Beech 200 King Air, VP-BBK

AAIB Bulletin No: 7/2003	Ref: EW/C2000/12/7	Category: 1.2
Aircraft Type and Registration:	Beech 200 King Air, VP-BBK	
No & Type of Engines:	2 Pratt & Whitney PT6A-42 turboprop engines	
Year of Manufacture:	1995	
Date & Time (UTC):	23 December 2000 at 1351hrs	
Location:	1 nm north-east of Blackbushe Airport, Surrey	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - 4
Injuries:	Crew - 1 (Fatal)	Passengers - 4 (Fatal)
Nature of Damage:	Aircraft destroyed	
Commander's Licence:	FAA Airline Transport Pilot's Licence	
Commander's Age:	53	
Commander's Flying Experience:	2,664 hours (of which 1,243 were on type)	
	Last 90 days - 108 hrs	
	Last 28 days - 24 hrs	
Information Source:	AAIB Field Investigation	

Synopsis

The aircraft, with the pilot and four passengers on board, departed Blackbushe from Runway 08 in fog with a visibility of less than 500 metres. As the aircraft reached the upwind end of the runway it was seen to bank to the left before disappearing from view. It crashed 13 seconds later into a factory complex where a major fire ensued. All on board were fatally injured. A substantial amount of the aircraft structure was consumed by fire. Engineering examination of that which remained showed that there was no malfunction found within the engines, propellers or controls that would have affected the flight. Analysis of the cockpit voice recorder however showed a reduction in one of the propellers rpm as the aircraft rotated that would have led to thrust asymmetry. Through a combination of lack of visual reference, confusion as to the cause of the power reduction and possible disorientation the pilot lost control of the aircraft and although he may have realised the situation seconds before impact with the ground there was insufficient height available to effect a safe recovery.

History of the flight

The pilot intended to fly from Blackbushe to Palma in Spain with four passengers. At 0830 hrs that morning he was joined at his home by a colleague who saw him printing weather information from his lap top computer. This included aerodrome forecasts (TAFs) and aerodrome meteorological reports

(METARs) for airfields including Farnborough, London Heathrow, Bournemouth and Palma. Furthermore, prior to leaving home, the pilot made a telephone call to the duty Aerodrome Flight Information Service Officer (AFISO) at Blackbushe asking him for the present airfield weather, which was relayed to him as 'RVR 500 metres in fog'. The pilot also instructed the AFISO to file the stored flight plan for a departure time of 1200 hrs.

During the car journey to the airfield the pilot commented to his colleague on the reducing visibility but did not appear concerned and did not reference it to his intended flight. They arrived at the airfield at approximately 1100 hrs and met with the four passengers. The pilot then went to the tower and asked the AFISO for permission to drive the length of Runway 26/08 to check the RVR for himself. Permