling propeller blade angle – this mode is referred to as 'Beta Mode'. In this mode fuel flow is automatically adjusted by the FCU to maintain the set engine speed. In 'Beta Mode' when the power lever is moved aft of the ground idle gate, the propeller blade angle is reversed to generate reverse thrust. Selecting 'Beta Mode' in flight is possible but prohibited.

During a normal takeoff both the power lever and speed levers are advanced to full forward. This will result in engine rpm of 100% at maximum power. If after takeoff the power lever is retarded to flight idle the power will reduce but the engine rpm will remain at 100% (assuming the idle fuel flow has been set correctly). The propeller blade angle can be reduced sufficiently to maintain 100% rpm at flight idle down to airspeed of about 1 to 2 kt above stall speed – approximately 71 to 72 kt.

Because of the low blade pitch angle required to maintain 100% rpm at flight idle power, the propeller will produce drag instead of thrust at in-flight airspeed.

The TPE 331 engine incorporates a negative torque sensing system (NTS). When this system detects negative torque – ie the engine has failed and the propeller is driving the engine rather than the engine driving the propeller – the feather valve will operate, reducing oil pressure in the propeller, and allowing the blades to move towards the feather/high pitch position. This will reduce the drag on the inoperative engine without the pilot needing to take any action. NTS is not an auto-feathering system and in order to fully feather and stop the propeller the pilot needs to select the speed lever to the feather position. The single-engine performance figures in the Pilot's Operating Handbook (POH) assume that NTS is operating.

Because NTS works to reduce drag on an inoperative engine, an engine operating at flight idle produces more drag than an inoperative engine.

1.7 Meteorological information

1.7.1 METAR

The general weather situation was partly cloudy with calm wind, mist at the airport and 95% humidity.

The 0020Z METAR for TIA reported calm wind, 3,000 m visibility in mist, scattered cloud at 2,000 ft AAL, broken cloud at 10,000 ft AAL, a temperature of 19° C and sea level pressure, QNH, of 1017 HPa.

1.7.2 Satellite report

The infra red satellite images for 0031 hrs and 0131 hrs (Figures 1.7-1 and 1.7-2 respectively) showed no significant cloud over the Kathmandu area. The accident occurred during the hours of sunlight when the position of the sun was on a bearing of 094°T at an elevation above the horizon of 4.2°.

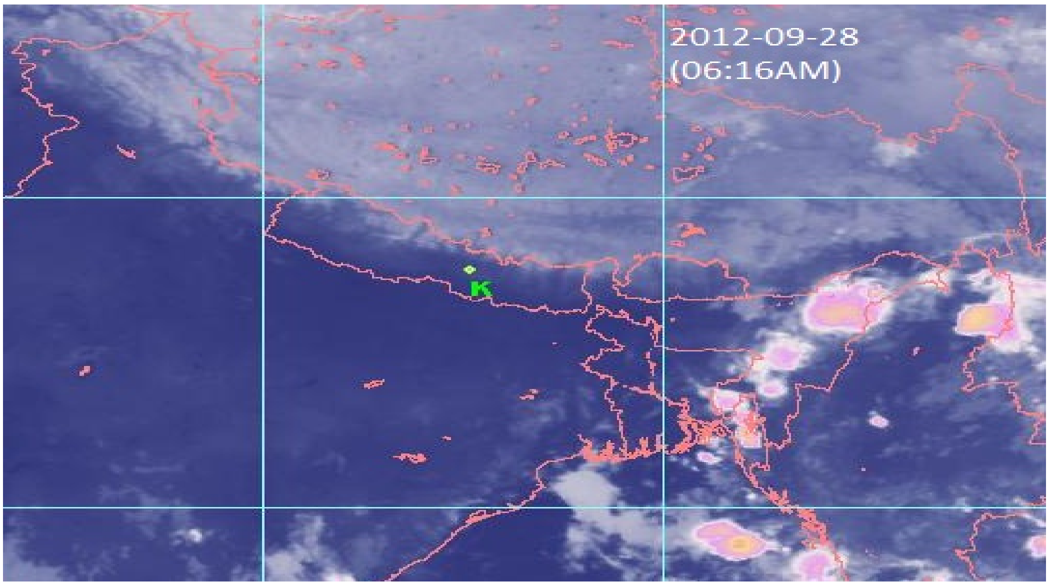

Figure 1.7-1
Infra red satellite image at 0031 hrs

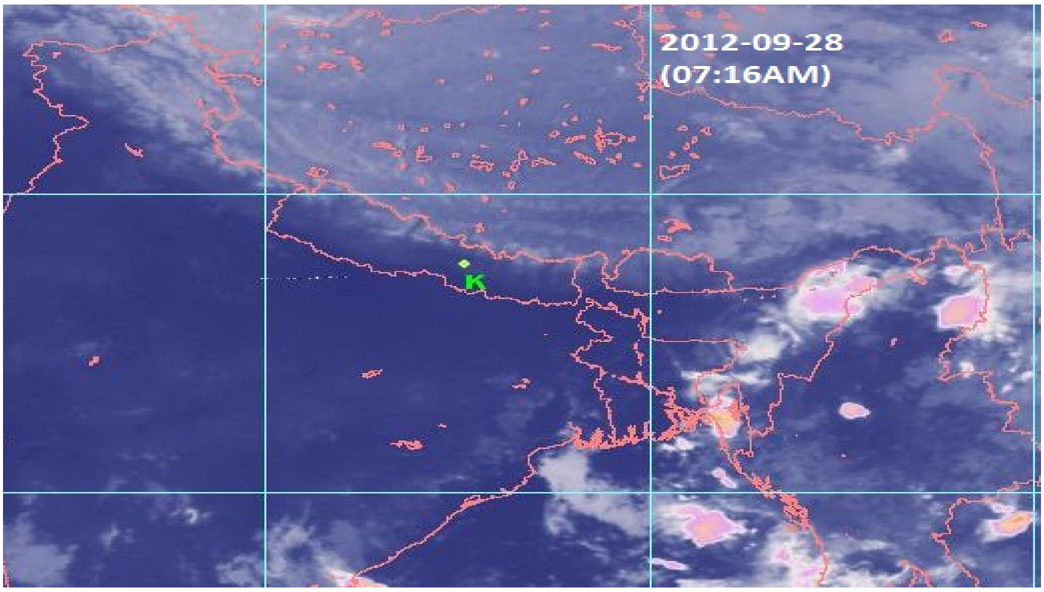

Figure 1.7-2
Infra red satellite image at 0131 hrs

1.8 Aids to navigation

Radar data captured the aircraft for 24 seconds of its flight and showed that, after liftoff, it drifted to the left of the runway before reaching the end of the runway.

1.9 Communications

Communications issues are discussed elsewhere in this report.

1.10 Aerodrome information

1.10.1 Tribhuvan International Airport (TIA)

TIA is the only International airport of Nepal serving both Domestic and International destinations. Airport elevation is 4390 ft. AMSL and runway length is 10,000 ft. 9N-AHA began its takeoff run from Intersection 2 of Runway 20 and the runway length available from that point was 6,929 ft.

1.10.2 Standard Instrument Departure (SID)

The aircraft was issued with an IGRIS 1A departure clearance from Runway 20. It was expected to climb straight ahead to cross the KTM VOR/DME at or above 4,700 ft amsl. At KTM it was expected to turn right remaining within the 4 DME arc. When crossing 084° radial from KTM, at or above 7,500 ft, the aircraft was expected to turn left to intercept the 105° radial outbound from KTM to IGRIS, which is at 15 nm on the 105° radial. The aircraft was expected to cross IGRIS at or above 10,500 ft climbing to its cruising altitude. Before takeoff, the commander instructed the co-pilot to cancel the IFR clearance when passing 5,000 ft amsl (assuming the aircraft would be in VMC) and request a left turn.

1.11 Flight recorders

The aircraft was fitted with a 25 hour FDR and a 30 minute CVR. Both recorders exhibited signs of being close to a fire but there were no signs of heat damage to the magnetic tapes of either flight recorder. The tape mechanism of the CVR was removed, installed in a donor unit and replayed successfully. The tape from the FDR was removed and replayed using a magnetic tape player.

1.11.1 Flight Data Recorder (FDR)

The FDR, Honeywell UFDR part number 980-4100-GMUN, recorded the basic five parameters: airspeed, altitude, magnetic heading, VHF keying and normal acceleration. The VHF keying parameter was used to align the FDR recordings with the CVR recordings.

The FDR installation uses sensors built in to the UFDR to sense the pressures on the captain's pitot/static lines. On initial inspection, the recorded values for airspeed appeared low. The UFDR sensors were calibrated and the airspeed sensor was found to be under reading. The recorded airspeed values given in this report are the corrected values. No sensor corrections were required for the recorded altitude values.

The heading and normal acceleration parameters used sensors external to the recorders that were destroyed during the post crash fire. The calibration of these values could not therefore be checked. The UFDR model collects data and creates one second frames that are then written to tape. A sudden power loss will result in the loss of the data that had been gathered but not yet written to tape.

The recorded data for the takeoff is shown in Figure 1.11-1 along with the calculated energy per unit mass for the aircraft. Energy is calculated by adding the aircraft's kinetic energy ($1/2.m.V^2$) to the aircraft's potential energy (m.g.h), but because the aircraft's weight was not accurately known, the energy per unit mass was calculated ($1/2.V^2 + g.h$).

The recorded pressure altitude dipped during the takeoff roll. A short duration dip in pressure altitude is normally associated with rotation just prior to lifting from the ground. In this case the dip was prolonged, indicating a long period with the aircraft pitched up but whilst still on the ground. This is corroborated by a reduction in noise recorded by the normal acceleration parameter that is likely to be associated with nose gear interaction with the runway. This is further

Corroborated by the "VEE ONE ROTATE" call just prior to these parameter changes. However, the rotate call and the observed effects of rotating the aircraft occurred before the aircraft reached the correct rotate speed.

As the aircraft lifted off, there was a step change in the rate of increase in total energy of the aircraft. After a further four seconds, the energy calculations indicate that there was more drag than thrust.

The altitude profile of the last samples does not correlate with the elevation of the accident site. Assuming between one and two seconds between the last data point and the impact, the last two recorded altitude points would need to be reducing to reflect a more likely altitude profile. Reflecting these deduced altitudes in the energy calculations yields an increasing loss of total energy at the end of the recording. Such errors in sensed altitude in the final samples may be linked to the aircraft departing from normal flight dynamics in the final seconds of flight.

The accident takeoff was compared to the previous takeoffs from the same airfield, one in the same direction and two in the opposite direction (Fig. 1.11-2). The loadsheet weights for these flights were the same as for the accident flight and it is clear that the acceleration for the initial part of the takeoff roll matches that of the previous flights up to approximately 70 kt, after which the speed profile becomes slower than the previous takeoffs. Despite this reduced speed, the behaviour of the altitude data and the vibration sensed by the normal accelerometer indicate that the aircraft rotated earlier in time and therefore at a lower speed than the previous flights.

Comparing the calculated energy per unit mass values indicates that the drag to thrust ratio of the accident flight was significantly higher compared to the previous takeoffs from the approximate point of rotation until lift-off. However, the rate of increase in energy was still on average greater than half that of the previous flights which would not have been the case if there had been a complete loss of thrust from one engine. Shortly after takeoff, however, the difference became more marked and the energy state of the aircraft started to reduce.

1.11.2 Cockpit Voice Recorder (CVR)

The CVR, part number 980-6005-076, recorded 30 minutes of audio on separate channels for each pilot and the Cockpit Area Microphone (CAM). Pertinent extracts from the CVR are given in Figure 1.11-1 and in Section 1.1.1 of this report.

Spectrum analysis is used to break down recorded audio into its component frequencies and establish how they vary over time. The prominent features are then compared to known characteristics of rotating mechanical parts to identify the most likely sources of vibration creating the sounds. The process is subject to limitations associated with the quality of the audio recording, not designed for vibration capture, and assumptions made about the viability of vibrations from all the various mechanical parts travelling through to the cockpit environment.

Spectrum analysis of the CVR CAM channel highlighted prominent features that have been associated with rotation rates, blade pass frequencies and gear teeth meshing frequencies of various propeller, engine or system parts during different phases of the accident flight. The key features are shown in Figure 1.11-3.

The takeoff sequence started with the appearance of strong propeller signatures at 100% rpm. After approximately 10 seconds, the sound energy across all frequencies increased and the propeller frequencies wavered slightly around the 100% mark. This is indicative of more power going through the engines. The propeller speed signatures gradually reduced in magnitude during the takeoff run as the effects of airspeed and other factors reduced the recorded propeller sound levels. Approximately 25 seconds after the increase in overall recorded sound energy a small ‘bang’ or ‘thud’ can be heard, and the signatures associated with the engine rotation rate of one of the engines dipped by approximately 4% before recovering. The bang occurred 44.0 seconds (± 0.2 seconds) before the end of the recording and occurred during the V_1, V_R call.

Approximately three seconds after the small bang or thud, the first signs of a mechanical signature reducing in frequency become apparent on the spectrogram.

Two potential sources for the reduction were identified: a propeller run down or the slowing down of the nose wheel after aircraft rotation. The propeller scenario

is not matched by a run down of the engine signatures and a detachment of the propeller from the engine is not supported by the physical evidence. The nose wheel noise scenario is supported by the coincidence of the onset of the reducing frequency signatures with the end of the rattling noise most likely associated with the nose wheel on the runway. Also, the rate of reduction in frequency of these signatures changed just before the gear retraction was completed, perhaps as the wind load on the wheel was removed.

There are two sets of signatures that have been associated with the engine shafts and the engine oil pumps. The signature of one of the engine shafts disappeared just prior to the completion of the gear retraction. The signature of one set of oil pumps also reduced in amplitude at this point, but appears to have dropped in frequency to 95% of the nominal frequency[5]. After a further 8 seconds, the oil pump signature reduced once more to 91% of the nominal frequency. At this point, a new signature appeared which equates to the engine shaft frequency at 91% nominal frequency; this remained for the rest of the flight.

At least one signature at a frequency associated with 100% engine rotation speeds, with only minor brief deviations, is detectable throughout the recording of the flight.

Prominent audio signatures associated with the hydraulic pump stopped after gear retraction, reflecting the fact that that the hydraulic pumps are automatically switched off in the air with the gear retracted.

Prominent audio signatures were present that were associated with two periods of stall warning at the end of the flight. No audio signatures were identified that were associated with flap or trim actuators.

[5] The nominal frequency is related to an engine speed of 1,591 rpm which is 100% rpm.

1.11.3 CCTV records in domestic terminal

CCTV camera recordings are discussed in Section 1.1.4 of the report. One of the recordings was used in conjunction with the FDR and CVR recordings and is discussed further here. The recording captured the aircraft from early in the takeoff roll until it disappeared in the haze after lift-off. The recording also captured the explosion of the aircraft on impact. The quality of the recording is poor. The recording included a time and date in the top left corner that did not reflect the time or date of the accident. Replay software indicated that the recording is 3 minutes and 4.6 seconds long but analysis of the clock transition times indicated a recording duration of 3 minutes and 0.1 seconds.

One frame of the CCTV recording clearly shows a flash, assessed to be a flash, in the proximity of the right engine, during the takeoff roll. A later frame shows an explosion in the distance. The time between these two events is 44 seconds or 45.2 seconds depending on whether the displayed clock or the number of recorded frames is used to calculate the interval. This period is consistent with the 44 seconds between the ‘bang’ captured by the CVR and the end of the CVR recording; the correlation is used to align the location of the aircraft at the point of the flash with the FDR data.

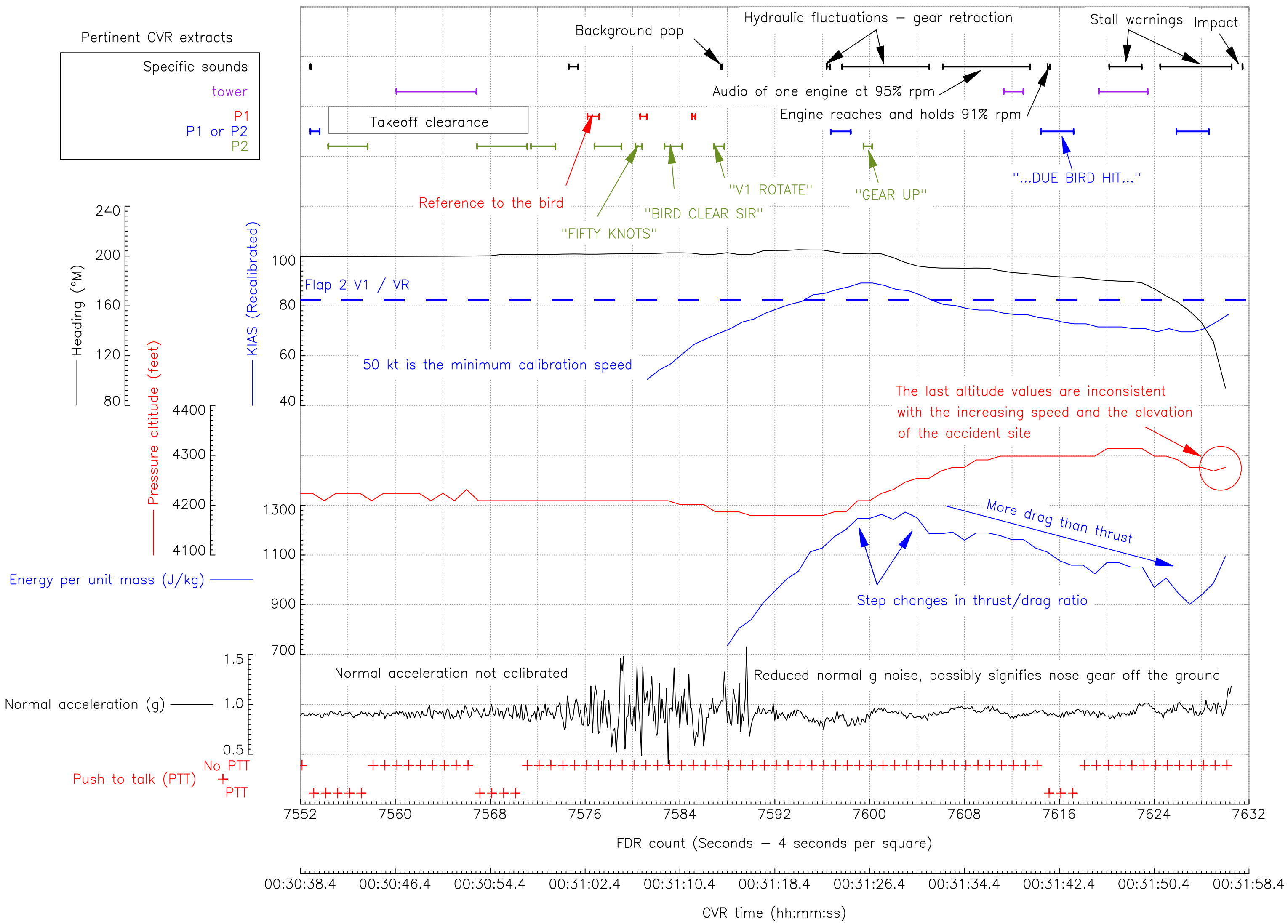

Figure 1.11-1 Pertinent extracts from recordings and calculated total energy per unit mass, zeroed at the airfield elevation.

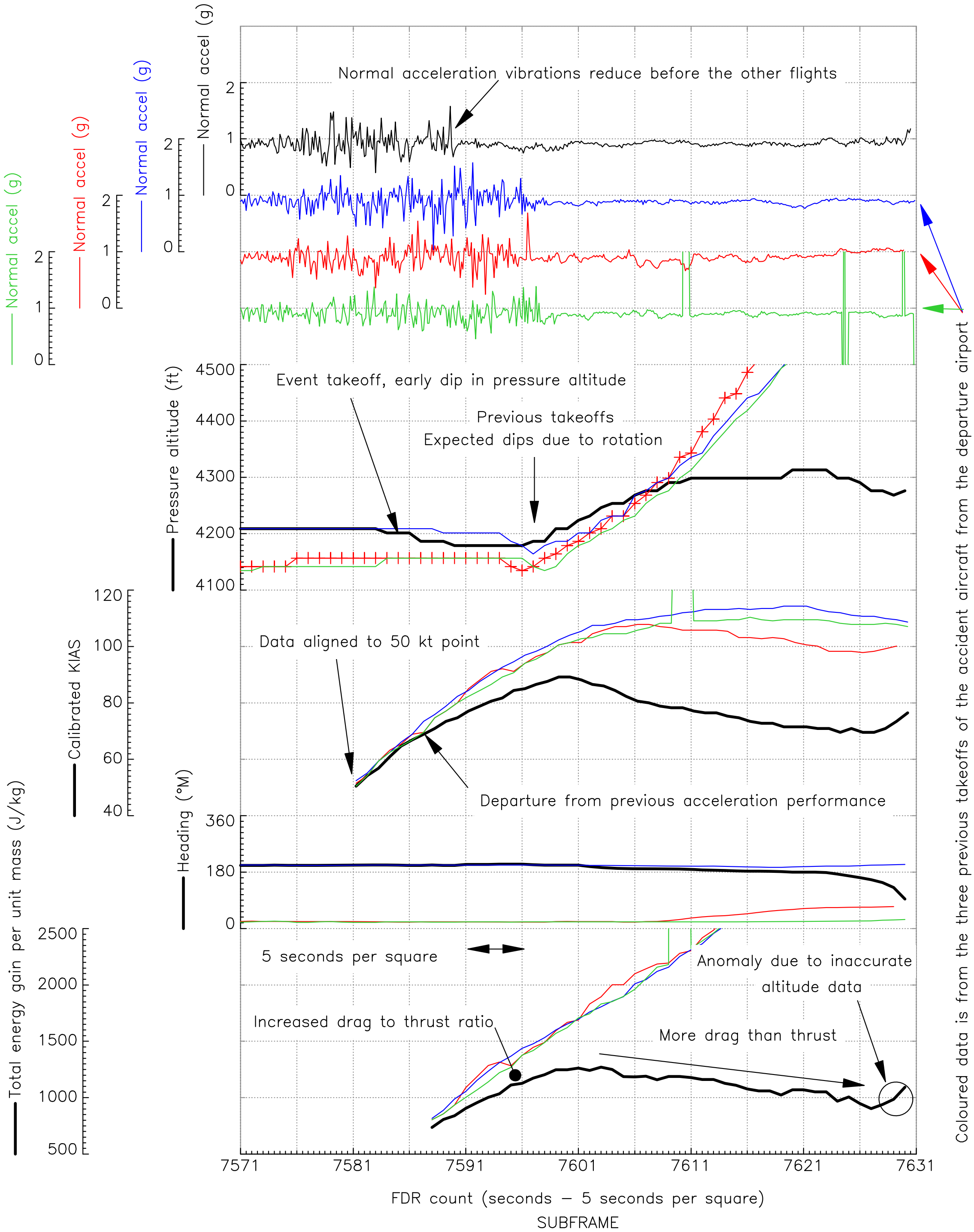

Figure 1.11-2

Comparison of the accident flight (black lines) with the previous take offs from the same airfield.

Not adjusted for wind differences.

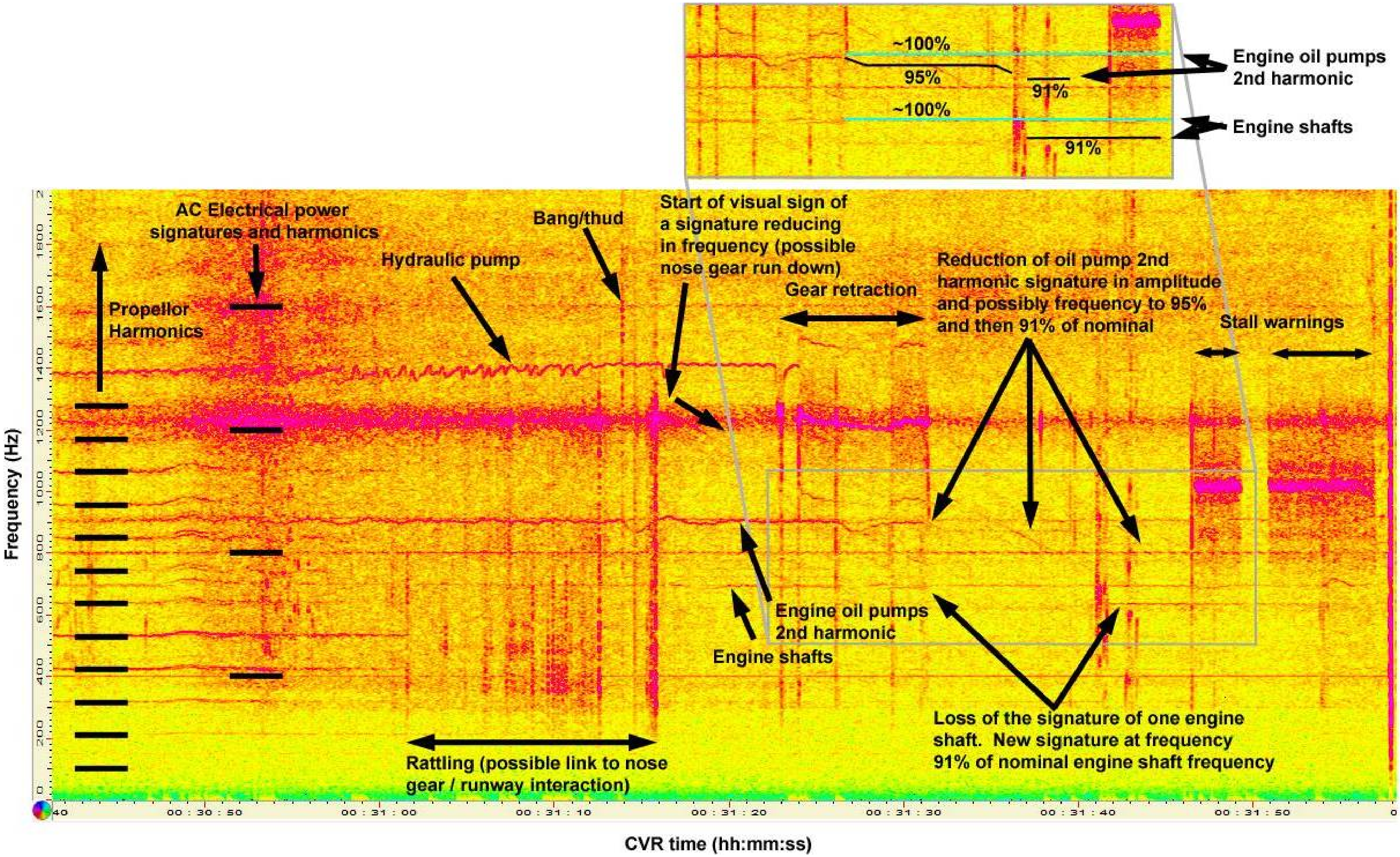

Figure 1.11-3.
Spectrum analysis of the CVR CAM channel

1.11.4 Flight path

The CCTV recording was analysed to determine the location of the aircraft when the flash occurred. This position was aligned in time with the CVR sound assumed to be associated with the flash and with the recorded data to synchronise all recorded data. Using the recorded data, and making estimated altitude corrections for the last two recorded seconds, a flight path was derived from the position on the runway where the flash occurred to the point on the ground where this process estimated the accident should have occurred. The results, shown in Figure 1.11-4, show that the derived position of the accident site was very close to the actual accident site and the final track was consistent with the direction of ground markings. This process provided confidence that the parameter values being used by the investigation were reasonable.

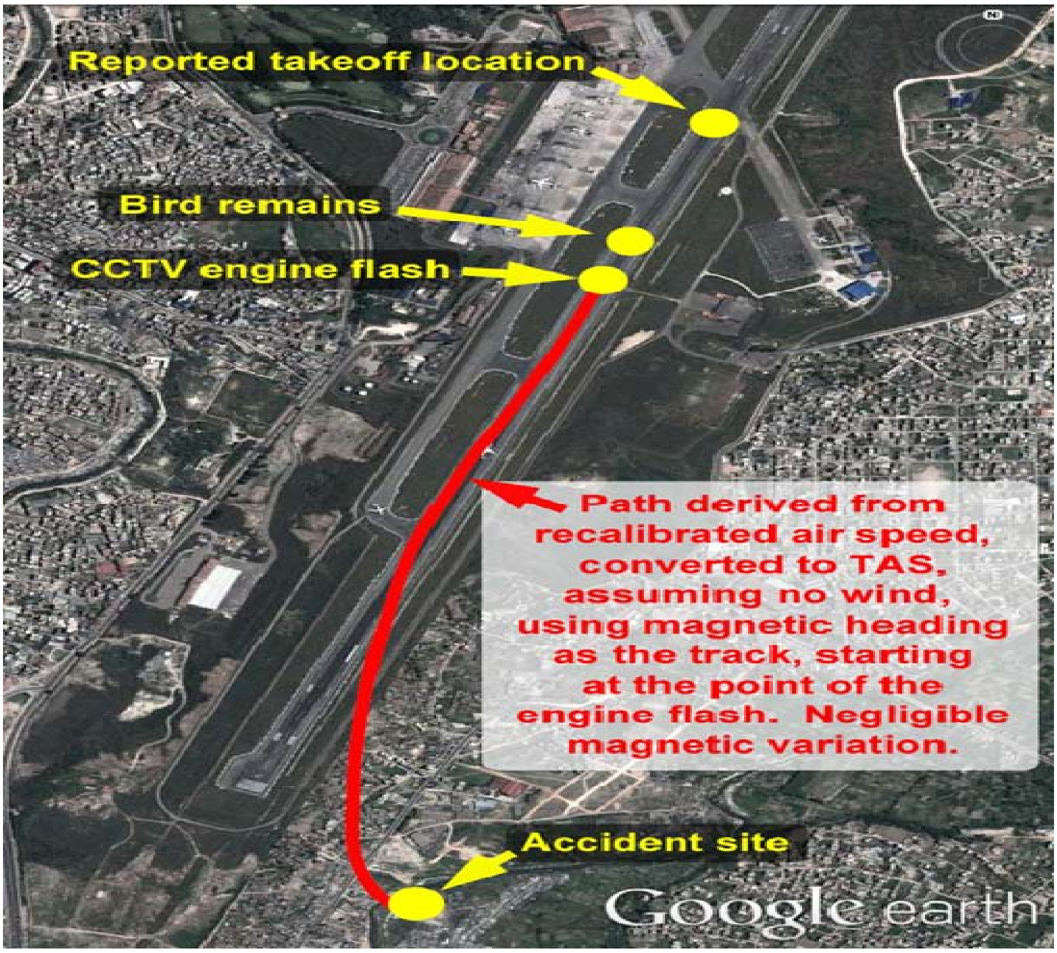

Figure 1.11-4
Derived flight path

1.12 Wreckage and impact information

1.12.1 Accident site examination

The aircraft struck the ground on the banks of the Manohara river, 420 m south-east of the threshold of Runway 02 (Figure 1.12-1). The impact crater and ground marks indicated that the aircraft struck the ground in the approximate direction of 124 °M[6]. There was a large post-impact fire which consumed most of the aircraft, but the tail section was mostly intact and only minimally affected by fire. The wreckage was moved by rescue personnel so it was difficult to establish an accurate impact attitude, but the small size of the main wreckage field (approximately 17 m in diameter) indicated a steep impact with high vertical speed. Photographs taken by the media shortly after the accident revealed a large post-impact fire and showed the tail section, upright, with the front pointing towards the north-west (Figure 1.12-2) – opposite to the direction of travel at impact. This suggested that the aircraft hit the ground in a near vertical attitude with its upper surface facing towards the north-west, but with some horizontal speed towards the south-east.

Figure 1.12-1
Location of accident site

[6] The difference between magnetic north and true north is less than 1 degree at Kathmandu.

Figure 1.12-2
Post-impact fire showing tail section remains pointing towards north-west
(Copyright AFP/GETTY)

1.12.2 Airframe examination

A preliminary examination of the wreckage was carried out onsite. The wings, cabin and cockpit had been severely consumed by fire but parts remained recognisable. Three flap jack actuators were identified and their extension was measured at 164 mm which corresponded to a flap position of 20° which is 'Flaps 2' (Figure 1.12-3). The main landing gear was found to be in the retracted position.

Figure 1.12-3
One of the flap jack actuators

The rudder trim tab was found deflected to the left by about 10° which means that 10° of right rudder trim was applied (maximum deflection is 19° +1°/-0.5°). The rudder trim tab is actuated by a rod and screw jack in the tail which is manually actuated via cables and a trim crank located in the flight deck above the right hand overhead switch panel. The trim tab will have retained its pre-impact position unless one of the cables was pulled during the impact sequence. The rudder was mostly undamaged by fire or impact, but there was a hole in its fabric covering near the top. The molten fabric edges and vertically orientated soot marks surrounding this hole indicated that it was probably formed by post-impact fire from hot flying debris.

The left engine power lever was found in the approximate flight idle position but was bent to the side (Figure 1.12-4). The right engine power lever was slightly forwards of the flight idle position. Due to the separation of the engines from the wing and the impact forces within the cockpit, the power levers could have moved during the impact sequence. The left speed lever was in a mid position, the right speed lever was slightly forward of a mid position and both levers were bent sideways. Both levers could have moved during the impact sequence, but if they had been in the gated feather position prior to impact then it is unlikely that they would have moved. Both engine fire levers were in the unselected position. The flap lever was in the Flaps 1 position.

Figure 1.12-4
Power and speed (rpm) levers – accident aircraft 9N-AHA (left); another Dornier 228 (right) with power levers in ground idle position and speed levers in fuel shutoff position

1.12.3 Engine examinations

Both engines had separated from the wings and had been affected by fire. They had also been moved from their post-impact positions so it was not apparent which engine was from which side. The data plate on one engine had a serial number of P101060C which according to the maintenance records meant that it was the right engine. The serial number on the other engine's data plate was not identifiable, but records indicated that it was P101360C – the left engine. The engines were shipped to the engine manufacturer where they underwent a detailed strip examination under the supervision of an investigator from the US NTSB.

1.12.3.1 Left engine examination

The left engine had separated into two main sections, the gear case and the power sections. Both had suffered fire and impact damage. The first stage compressor impeller blades were bent back opposite to the direction of rotation (Figure 1.12-5) and there was corresponding rotational scoring through 360° on the surrounding shroud. There was no impact damage to the leading edges of the first stage compressor blades. There was scoring on the tips of the second stage compressor blades and corresponding rotational scoring on the surrounding shroud, and there was also rotational scoring in the turbine section of the engine. This evidence indicated that the engine was rotating at impact. The combustion chamber and plenum were undamaged and the fuel nozzles were in place with no blockages. The three stages of the turbine section were undamaged apart from rotational scoring, but the test result did not confirm the metal spray in the form of aluminum deposits on the suction (back) faces of the turbine rotors and stators of all three stages. These metal spray deposits were determined to be material from the compressor shroud which has an aluminium coating. The rotational scoring of the shroud which occurred during impact would have released aluminium particles into the combustion chamber, where they melted and then re-solidified when they struck the turbine stators and rotors. This evidence indicated that the combustion chamber was lit at impact and therefore the engine was operating at impact. The engine manufacturer could not determine a power setting at impact – the evidence was consistent with idle power, full power, or any power in between.

There was no evidence of bird remains inside the engine and a black ultra-violet light was also used to identify any protein remains inside the power section of the engine which could be indicative of bird remains, but none were found. There was also no odour of bird remains inside the engine.

The gearbox contained evidence of rotational scoring and no evidence of pre-impact failures. The propeller shaft and coupler had fractured, but metallurgical analysis determined that they had failed in bending overload with no evidence of fatigue.

The FCU had suffered significant impact damage and thermal distress with some parts of its cover missing or melted. The FCU could not be tested so a strip examination was carried out. No internal faults were found although due to its poor condition a pre-impact fault could not be ruled out.

The engine-driven fuel pump had separated from the FCU. The propeller governor had also suffered significant impact damage and thermal distress with some parts of its cover missing or melted. The governor could not be tested so a strip examination was carried out. No internal faults were found although due to its poor condition a pre-impact fault could not be ruled out.

Figure 1.12-5
Left engine first stage compressor impeller – blades bent back opposite to the direction of rotation

1.12.3.2 Right engine examination

The right engine had separated into two main sections, the gear case and the power sections. Both had suffered fire and impact damage. The first stage compressor impeller blades were bent back opposite to the direction of rotation and there was corresponding rotational scoring through 360° on the surrounding shroud. Some parts of the impeller blade tips were missing and had a jagged appearance (Figure 1.12-6). One of the first stage compressor blades had leading edge damage near the tip. There was scoring on the tips of the second stage compressor blades and corresponding rotational scoring on the surrounding shroud, and there was also rotational scoring in the turbine section of the engine. This evidence indicated that the engine was rotating at impact. The combustion chamber and plenum were undamaged and the fuel nozzles were in place with no blockages. The three stages of the turbine section were undamaged apart from rotational scoring, but there were metal spray deposits on the suction (back) faces of the turbine rotors and stators of all three stages. There were also metal deposits on the leading edge and pressure (front) side of the first stage turbine rotor blades. These metal deposits were determined to be material from the compressor shroud. This evidence indicated that the combustion chamber was lit at impact and therefore the engine was operating at impact. The engine manufacturer could not determine a power setting at impact – the evidence was consistent with idle power, full power, of any power in between.

There was no evidence of bird remains inside the engine and a black ultra-violet light was also used to identify any protein remains inside the power section of the engine which could be indicative of bird remains, but none were found. There was also no odour of bird remains inside the engine.

The gearbox was also examined which contained evidence of rotational scoring and no evidence of pre-impact failures.

The FCU had suffered some impact damage and could not be tested so a strip examination was carried out. No internal faults were found although due to its poor condition a pre-impact fault could not be ruled out.

The engine-driven fuel pump had separated from the FCU.

The propeller governor was sooted with some impact damage and could not be tested so a strip examination was carried out. No internal faults were found although due to its poor condition a pre-impact fault could not be ruled out.

Figure 1.12-6
Right engine first stage compressor impeller – blades bent back opposite to the direction of rotation

1.12.4 Propeller examinations

The propeller blades from both engines had suffered fire damage and some blades had molten tips where their blade tips had separated. All propeller blade tips were accounted for although of the three separated blade tips it was not possible to determine from which blades they had separated. After an onsite examination the propeller blades were cut near their root to facilitate shipment to the engine manufacturer with the engines. The engine manufacturer removed the propeller hubs from the engines and sent them, together with the blades, to the propeller manufacturer where a strip examination was undertaken under the supervision of an investigator from the US NTSB.

1.12.4.1 Left propeller examination

The left propeller blades were numbered L1 to L4. Blade L1 was intact and had a slight aft bend at the outer ¼ radius and was twisted slightly towards low pitch. Its leading edge and trailing edge were undamaged (Figure 1.12-7). Blade L2 was intact and had a 45° forward bend at mid-blade and its tip was mildly twisted towards low pitch. Its leading edge and trailing edge were undamaged. Blade L3 was intact and had a sharp 45° aft bend at about 10 inches from the butt end. Its leading edge was undamaged and its trailing edge had a small dent near the tip. Blade L4 had melted and was missing two-thirds of its outer length and it could not be matched with any of the three separated blade tips. Its remaining leading edge and trailing edge were undamaged.

Examination of the hub unit revealed that the L3 hub arm had three adjacent blade butt impact marks caused by contact with the blade butt. These three marks suggested multiple impacts while the blade was changing pitch during the ground impact sequence. The location of the marks indicated that the blade had been in a normal operating position and then moved towards reverse pitch. The L2 blade butt had 1 mark indicating reverse pitch. The internal surface of the piston had an impact mark indicative of the piston being in a reverse pitch position. According to the propeller manufacturer it is common to see propeller blades being driven towards reverse pitch in an impact sequence. Compressive bending in the link arms and gouging of link screws that had made contact with the guide collar were also evidence of the propeller having been driven towards the low/reverse pitch position. It could be concluded that the left propeller was at a normal positive blade pitch angle at the time of impact – not feathered or in reverse pitch.

Based on the very mild damage to the propeller blades and the lack of significant twisting, tearing, or leading edge damage in the tip area, the propeller manufacturer concluded that the propeller was operating at low or no power at the time of impact. This evidence combined with the evidence of a normal positive blade pitch angle indicated that the engine was probably at low power and not ‘no power’, because a functioning NTS system would have driven the blade angle to a very high, near feather, pitch angle.

Figure 1.12-7
Left propeller blades – three blades cut near the butt to facilitate shipment

1.12.4.2 Right propeller examination

The right propeller blades were numbered R1 to R4. Blade R1 was missing its outer third where it had melted, and it could not be matched with any of the three separated tips. The blade was not bent or twisted and had no leading or trailing edge damage (Figure 1.12-8). Blade R2 was intact and had a 45° aft bend at ¼ radius and no twist. Its leading edge was undamaged and its trailing edge contained a large gouge at mid-blade. Blade R3 was intact and had a 45° aft bend at ¼ radius and slight additional forward bending at the outer 1/3 of the blade. Its leading edge had mild gouges at 1/3 blade and no trailing edge damage. Blade R4 was missing its outer two-thirds and could not be matched with any of the three separated tips. The blade was bent 45° forward at about 10 inches from the butt end. Its remaining leading edge and trailing edge were undamaged.

The three separated blade tips that could not be matched up are shown in Figure 1.12-9 - two of these were from the right propeller. There was no significant leading edge or trailing edge damage to any of these blade tips, but one blade tip had a leading edge nick and one had chordwise scratches.

Examination of the hub unit did not reveal any hub arm impact marks and there were no marks on the propeller butts either to determine a blade angle. However, a fragment of the damaged spinner was deformed over the piston which provided an indication of piston position. This fragment was 4 inches from the guide collar which indicated that the piston was in a position representative of a blade angle of approximately 20° at the time the spinner was crushed. The low pitch stop is 15° and a typical blade angle at takeoff power is approximately 35°. The blade angle at feather is 76°. This evidence combined with the lack of significant blade twisting, tearing, or leading edge damage in the tip area, indicated that the engine was at low power.

Figure 1.12-8
Right propeller blades – three blades cut near the butt to facilitate shipment

Figure 1.12-9
Separated propeller blade tips that could not be matched to the separated blade ends, although two of these are from the right propeller

1.13 Medical and pathological information

The post mortem reports on both flight crew members found nothing that would have a casual or contributory factor of the events. The results of all tests for drugs and alcohol were negative.

The impact was not survivable and all occupants within the aircraft received fatal injuries during the impact sequence before the aircraft caught fire.

1.14 Fire

There was a large post-impact fire which consumed most of the aircraft but the tail section was mostly intact and only minimally affected by fire.

1.15 Survival aspects

1.15.1 Search and rescue operations

The Tower Controller activated the crash alarm and informed the fire station that there had been an accident. The person in the Airport Fire Watch Tower was unable to see where the accident had taken place because his view was restricted in a number of directions by the structure of the building. Two large foam tenders, one medium foam tender, two ambulances and one rescue vehicle were dispatched immediately from the fire station. However, one route to the exit gates was blocked by Army personnel and the other was unsuitable because of the large size of the vehicle. The exit gates were manned by army personnel who required permission from a senior officer before opening the gates. This requirement, along with a requirement to clear army personnel from the road, delayed the fire vehicles. Once on public roads, the vehicles were delayed further by the weight of traffic and a crowd of people near the impact site. The accident site was across a small river the bank of which prevented the vehicle from reaching the site. The fire vehicles began to fight the fire from the nearest point across the river and reported that it was under control at 0057 hrs. Local police, armed police and army personnel were also involved in the rescue operations. The CVR and FDR were recovered from the accident site by TIACAO and were taken to the RCC.

1.16 Tests and research

1.16.1 Performance calculations by the Type Certificate (TC) holder

1.16.1.1 Performance calculation for the climb phase

The aircraft TC holder, RUAG, was given data relating to the actual performance of the aircraft during its flight and used an aircraft performance model to test hypothetical scenarios to see if any scenario matched the actual performance. The simulation software aimed to find solutions in terms of takeoff weight (TOW) and engine power output that matched the speed of the simulated aircraft with the speed of the real aircraft at a given altitude on the actual climb profile. The time to climb to the given altitude was allowed to vary and, if the aircraft had an excess of power at a particular data point, the time to climb to the altitude would be reduced to find a matching solution and vice versa.

Scenarios with all engines operating (AEO), AEO but with a power reduction and one engine inoperative (OEI) were examined. Only data relating to a 'new' 5-blade propeller were available and it was assumed that the 'old' 4-blade Hartzell propeller installed on the Do228-202(K) delivered similar thrust to the new propeller in the speed range under consideration. This assumption was considered valid by the TC holder following consideration of data available from comparative flight tests between the new and old propellers during certification of the Do228-212NG aircraft. All the OEI cases were calculated assuming a wind milling propeller with NTS working.

Since engine data were available only for the 776 shaft horse power (SHP) version of the TPE engine, the power available was scaled down in the calculations to match the 715 SHP TPE engine installed on the Do228-202(K).

The TC holder confirmed that the engines fitted to 9N-AHA should have been capable of producing 715 SHP in a temperature of up to 30° C at 4,300 ft pressure altitude.

The software used Calibrated Airspeed (CAS) whereas speed derived from the FDR was Indicated Airspeed. This potentially introduced a difference of up to 2 kt (Flaps Up) or 1 kt (Flaps 2) especially in the low-speed range of the climb segment under consideration.

The results of the calculations are shown in Figures 1.16-1 and 1.16-2. The red line in each graph represents the actual performance of the aircraft. The calculations were made using a pressure altitude of 4,250 feet and a temperature of 19 °C.

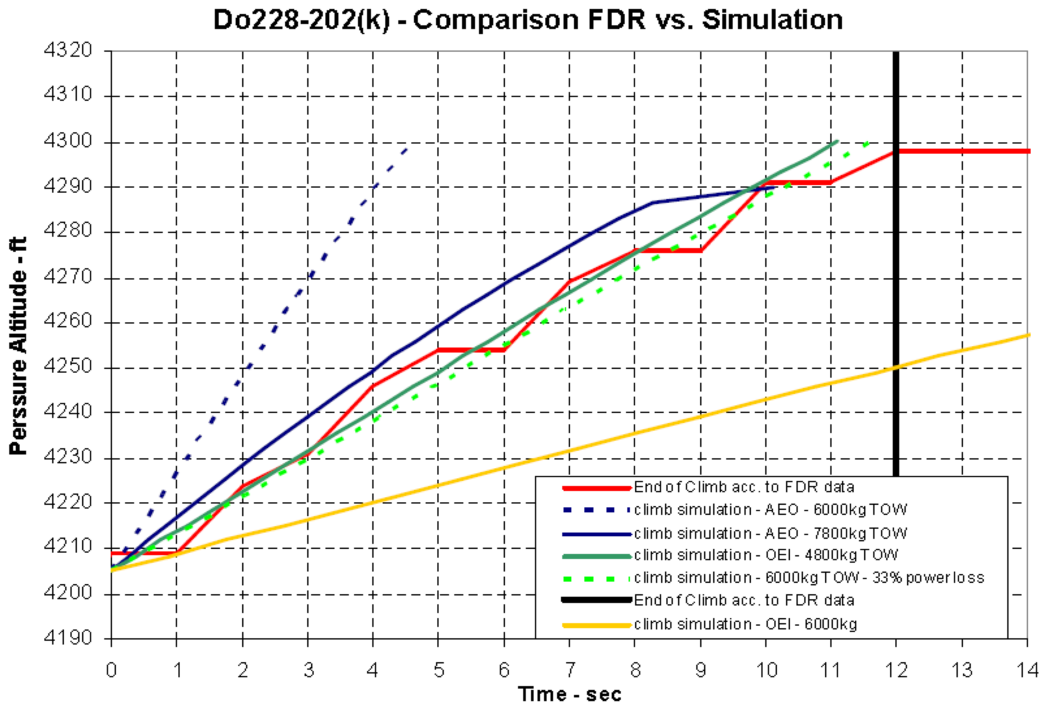

Figure 1.16-1
Climb situation considering altitude (red line is the actual performance of the aircraft)

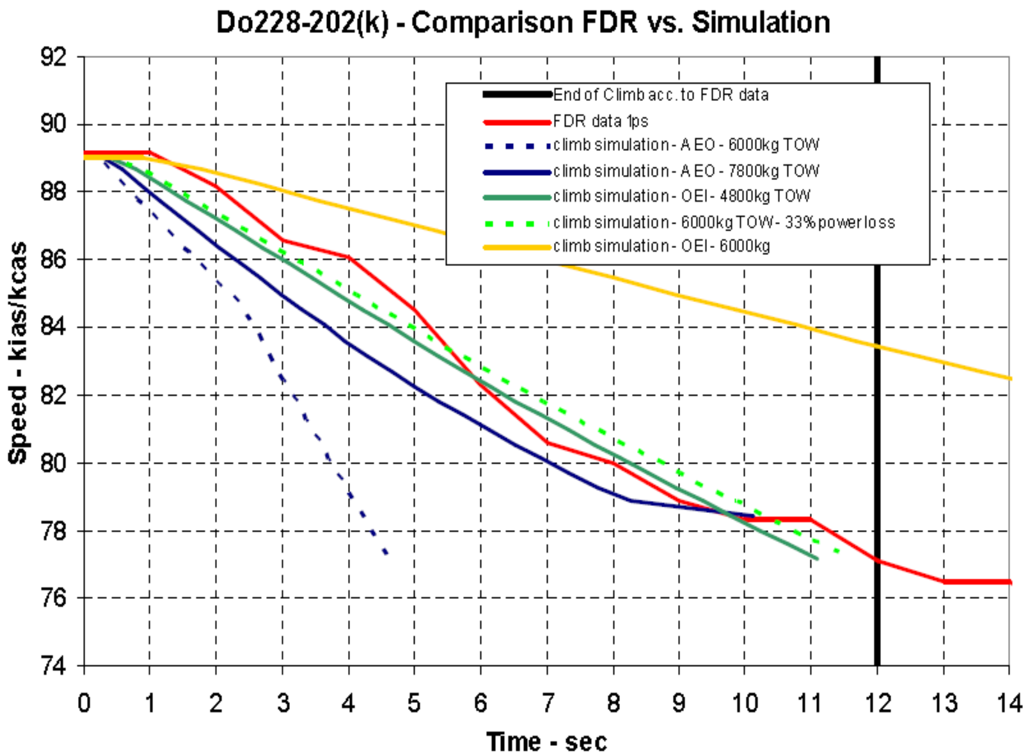

Figure 1.16-2
Climb simulation considering speed (red line is the actual performance of the aircraft)

Using a takeoff weight of 7,800 kg, the maximum weight that could be entered into the software and a figure representing a grossly overweight aircraft, the simulated aircraft AEO would have been able to out-perform the actual speed-altitude profile: in Figure 1.16-1, the simulated aircraft would have reached a given altitude in less time than the actual aircraft while maintaining the observed speed profile; and in Figure 1.16-2, the simulated aircraft would have reached a given speed earlier than the actual aircraft while maintaining the observed altitude profile. Therefore, overloading alone was not the cause of the lack of performance in the climb phase.

The graphs for a simulated takeoff weight of 6,000 kg AEO show an even more marked increase in performance over the actual aircraft. These results show that the simulated aircraft AEO with a takeoff weight similar to the accident aircraft (between 5,800 kg and 6,100 kg[7]) would have had an excess of thrust over the accident aircraft at all data points. This indicated that the accident aircraft must have lost power.

Following a single engine failure, an aircraft would be expected to maintain a speed of V_2 and follow a lower climb rate than the one observed. The yellow lines in Figures 1.16-1 and 1.16-2 show the expected climb profile of an aircraft at 6,000 kg OEI. The lines show that the simulated aircraft would have reached a given altitude at a later time than the actual aircraft while matching the speed profile, and would have reached a given speed at a later time than the actual aircraft while matching the altitude profile. The solid green lines show that the takeoff weight of the simulated aircraft had to be reduced to 4,800 kg before it had the power available OEI to match the observed speed-altitude profile of the accident aircraft. Given the assumed takeoff weight of between 5,800 and 6,100 kg, this shows that the aircraft had more power during the climb phase than would have been the case under OEI conditions.

The broken green lines in the graphs show that a simulated aircraft with a takeoff weight of 6,000 kg would have matched the observed speed-altitude profile had it suffered an average 33% power loss during the climb phase. An average total power loss of 33% from two engines each capable of producing 715 SHP equates to a loss of 472 SHP which would leave 958 SHP available. The power loss required to match the observed performance at other takeoff weights is shown in Table 1.16-1

Weight (kg)	Power Loss (%)
4,800	50
6,000	33
6,200	31
6,400	27

Table 1.16-1
Overall power loss required to match the observed aircraft performance during the climb phase

1.16.1.2 Performance calculation for the level flight phase

The TC holder was unable to model the level-flight deceleration phase of the aircraft after it reached 100 ft AAL, so it calculated the steady-state power required to maintain level flight at different weights and the results are shown in Figure 1.16-3.

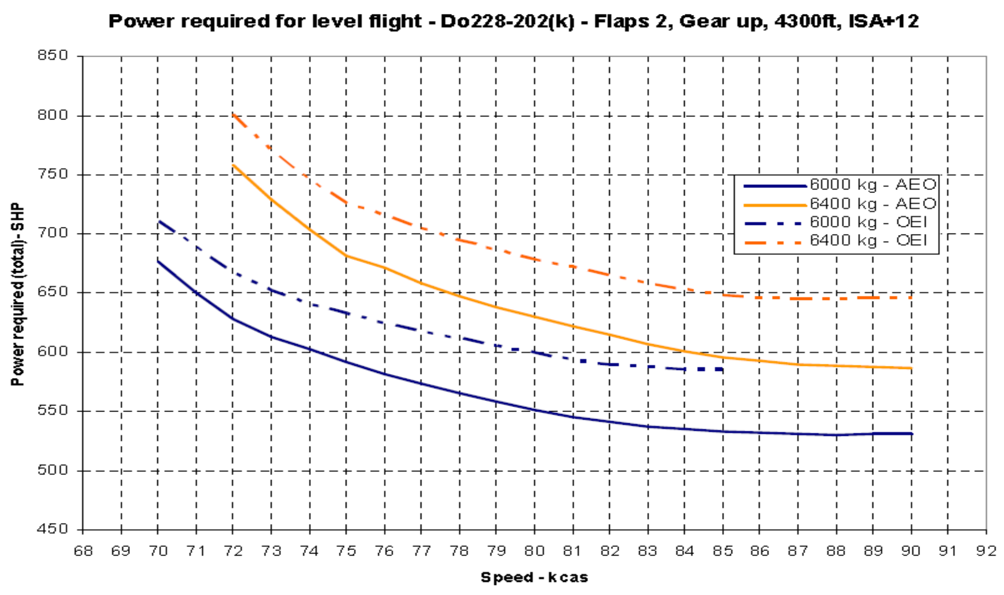

Figure 1.16-3
Power required curve for level flight at different weights

[7] See section 1.17.5.

The aircraft flew level for approximately 14 seconds during which time the airspeed decreased from 77 to 69 kt. The graphs show that, at these speeds, an aircraft with a takeoff weight of between 6,000 and 6,400 kg would have been operating in the region 'behind' the power required curve[8] in both the AEO and OEI cases.

Tables 1.16-2 and 1.16-3 show that, for an aircraft weight of 6,000 kg, the power required to maintain level flight at 77 kt would have been 573 SHP AEO and 625 SHP OEI[9]. The corresponding figures for 84 kt (V_2) would have been 535 SHP AEO, and 587 SHP OEI. The fact that the accident aircraft could not maintain 77 kt in level flight showed that it had suffered a minimum power loss of either 60% AEO, or one engine had failed and there was also a 13% power loss from the operating engine.

For an aircraft weight of 6,200 kg, interpolating between columns on Table 1.16-3 shows that the power required to maintain 77 kt in level flight would have been 665 SHP OEI, or 93% of the power available. For an aircraft weight of 6,400 kg the power required would have been very close to 100% of the power available OEI.

Since an engine operating at flight idle produces a net drag force which is greater than the drag of an inoperative engine (NTS working), the power required to maintain level flight AEO but with one engine at flight idle is greater than the power required to maintain level flight with OEI. The TC holder was unable to calculate the difference but, for a takeoff weight of 6,200 kg, the extra power required would not need to be significant to prevent the aircraft from maintaining 77 kt in level flight with AEO and one engine at flight idle.

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[8] The part of the curve where a decrease in speed leads to an increase in the power required to maintain level flight.

[9] More power is required to maintain level flight under OEI conditions than under AEO conditions because of the drag on the inoperative engine.

Level Flight 6000kg AEO		
CAS	SHP per engine	SHP total
69	408	816
70	338	676
71	325	650
72	314	628
73	306	612
74	301	602
75	296	591
76	291	581
77	286	573
78	283	565
79	279	558
80	276	551
81	273	545
82	270	541
83	269	537
84	267	535
85	267	533
86	266	532
87	266	531
88	265	530
89	265	530
90	265	531

Table 1.16-2
Power required for level flight AEO – tabulated data

Level Flight OEI		
	6000kg	6400kg
CAS	SHP	SHP
70	862	-
71	711	-
72	689	801
73	667	771
74	652	745
75	641	726
76	632	715
77	625	705
78	618	695
79	611	686
80	606	679
81	600	672
82	594	665
83	590	658
84	587	653
85	586	648

Table 1.16-3
Power required for level flight OEI – tabulated data

1.16.1.3 Rate and angle of climb

The OEI rate of climb was calculated for different weights, with the aircraft at V_2 and configured with Flaps 2, and the results are shown in Table 1.16-4.

Weight (kg)	Rate of climb – ft/min	
	Gear down	Gear up
6,000	123	240
6,200	87	206
6,400	52	173

Table 1.16-4
Rate of climb OEI

The speed required to obtain the best angle of climb with Flaps 2, landing gear up, at different weights are shown in Table 1.16-5.

Weight (kg)	Speed (kt CAS)
6,000	92
6,200	94
6,400	95

Table 1.16-5
Speed for best angle of climb

1.16.2 Power calculations by the engine and propeller manufacturers

The engine manufacturer was asked to calculate the power delivered by the engine to the propeller at flight idle using the idle fuel flow setting recorded by the operator when the engines were installed. The conditions used in the analysis were:

- Altitude 4,046 ft
- Airspeed 80 kt
- Temperature 19 °C
- Fuel flow 180 pounds per hour (taken from the operator's ground run records)
- No installation losses (does not include losses due to a propeller being attached)

The analysis was performed for two different speeds 100% and 95% rpm. At 100% rpm the power output to the propeller was 6 hp and at 95% rpm it was 72 hp.

The propeller manufacturer was asked to calculate how much power was required to turn the propeller at 100% rpm and 95% rpm in the same conditions. The propeller manufacturer's calculations are shown in Figure 1.16-4. Hp is the power required to turn the propeller. Thrust is the thrust delivered by the propeller and negative values of thrust mean that drag is being produced. Propeller blade angle is presented on the x-axis and the minimum in-flight blade angle is 15°.

The results show that at 100% rpm and a blade angle of 15° the power required to turn the propeller is 125 hp and the net result is a drag of about 180 lb (-180 lb thrust). Because only 6 hp is available at flight idle in this condition it means that 100% rpm would not be maintained.

The results show that at 95% rpm and a blade angle of 15° the power required to turn the propeller is about the same as at 100% rpm (in reality probably slightly less depending upon how the curve fit is drawn) with a drag of about 350 lb. At this speed only 72 hp is available at flight idle which means that 95% rpm would not be maintained either at flight idle.

The results show that because of the low idle fuel flow setting on 9N-AHA, if flight idle had been selected at airspeed of 80 kt, the rpm would have reduced below 95% rpm and the drag produced by the propeller would have been greater than 350 lb.

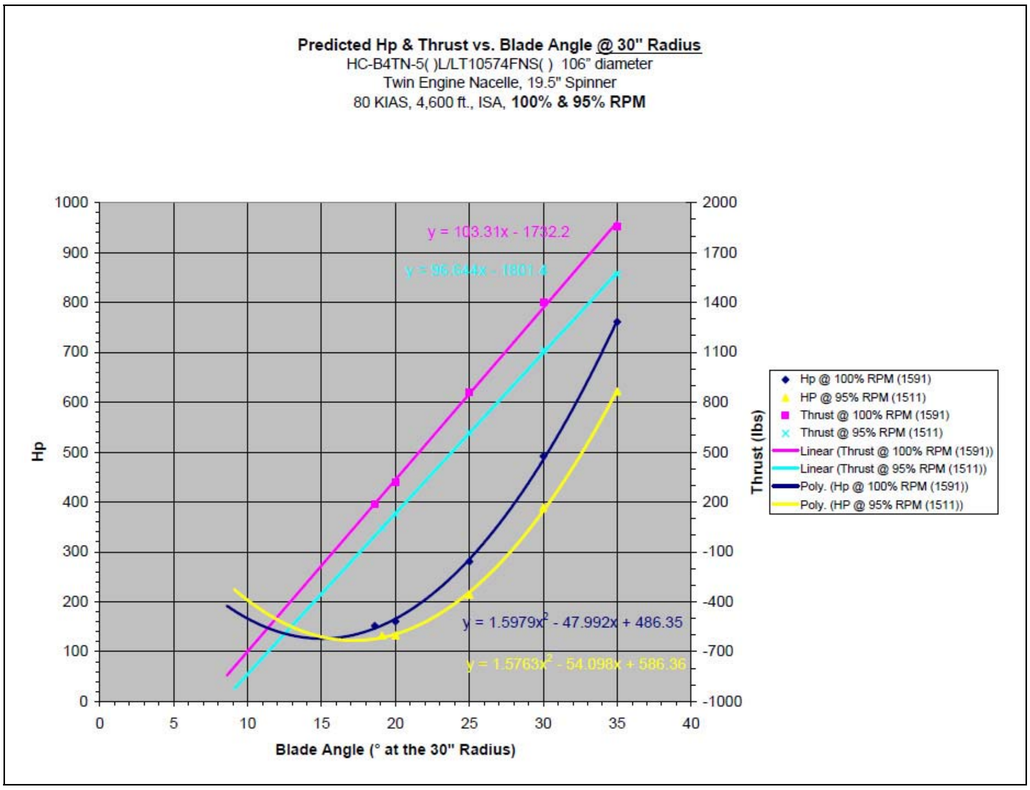

Figure 1.16-4

Hartzell predicted Hp and Thrust Vs Blade Angle and rpm

1.17 Organizational and management information

1.17.1 Speeds and weights from Pilot's Operating Handbook (POH)

1.17.1.1 Aircraft reference speeds

The POH defines V_{MC} as the lowest speed that the aircraft is controllable with a maximum 5° angle of bank following a loss of the critical engine (which is not feathered) with the other aircraft engine at takeoff power. V_{MC} is given as 75 KIAS with Flaps 2.

The speed for best rate of climb with one engine operating, V_{YSE}, is 108 KIAS reducing by one kt for every 200 kg below MTOW.

For Short Takeoff and Landing (STOL) operations up to 5,700 kg takeoff weight, with Flaps 2 selected, Supplement No.1102 to the POH states that:

V_R = 71 kt

1.17.1.2 Aircraft reference weights

The POH details limitations for the aircraft as shown below:

Maximum takeoff weight (MTOW):	6,200 kg
Maximum Zero Fuel Weight (MZFW):	5,590 kg
Maximum Landing Weight (MLW):	6,100 kg

For STOL operations, Supplement No.1102 to the POH states:

MTOW = MLW = 5,700 kg

Maximum weights allowed in the cargo compartments are:

Forward cargo compartment:	120 kg
Aft cargo compartment:	210 kg

1.17.2 Aircraft loading – Airline policy

1.17.2.1 Traffic load for planning purposes

For planning purposes, the airline stated that it assumes each flight will be operated with 15 passengers comprising 10 foreigners and 5 Nepalese citizens. Each passenger is allowed 15 kg of checked-in baggage and 5 kg of hand baggage.

Chapter 5-2 of the Civil Aviation Authority of Nepal (CAAN) *Flight Operations Requirements (FOR) – Aeroplanes* gives standard weights that can be used to calculate the weight of passengers in aircraft with a seating capacity of 12 or more persons.

The figures below include 3 kg for hand baggage.

Nepalese male:	70 kg
Foreign male:	75 kg
All females:	65 kg

Assuming a flight departs with five Nepalese and five foreign male passengers, and five female passengers[10], the traffic load assumed during planning is:

5 passengers at 75 kg:	375 kg
5 passengers at 70 kg:	350 kg
5 passengers at 65 kg:	325 kg
15 passengers with 15 kg of baggage:	225 kg
Assumed traffic load:	<u>1,275 kg</u>

The planning figures should be increased by 2 kg per passenger to allow for the extra hand baggage allowed by the airline (5 kg) over and above the CAAN assumed weights (3 kg). On a flight with 15 passengers, this would amount to an extra 30 kg.

Assumed traffic load (corrected):	<u>1,305 kg</u>

1.17.2.2 Aircraft weight

The following analysis is made using weights from the accident aircraft, which are assumed to be representative of other similar aircraft.

Aircraft operating to Tensing/Hillary Airport must observe the STOL MLW limit of 5,700 kg. The trip fuel required on a flight from TIA is 136 kg and so the MTOW departing TIA is 5,836 kg.

The Dry Operating Weight (DOW) of the aircraft is 4,049 kg. The departure fuel required at TIA is 635 kg, which is for a return trip, arriving back at TIA with fuel

[10] This was an assumption made during the investigation. The airline did not state that it made the same assumption during planning.

for the alternate airport and final reserve fuel. The weight of the aircraft before adding the traffic load is therefore 4,684 kg. The total traffic load allowed is therefore 1,152 kg, which is the MTOW, 5,836 kg, less 4,684 kg.

1.17.2.3 Procedures on the day of a flight

The airline procedure assumes a traffic load of 15 passengers, made up of five Nepalese citizens and 10 foreigners, for flights from TIA to Tensing/Hillary Airport. Using the investigation's assumptions about their gender, this represents a traffic load of 1,305 kg whereas the total traffic load allowed is 1,152 kg. Flights cannot dispatch under these circumstances for STOL operations to Tensing/Hillary Airport. The airline stated that bookings would be made based on the planning assumptions but, on the day, if the actual traffic load was greater than 1,152 kg, baggage would be offloaded as required to observe the STOL-limited MTOW. The airline stated that, on most days, it would operate a cargo flight from TIA to Tensing/Hillary Airport and baggage offloaded from earlier flights would be loaded onto this cargo flight.

The airline's SOPs state in Section 2.18 that:

"*a) [The] company's designated operation personnel is responsible for the loading and securing of both passengers and freight.*

b) Prior to each flight, 'Weight and Balance Documents' are prepared by the company's designated operation staff at the airport. The Captain should check and review the documents and ensure that the required information is properly completed.

c) The company's designated marketing person signing off on the load and trim sheet is responsible for the actual weight of the passengers, baggage and cargo etc.

d) The pilot-in-command is responsible for the load distribution of the passengers and baggage and to ensure that the C.G is within limits before the flight".

The airline stated that the person responsible for signing off the load sheet is likely to have received approximately one day's training in that role and that the

Commander would have very little time before flight to scrutinise the load sheet. The load sheet takeoff weights for the three flights prior to the accident flight were: 5,834 kg; 5,835 kg; and 5,835 kg.

1.17.3 Aircraft loading – the accident flight

1.17.3.1 Load sheet for the accident flight

The allowable traffic load for the flight was recorded on the loadsheet as 1,152 kg.

There were 16 passengers on board, made up of 9 foreign and 3 Nepalese men, and 4 women. Using standard weights, these passengers would weigh 1,145 kg. The loadsheet recorded the passenger weight (and the total traffic load) as 1,150 kg and noted that there was a 2 kg under-load.

The loadsheet recorded that two seats, with a total weight of 20 kg, were removed (thought by the investigation to be the two seats in row 8) and replaced with baggage weighing 20 kg.

The takeoff weight was recorded as 5,834 kg and the landing weight as 5,698 kg.

The takeoff CG was recorded as 26.8% of Mean Aerodynamic Chord (MAC).

1.17.3.2 Trim sheet for the accident flight

The trim sheet made no allowance for baggage in the forward or aft cargo compartments. The passenger manifest had a hand written note across it that read: "*All baggage offloaded*".

The actual C.G. positions for various aircraft weights were approximately:

TOW:	29.2% MAC
ZFW:	28.8% MAC
LW:	29.1% MAC

The trim sheet erroneously recorded the following C.G positions:

TOW:	26.8% MAC
ZFW:	26.5% MAC
LW:	26.7% MAC

The actual and recorded C.G. positions were within limits for STOL and normal operations and this would also have been the case had 80 kg of baggage been loaded into the aft cargo compartment.

1.17.3.3 Baggage on board the aircraft

The original passenger list for the flight showed that there would be 15 passengers and 150 kg of baggage made up of bags belonging to the passengers and items containing provisions for an organisation at the destination airport. Subsequently, an additional passenger joined the flight and this was reflected on the Passenger Manifest along with a statement to the effect that all bags had been offloaded.

The CCTV recording showed that baggage was loaded into the aft cargo compartment but there was no evidence in respect of the forward compartment. The investigation was unable to verify the actual weight of baggage on board the aircraft but the airline stated that it was between 70 and 80 kg.

1.17.4 Weighing requirements – passengers, crew and hand baggage

Weighing requirements for flights within Nepal, given in the Civil Aviation Authority of Nepal (CAAN) *Flight Operations Requirements (FOR) – Aeroplanes,* were shown earlier. Within the UK, the equivalent figures are contained in Civil Aviation Publication (CAP) 393, *Air Navigation: The Order and the Regulations*. For aircraft with 10 to 19 passenger seats, the UK requirements are shown below where the figures include 6 kg for hand baggage.

Male passengers:	92 kg
Female passengers:	74 kg

Using these figures, the weight of the passengers (12 men and 4 women) would have been 1,400 kg. This figure would have been reduced by 1 kg per passenger to account for the airline's hand baggage allowance of 5 kg giving a passenger load (traffic load) of 1,384 kg. Using UK assumptions about passenger weights, the traffic load would have been 232 kg above the maximum allowable traffic load before hold baggage was added.

Section OPS 1.620 of European Commission Regulation No 859/2008 contains average mass values for passengers and baggage, which are the same as in CAP 393. If an operator wishes to use standard mass values other than those contained in the regulation, a detailed weighing survey must be undertaken along with a statistical analysis of the results. The methodology, shown in *Appendix 1 to OPS 1.620 (g)*, is reproduced in Appendix A to this report.

The Civil Aviation Requirements of India, Series 'X' Part II contains standard weights for passengers in Section 2 – Airworthiness. The standard weight (including hand baggage) for all adult passengers, male or female, is given as 75 kg. The requirements also state that the scales used to weigh passenger baggage must be calibrated at specified intervals.

Using the standard weight of 75 kg, the passenger load would have been 1,200 kg.

1.17.5 Performance calculation – the accident flight

The takeoff Weight-Altitude-Temperature (WAT)[11] limit for the flight, calculated from the POH, was 6,075 kg assuming the following information:

Aircraft configuration:	Flaps 2
Atmospheric conditions:	QNH 1018 HPa; 19° C; wind calm
Runway conditions:	Dry; 4,237 ft pressure altitude; slope 1% downhill

1.17.5.1 Performance calculation for the accident flight

TOW = 5,834 kg (loadsheet TOW) + 80 kg (baggage) = 5,914 kg

[11] The WAT limit weight restriction ensures that the aircraft has sufficient climb performance in the event of an engine failure at or above V_1.

(MTOW = 5,836 kg for departure from TIA, which was limited by the STOL MLW at Tensing/Hillary Airport).

$V_1 = V_R$ = 83 kt

V_2 = 83 kt

V_{MC} = 75 kt

V_S = 69 kt (no bank); 71 kt (20° bank angle); (both engines idling)

Takeoff run = 2,300 ft

Takeoff distance = 2,950 ft (to 35 ft; assumes critical engine failure at V_1)

Accelerate-Stop-Distance = 2,750 ft (engine failure recognised at V_1)

There was approximately between 2,500 and 3,000 feet of runway available ahead of the aircraft once it left the ground.

1.17.5.2 Performance calculation using hypothetical weights

The investigation assumed that 80 kg of baggage was on board during the flight. Using European standard weights for the passengers, the takeoff weight would have been:

4,684 + 80 + 1,384 = 6,148 kg (WAT-limited MTOW = 6,075 kg).

Using Indian standard weights for the passengers, the takeoff weight would have been:

4,684 + 80 + 1,200 = 5,964 kg

Using a TOW of 6,100 kg:

$V_1 = V_R$ = 83 kt

V_2 = 84 kt

V_{MC} = 75 kt

V_S = 71 kt (no bank); 73 kt (20° bank angle); (both engines idling)

Takeoff run = 2,600 ft

Takeoff distance = 3,400 ft (to 35 ft; assumes critical engine failure at V_1)

Accelerate-Stop-Distance = 3,000 ft (engine failure recognised at V_1)

1.17.6 Pilot training

There is no precision runway approach aid in Nepal and pilots flying this type of aircraft[12] take their Instrument Rating (IR) test in a Flight Training Device (FTD) located in Thailand. The FTD is a fixed base device, which does not accurately reflect the handling of any particular aircraft type. It is not used specifically to train the airline's pilots to handle an engine malfunction at or near to V_1.

Company policy in the case of an engine malfunction during takeoff is that the takeoff should be rejected below V_1 and continued above V_1. In the case of a continued takeoff, the aircraft would be climbed to 400 ft AAL before any action was taken, including feathering propeller on the failed engine. The airline's pilots undertake proficiency checks every six months, which are flown in a Dornier 228 aircraft filled with ballast so that its takeoff weight is 5,400 kg, about 400 kg less than the takeoff weight of passenger flights. When simulating an engine failure during takeoff, the power lever is reduced to a zero thrust setting at between 200 and 400 feet AAL for captains and at about 400 AAL for co-pilots.

The Dornier 228 POH states in Section 3, E*ngine Malfunctions During Takeoff* that:

> *"if an engine malfunction occurs before reaching* V_1*, the takeoff must be aborted"* and
>
> *"If an engine malfunction occurs on takeoff at or after* V_1*, the takeoff can be continued safely. If sufficient runway remains available to bring the airplane to a stop, an abort may be considered."*

Section 3 of the POH, *Emergency and Abnormal Procedures,* also lists the actions to be taken in case of an engine malfunction. For an engine malfunction after V_1, the following actions are listed:

Aeroplane control	Maintain
POWER levers	MAX
LDG GEAR	UP (airborne)
Airspeed	V_2
Faulty engine	SHUTOFF and FEATHER
FLAPS (clear of obstacle)	UP (≥ 100 KIAS)
Airspeed	V_{YSE}

1.17.7 Inspection of the operator by a European travel company

In February 2011, a major European travel company carried out an inspection of the operator as part of the travel company's Quality Management system. The inspection was required in order to meet its obligations under European legislation. Three sample loadsheets were recalculated as part of a quality check and all three were found to have been miscalculated with under-load errors of between 3 and 45 kg. Several load sheets showed an under-load of 1 kg. The loadsheet for the flight observed by the auditor showed an under-load of 1 kg but, when recalculated by the auditor, the aircraft was actually overloaded by 23 kg.

The report noted that on the flight observed by the auditor there was no passenger safety demonstration. The report recommended that:

> *'A passenger briefing pre-departure should be implemented to include the use of seat belts and emergency evacuation.'*

1.17.8 Cabin safety requirements

Chapter 4-5 of the Civil Aviation Authority of Nepal (CAAN) *Flight Operations Requirements (FOR) – Aeroplanes* instructs operators to ensure that passengers are made familiar with the location and use of specified safety equipment.

[12] the Twin Otter which is also used on STOL routes.

Part A General of the airline's Operations Manual states that the commander is responsible for ensuring that all the passengers are given the appropriate briefing or equipment demonstration for the various stages of flight. Passengers' attention is to be drawn to the briefing cards, which they should be advised to read, and they are to be verbally briefed on: restrictions on smoking; position of seat-backs and safety belts; and the location and use of emergency exits.

1.17.9 Flight idle fuel flow adjustment

Section 4 of the POH, *Normal Procedures,* contains a procedure for checking the flight idle fuel flow rate. This is a post-maintenance procedure and consists of an on-ground check and an airborne check. During the on-ground check the Power Lever is set to FLIGHT IDLE and the Speed Lever set to LOW and the engine rpm should be 96.5 ± 0.5 %. During the airborne check the Speed Lever is set to 100% (high) and at 85 KIAS the Power Lever is set to FLIGHT IDLE; the resulting descent rate should be between 1,300 and 1,400 ft/min. If the descent rate is lower or greater than this the flight idle fuel flow needs adjusting. The Aircraft Maintenance Manual states that the flight idle fuel flow check should be carried out following an engine change or an FCU change.

The Operator's engine ground run performance check requires the flight idle fuel flow check to result in an engine rpm "Approximately 88%". When the engines were installed on 9N-AHA, their rpm at flight idle and speed lever low were recorded to be 90% rpm. This was 6% below the minimum permissible in the AMM. There was no record of any airborne flight idle fuel flow check having been carried out by the operator. This lower than required rpm would result in a lower than required fuel flow rate which would result in higher drag from an engine at flight idle. It could also result in the in-flight flight idle rpm dropping below 100% rpm with the Speed Lever remaining in high.

1.18 Additional Information

1.18.1 Bird deterrence procedures at TIA

The international airport is located about 6 km from the city centre and between the heavily polluted Bagmati river in the north and west and Manohara river in the east and south. High population density, particularly along the river banks, combined with wetlands, grains, crops, open markets, etc have created a number of haphazard waste deposit areas which are highly attractive to birds.

1.18.1.1 Regulatory provisions

According to the Local Self-Governance Act, 2005, Metropolis, Sub-metropolis and Municipalities are:

(a) Made responsible for waste management, kanji house, butcheries, river pollution control etc.

(b) Authorized to impose a fine up to Rs. 15000/- to those who dispose the garbage in haphazard way.

Civil Aviation Rule 2058, Clause 77 states that no butchery shall be established within 3 km from the airport and also that:

(a) Waste material shall not be thrown in a haphazard way within the airport boundary.

(b) CAAN can punish and impose fines upon the person or the firm found responsible for haphazardly throwing the waste material.

(c) Nobody is allowed to operate flights at TIA that exceed the pollution level in order to preserve the cultural heritage, atmosphere and environment.

(d) CAAN can impose separate charges on all arrivals and departures in order to maintain a sustainable environment at the airport.

TIA has its own Aerodrome Manual, TIA Bird Control Procedures and TIA Civil Aviation Office (CAO) Bird Control Manual to aid those personnel involved in bird control administration and management at TIA. The Aeronautical

Information Publication of Nepal also provides information on *Bird Concentration on or in the vicinity of Airports*. It also includes the format of CAAN Bird Strike Reporting Forms.

The Government of Nepal, by cabinet level decision, has established in 1999 a national level Airport Bird Control and Reduction Committee under the Chairmanship of the Secretary at the Ministry of Culture, Tourism and Civil Aviation. This committee created an airport level committee under the Chairmanship of the Chief of the respective Civil Aviation Authority office.

1.18.1.2 Bird dispersal techniques

There are some bird dispersal techniques being applied at TIA to scare birds away from airports: 'wailer' units producing sonic and ultrasonic sound; 'quad blaster' ultrasonic units; gas cannons; scare crow visual equipment; patrols with personnel armed with weapons; earthworm control techniques; cleaning of the runway and taxiways; issuing of NOTAMs about bird activities; and a public awareness program. Despite applying these measures, bird activity remains an issue at TIA (Figure 1.18-1).

Figure 1.18-1
Birds over the runway at TIA on 3 October 2012

1.18.2 Bird remains examination

The remains of the bird found on the runway were examined with the following results:

Common Name: Black Kite

Scientific name: Milvus migrans

Tentative age: Sub adult

Length: 56 cm (after joining broken parts)

Weight when it was alive would be approximately 650-750 g

Typical wing span of a Black Kite is 130 to 155 cm.

The total weight of the carcass was 695 g. There were no missing parts but the carcass body was broken into three parts: the largest part, weighing 460 g, included the head, body and right wing; the pelvic part, weighing (185 g) included the two legs; and the right wing, weighing 50 g. The bird appeared to have been cut or sliced through the propeller tips was examined in the national zoo laboratory.

Figure 1.18-2
The remains of the bird found on the runway were examined in national zoo lab

1.18.3 Engine air intake

The engine air intake is U-shaped and is approximately 39 cm wide and 13 cm high in the centre (Figure 1.18-3).

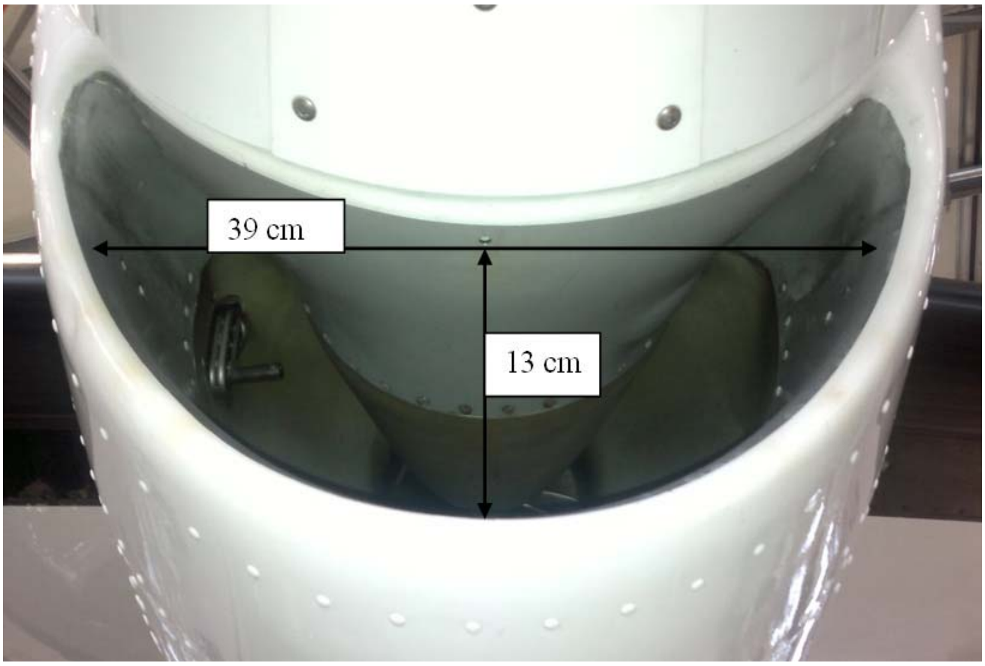

Figure 1.18-1
Dimensions of engine air intake

2 Analysis

2.1 Engineering analysis

2.1.1 Accident site evidence analysis

The evidence from the accident site indicated that the aircraft had struck the ground in a near-vertical attitude with its upper surface facing towards the north-west, but with some horizontal speed towards the south-east. The main landing gear was found in the retracted position, the flaps were set to 'Flaps 2' and the rudder trim was set to about 10° right rudder (about half the maximum). The speed levers were in a position which indicated that 'feather' had not been commanded. The post-impact fire had consumed a large part of the fuselage and because the FDR data revealed that the aircraft had not suffered any controllability problems until after the stall warning, an examination of the flight control remains was not carried out. The engineering investigation was focused on the examination of the engines and propellers to try and explain the aircraft's loss of performance.

2.1.2 Powerplant evidence analysis

Detailed examinations of the engines and propellers were carried out by the respective manufacturers under the supervision of an investigator from the US NTSB. No pre-impact faults were found inside the engines and the evidence of bent compressor blades and rotational scoring in both the compressor and turbine sections indicated that both engines were rotating at impact. The metal spatter deposits in the turbine sections indicated that the burners were lit at impact so it could be concluded that both engines were operating at impact, although the amount of power could not be determined from the engine examinations alone.

The propeller examinations revealed minimal damage to the propeller blades which indicated that the engines were at low or no power at impact. However, there was also evidence that both blades had been at normal blade angles at impact – not in reverse or in high pitch/feather. An operating NTS system would have driven the blades towards feather if the engine had failed, so the blade angle evidence indicated that the engines were operating at impact.

The combined evidence from the engines and propellers indicated that the engines were both at low power at impact, probably at or near flight idle power. In an accident scenario it is not uncommon for a pilot to pull the power levers back to idle just before ground impact, so this does not provide evidence for what the engine power was during the flight. However, it does indicate that the engines probably did not flame-out in-flight because there was limited time to relight them and there was no evidence on the CVR that the pilots were attempting a relight.

No evidence of bird remains was found inside either engine and so, although there was evidence that the black kite had probably been struck by a propeller, there was no evidence that any part of it was ingested. It is possible that the bird momentarily disturbed the air flow into the engine before it was struck by the propeller, causing a surge and the suspected flame seen in the CCTV footage, but the engine manufacturer considered this unlikely. The manufacturer considered that if the bird had been sufficiently close to the air intake to disturb the air flow it would have been sucked in. If the flame seen in the CCTV and accompanying 'bang' heard on the CVR were evidence of an engine surge, then another possible cause is a fuel flow problem. However, the manufacturer also commented that this type of engine was very resistant to surge.

It is possible that there was a problem with one or more engines that caused the power to reduce to a near flight idle condition. A problem which resulted in a lower than commanded fuel flow rate would cause a loss of power. Because of the poor condition of the fuel control units, a fuel flow problem could not be entirely excluded. However, fuel exhaustion can be ruled out as an issue because the extensive post-impact fire revealed that there was significant fuel onboard. Fuel contamination was possible but considered unlikely as other aircraft that had refueled from the same tanks had not suffered problems.

2.1.3 Flight idle fuel flow adjustment

There is a requirement to set the fuel flow on the ground, with the Power Lever at FLIGHT IDLE, with the Speed Lever at LOW, and with the propellers on the start lock, such that the engine rpm is 96.5 ± 0.5 %**.** The operator set the rpm to approximately 88% which is likely to lead to a low engine flight idle rpm during flight and increased drag, especially during approach and landing. There is also a requirement to check the descent rate at FLIGHT IDLE in the air but this check was not carried out. The following Interim Safety Recommendation was therefore made by the Commission:

It is recommended that the Flight Safety Standards Department at the Civil Aviation Authority of Nepal, ensures that all Dornier 228 aircraft flying in Nepal are checked to confirm that the flight idle fuel flow of their engines has been set in accordance with the Aircraft Maintenance Manual and the Pilot's Operating Handbook.

2.2 Operational analysis

2.2.1 Aircraft energy during the flight

During the takeoff, the speed was checked at 50 kt by both pilots, and the recording of this check on the CVR occurred at a time only marginally before 50 kt was recorded on the FDR. This suggested that there was no gross indication error between the Captain and Co-pilot's airspeed indicators. As the Co-pilot called "VEE ONE ROTATE", with the aircraft approaching 70 kt, a sound was recorded on the CVR which was (as far as could be ascertained) coincident with a flash or flame seen on the CCTV recording of the takeoff. Coincident with the sound and flash was a momentary dip in the rpm of one of the engines but it was not possible to tell which one. The captain rotated the aircraft but it did not lift off because the V_1, V_R call had been made approximately 13 kt below V_1. The STOL V_R with Flaps at 2 is 71 kt and it is conceivable that the Co-pilot used this speed in error. The STOL MTOW is 5,700 kg and the aircraft weight was above this, which explains why the aircraft did not become airborne at this speed.

Up to approximately 70 kt, the acceleration during the accident takeoff was similar to the acceleration of the aircraft on earlier takeoffs at the same airport. Above 70 kt, however, the aircraft during the accident flight accelerated at a lower rate than it had on earlier fights. However, the rate of increase of energy was still sufficient to suggest that there had not been a complete loss of thrust from one engine.

The aircraft lifted off at approximately 86 kt (which was faster than V_1, V_R and $V_{2)}$, the gear was raised immediately and the aircraft accelerated to 89 kt over two seconds. As the aircraft left the ground, the rate of increase of its total energy reduced to a marginally positive value. After four seconds, the marginal increase in energy became a steady decrease, indicating that there was more drag than thrust, and by this point the speed had started to decrease.

Audio analysis of the CVR recording suggested that, just before the gear was fully retracted, and with the aircraft already decelerating, one engine ran down to 95% of its nominal speed. The aircraft levelled off approximately 100 ft above the runway at 77 kt and flew level for approximately 14 seconds. During this time, the net loss of energy continued and the aircraft decelerated, eventually to 69 kt. The lack of performance was marked enough compared to the norm to be noticeable from the ATC tower prompting the controller to ask if the aircraft had a technical problem.

Audio analysis suggested that, during the level flight phase, the engine ran down a second time to reach 91% of its nominal value just as the pilot said "DUE BIRD HIT". The evidence suggested that this engine remained at 91% until the end of the flight and that the other engine operated at 100% throughout the flight.

The stall warning was triggered for nine of the final 11 seconds of flight, initially when the aircraft was level and decelerating through 71 kt, and then as the aircraft decelerated to 69 kt and began to descend. Witness evidence was that the aircraft was in a left turn when it became inverted with a very low nose attitude. Evidence at the accident site suggested that the nose was the first part of the aircraft to impact the ground following which the aircraft came to rest the right way up facing back the way it had come. This evidence is consistent with the aircraft stalling in a left turn and departing from controlled flight, probably with a marked drop in the left wing and with the nose dropping to an extremely low nose attitude such that it was the first part of the aircraft to hit the ground.

2.2.2 Aircraft performance during the flight

Performance calculations by the TC holder showed that a grossly overweight aircraft would have had better performance than the accident aircraft and so overloading alone was not the cause of the reduced performance.

If one engine had failed 9N-AHA would not have had the performance to follow the observed climb profile. The simulation showed that, at a takeoff weight of 6,000 kg, the observed climb profile would have been the result of an average 33% power loss which showed that the thrust available in the climb was greater than would have been available following the complete failure of one engine.

When configured with Flap 2 and landing gear UP the aircraft should have had a climb rate of approximately 220 fpm at V_2 (83 kt) even with a 50% loss of thrust. The aircraft actually climbed 100 feet over 13 seconds, an average climb rate of 460 fpm, and this climb rate was probably achievable only with a nose attitude that was too high to maintain the airspeed. Consequently, the airspeed dropped to 77 kt by the end of the climb phase.

If the aircraft was suffering a 33% power loss at the end of the climb phase, there should have been sufficient power available to maintain level flight at 77 kt. The fact that the aircraft decelerated indicated that there was a further power loss during the level flight phase, or just before the level flight phase, which was quantified approximately by the simulation as a minimum of either 60% AEO or 13% from the operating engine OEI. The lack of power to maintain level flight might also have resulted from: an aircraft at 6,200 kg OEI where the operating engine was delivering 93% of the power available; or an aircraft at 6,400 kg OEI where the operating engine was delivering 100% of the power available.

The drag on an engine at flight idle is greater than the drag on an inoperative engine (OEI), and in the case of 9N-AHA where the flight idle fuel flow was incorrectly set too low, the drag would have been even greater at idle (in excess of 350 lb of drag – reference section 1.16.2). It is therefore possible that at about 6,200 kg with one engine at 100% power and one engine at flight idle, there would have been insufficient thrust to maintain 77 kt, and the additional drag on one side would have affected controllability more than in the OEI case.

The speed 77 kt was behind the power required curve for both the AEO and OEI cases and, once the speed started to decay, the power required to maintain the new speed would have increased. This power would not have been available and so the speed would have decayed further leading to a further increase in power required and, therefore, a continual deceleration. The only way to maintain speed would have been to lower the nose and descend but the aircraft had insufficient height to do so and, by this time, had drifted left of the runway and was heading towards a populated area.

Had the aircraft maintained V_2 during the climb, it would have attained an altitude greater than that shown by the yellow line in Figure 1.16-1, because the yellow line assumes the total loss of power from the operative engine, and it would have had a speed of V_2 (83 kt) at the beginning of the level flight phase. At this speed, less power would have been required to maintain level flight than was required at 77 kt. The investigation could not determine whether the power available would have been sufficient to maintain speed during the level flight phase had V_2 been maintained during the climb phase.

2.2.3 Pilot training

The evidence suggests that there was a loss of power that began as the aircraft accelerated through approximately 70 kt, which was below V_1. The POH requires flight crews to reject the takeoff following an engine malfunction before V_1 but this requires flight crews to recognise that there has been a malfunction. There was no evidence to suggest that the flight crew recognised that a power loss had occurred on the ground, possibly because it occurred gradually and progressively rather than instantaneously. This would account for why the takeoff was continued.

From approximately two seconds after leaving the ground until it began to descend at the end of the level flight phase the aircraft turned left slowly from 200°M to approximately 173°M. Once it started to descend, the rate of turn increased markedly. There was 10° of right rudder trim applied which was consistent with there being more thrust from the right engine than the left. Therefore, the turn to the left was probably the result of insufficient application of right rudder, either through rudder trim or foot pressure on the right rudder pedal.

For an engine malfunction that occurs on takeoff at or above V_1, the POH allows flight crews to continue the takeoff or land back on the runway should it be long enough to safely bring the aircraft to a stop. There was probably between 2,500 and 3,000 ft of runway available ahead of the aircraft which should have been sufficient to bring the aircraft to a halt but the flight crew did not select this option. One reason the commander might have decided not to land was because company policy is that the takeoff should be continued for an engine malfunction at or above V_1.

When asked by ATC, the Commander stated that the aircraft had suffered a bird strike which suggested that he was aware that the aircraft was not performing correctly. However, there was no evidence on the CVR that the flight crew tried to diagnose the malfunction or that they ran through any emergency checklist actions. Evidence from the FDR showed that the aircraft did not maintain V_2 which would have been expected following an engine malfunction that had been recognised during this phase of flight. Pilots flying this type of aircraft in Nepal do not train in simulators for engine malfunctions at or near V_1 and therefore the flight crew was faced with a circumstances that they were not fully trained to deal with. Therefore:

It is recommended that the Civil Aviation Authority of Nepal reviews its training requirements in relation to engine malfunctions at or near V_1 to ensure that they are adequate for commercial pilots flying aircraft for which training is currently not carried out in a flight simulator.

It is recommended that Sita Air Ltd reviews the policy that prevents pilots from landing on the remaining runway following an engine malfunction just after V_1.

2.2.4 Baggage and aircraft loading

CCTV evidence showed baggage being loaded into the baggage compartment at the rear of the aircraft and also showed that it was not removed before the aircraft taxied. The load sheet recorded that the baggage had been offloaded but the airline subsequently stated that 70 to 80 kg was on board. It was not possible to verify how much baggage was on the aircraft but all that was loaded into the aft cargo compartment remained for the takeoff and there was no evidence in respect of the forward cargo compartment.

Witness evidence was that there was a lack of consistency between baggage scales at Tribhuvan and Tensing/Hillary airports. The error, if substantiated, was in the sense that would lead to an aircraft being overloaded for departure from Lukla which would reduce safety margins.

Passengers on the accident flight had standard weights totalling 1,145 kg although they were recorded as weighing a total of 1,150 kg. A 2 kg under load was recorded on the load sheet but this did not account for the 70 to 80 kg baggage that the airline stated subsequently on the aircraft. The aircraft was therefore dispatched with an overload of up to approximately 80 kg, according to airline figures.

Incorrect CG positions were recorded on the trim sheet for the flight. The inspection by a European travel company recorded three miscalculations in the load sheets it assessed, all in the sense of recording a lower traffic load than was actually the case. It also noted that several flights departed 1 kg under MTOW and that the flight it assessed was actually overloaded by 23 kg. The load sheets for the three flights before the accident flight also showed takeoff weights within 2 kg of MTOW.

The UK, European and Indian regulations use higher standard weights for passengers than the CAAN regulations. Using the UK, European or Indian regulations, the aircraft would have been above the STOL-limited MTOW for a flight on this route even without an allowance for baggage.

The actual weight of passengers and baggage on board is unknown. However, it is feasible that the passengers weighed more than was recorded and it was shown that the aircraft took off above its STOL-limited MTOW because of baggage on board that was unaccounted for. In the worst case, the TOW could have been 6,168 kg which would also have been above the higher, WAT-limited, MTOW of 6,075 kg and, in this case, takeoff performance might have been compromised.

In the discussion above: the errors on the load and trim sheet; the fact that baggage was on board the aircraft that was stated to have been off-loaded; the doubt about the accuracy of scales used for weighing baggage; the use of standard passenger weights that are less than other European, British and Indian equivalents; and the practice of loading the aircraft to within 2 kg of MTOW means there can be little confidence in the accuracy of actual takeoff or landing weights and whether or not they are above the maximum allowable in the circumstances. It is essential that aircraft performance planning is based on realistic takeoff weights or there is a risk that aircraft performance will be compromised following an engine malfunction or during normal operations, especially into a STOL-limited airport. Therefore the following interim safety recommendations were made:

> The Operators and the Civil Aviation Authority of Nepal must ensure that their respective weighing machines at the check in counter of all the airports are calibrated regularly by the appropriate authority of the Government of Nepal.

The Operators and the Civil Aviation Authority of Nepal (CAAN) must ensure that all the hand bags and checked baggage, especially when carried to and from STOL airports, are weighed and tagged with their weight mentioned in the respective tags before they are boarded, and load and trim sheets of all the departing aircrafts are prepared by qualified CAAN authorized airline personnel.

The Flight Safety Standards Department at the Civil Aviation Authority of Nepal must ensure that all Dornier 228 aircraft flying in Nepal are checked to confirm that the flight idle fuel flow of their engines has been set in accordance with the AMM and POH.

In addition, the following recommendations are made as a result of this investigation:

It is recommended that the Civil Aviation Authority of Nepal reviews the training requirements for airline personnel responsible for the loading of aircraft to ensure there is confidence that aircraft takeoff properly loaded.

It is recommended that the Civil Aviation Authority of Nepal reviews the suitability of the average weights used for passengers on flights within Nepal and modifies them if necessary.

It is recommended that the Civil Aviation Authority of Nepal carries out periodic checks of aircraft load sheets to ensure they have been completed correctly and accurately.

2.2.5 Pre-flight safety demonstration

FOR (Aeroplanes) requires operators to ensure that passengers are made familiar with the location of safety equipment. The operator's Operations Manual requires passengers to be briefed verbally on certain safety matters including safety belts and emergency exits. The inspection of the operator carried out by a European travel company noted that there was no passenger safety demonstration on the flight it observed and recommended that passenger briefings before departure should be implemented. Witness evidence during this investigation was that the operator did not provide pre-flight safety demonstrations to the passengers on two flights. Therefore:

It is recommended that Sita Air (P) Ltd ensures that passengers on its flights are given safety briefings before departure in accordance with FOR-Aeroplanes and its Operations Manual.

It is recommended that the Civil Aviation Authority of Nepal monitors airlines within Nepal to ensure that passengers are given safety briefings before departure.

2.2.6 Bird control at TIA.

There are provisions in place to reduce bird activity in the vicinity of TIA: Local Self-Government legislation; Civil Aviation Rules; procedures within the TIA Aerodrome Manual and the TIACAO Bird Control Manual. Despite these provisions, bird activity remains a threat to aircraft using TIA. Therefore, the following recommendations are made:

TIACAO should review its bird control program, the bird strike reporting system and the bird activity monitoring system to determine whether their effectiveness at reducing bird activity can be improved.

TIACAO should manage and control more effectively and efficiently the habitats attractive to birds on and near to TIA.

Kathmandu Metropolis, Lalitpur Sub-Metropolis, Bhaktapur Sub-Metropolis and Madyapur Thimi Municipality should adopt more effective measures for waste management, kanji house, butcheries and river control in order to reduce bird activity near to TIA.

2.2.7 Airport Fire Service

The Airport Fire Service response was hampered by difficulty getting to the exit gates and an inability to pass the Army-controlled exit easily. Also, the view from the fire service watch tower was restricted by the structure of the building. Therefore:

> It is recommended that the Civil Aviation Authority of Nepal should ensure that personnel in the Airport Fire Watch Tower are able to see all areas appropriate to their role in and around TIA.
>
> It is recommended that the Civil Aviation Authority of Nepal should ensure that Airport Fire Service vehicles have clear and unhindered access to the exit gates and free movement through the gates in case of emergency.

2.3 **Summary**

Evidence from the accident site and subsequent analysis of the engines and propellers showed that the engines were producing low power at impact and neither propeller had been feathered. No faults were found during the engine examinations and there was no evidence of bird ingestion. Due to the extensive damage of some components a fuel flow problem could not be entirely excluded.

The aircraft suffered an insidious reduction in power approximately 70 kt during the takeoff run. The reduction in acceleration seems not to have been noticed by the flight crew because there was no decision to reject the takeoff. After lift-off, the nose attitude was too high for the aircraft to maintain V_2, the thrust was insufficient to maintain speed at the selected attitude and the aircraft decelerated.

The aircraft levelled off at approximately 100 ft AAL and 77 kt but the thrust had decreased further and was insufficient to maintain 77 kt. At 77 kt, the aircraft was operating behind the power required curve and so the reduction of speed led to an increase in the power required to maintain level flight and the aircraft continued to decelerate.

The position of the rudder trim tab, and the fact that the acoustic signature associated with one of the engines remained at 100% throughout the flight, suggested that the thrust reduction was probably on the left engine. This was consistent with the fact that the aircraft drifted to the left of the runway after lift-off. The aircraft continued to decelerate and drift away from the runway until it stalled and then departed from controlled flight.

The investigation was unable to determine the cause of the thrust reduction.

3. Conclusions

(a) Findings

1. The flight crew was properly licenced and rested.

2. The aircraft had valid Certificates of Registration and Airworthiness.

3. The aircraft had a valid Maintenance Release Certificate.

4. On ground, the flight idle fuel flow of the engines on the aircraft had been set to give an idle rpm of 90% instead of the correct value of 96.5 ± 0.5 % and flight idle descent check had not been carried out as per the AMM/POH.

5. The aircraft began its takeoff run from Intersection 2 of Runway 20 at TIA and the runway length available from that point was 6,929 ft.

6. The acceleration of the aircraft was normal until approximately 70 kt.

7. The flight crew made an unsuccessful attempt to rotate the aircraft at approximately 70 kt, 13 kt below V_1.

8. The aircraft hit a bird at approximately 70 kt during the takeoff run. Bird remains were found on the runway that constituted the entire bird and no evidence of bird remains was found in the engines.

9. Above 70 kt, but below V_1, the aircraft's acceleration was below normal.

10. The aircraft lifted-off at approximately 86 kt.

11. Audio signatures associated with one of the engines remained constant at 100% while the aircraft was airborne.

12. Audio signatures associated with one of the engines dropped to 95% of their nominal frequencies just after the landing gear was raised, and dropped to 91% shortly thereafter.

13. The aircraft accelerated to 89 kt in the two seconds after lift-off and then decelerated to 77 kt as it climbed to 100 ft AAL.

14. At 100 ft AAL and 77 kt, there was insufficient thrust from the engines to overcome the drag of the aircraft and the aircraft began to decelerate.

15. The aircraft drifted to the left of the runway, probably because the left engine was delivering less power than the right.

16. The aircraft stalled while in a left turn, departed from controlled flight and impacted the ground in an extremely nose-low attitude.

17. The impact with the ground was not survivable.

18. The engines were operating and delivering low or flight idle power at impact and the propellers had not been feathered.

19. The airport fire service reported that the fire was under control at 0057 hrs. The fire service response was delayed because Army personnel were blocking the route to the exit, and personnel manning the exit required permission to unlock the gates to let the fire vehicles pass.

20. The passenger manifest recorded that all baggage had been offloaded when at least 80 kg was on board the aircraft.

21. The aircraft loadsheet recorded a takeoff weight of 5,834 kg but this figure did not include an allowance for baggage.

22. The aircraft takeoff weight was 5,914 kg (calculated using regulated standard weights for passengers) whereas the maximum takeoff weight allowed for the flight was 5,836 kg.

23. The trim sheet for the flight recorded incorrect positions for the aircraft centre of gravity but the aircraft was not in an out-of-trim condition.

(b) Causal Factors

The investigation identified the following causal factors:

1. During level flight phase of the aircraft, the drag on the aircraft was greater than the power available and the aircraft decelerated. That resulted in excessive drag in such critical phase of ascent lowering the required thrust. The investigation was unable to determine the reason for the reduced thrust.

2. The flight crew did not maintain the airspeed above the stall speed and there was insufficient height available to recover when the aircraft departed controlled flight.

(c) Contributory Factors

The investigation identified the following contributory factors:

1. The flight crew did not maintain V_2 during the climb and so the power required to maintain the level flight was greater than it would otherwise have been.

2. The flight crew did not maintain the runway centreline which removed the option of landing the aircraft on the runway remaining.

4. Safety Recommendations

The Commission issued the following Interim Safety Recommendations to the Government of Nepal on 29 November 2012 so that instructions could be issued to those concerned:

1. The Operators and the Civil Aviation Authority of Nepal must ensure that their respective weighing machines at the check in counter of all the airports are calibrated regularly by the appropriate authority of the Government of Nepal.

2. The operators and the Civil Aviation Authority of Nepal (CAAN) must ensure that all the hand bags and checked baggage, especially when carried to and from STOL airports, are weighed and tagged with their weight mentioned in the respective tags before they are boarded, and load and trim sheets of all the departing aircrafts are prepared by qualified CAAN authorized airline personnel.

3. It is recommended that the Flight Safety Standards Department at the Civil Aviation Authority of Nepal, ensures that all Dornier 228 aircraft flying in Nepal are checked to confirm that the flight idle fuel flow of their engines has been set in accordance with the AMM and POH.

The following Safety Recommendations were made as a result of this investigation:

4. It is recommended that the Civil Aviation Authority of Nepal reviews its training requirements in relation to engine malfunctions at or near V_1 to ensure that they are adequate for commercial pilots flying aircraft for which training is currently not carried out in a flight simulator.

5. It is recommended that Sita Airlines Pvt. Ltd reviews the policy that prevents pilots from landing on the remaining runway following an engine malfunction just after V_1.

6. It is recommended that the Civil Aviation Authority of Nepal reviews the training requirements for airline personnel responsible for the loading of aircraft to ensure there is confidence that aircraft dispatch properly loaded.

7. It is recommended that the Civil Aviation Authority of Nepal reviews the suitability of the average weights used for passengers on flights within Nepal and modifies them if necessary.

8. It is recommended that the Civil Aviation Authority of Nepal carries out periodic checks of aircraft loadsheets to ensure they have been completed correctly and accurately.

9. It is recommended that Sita Air Pvt. Ltd ensures that passengers on its flights are given safety briefings before departure in accordance with FOR-Aeroplanes and its Operations Manual.

10. It is recommended that the Civil Aviation Authority of Nepal monitors airlines within Nepal to ensure that passengers are given safety briefings before departure.

11. It is recommended that TIACAO reviews its bird control program, the bird strike reporting system and the bird activity monitoring system to determine whether their effectiveness at reducing bird activity can be improved.

12. It is recommended that TIACAO manages and controls more effectively and efficiently the habitats attractive to birds on and near to TIA.

13. It is recommended that Kathmandu Metropolis, Lalitpur Sub-Metropolis, Bhaktapur Sub-Metropolis and Madyapur Thimi Municipality adopt more effective measures for waste management,

kanji house, butcheries and river control in order to reduce bird activity near to TIA.

14. It is recommended that the Civil Aviation Authority of Nepal should ensure that controllers in the Airport Fire Watch Tower are able to see all areas appropriate to their role in and around TIA.

15. It is recommended that the Civil Aviation Authority of Nepal should ensure that Airport Fire Service vehicles at TIA have clear and unhindered access to the exit gates and free movement through the gates in case of emergency.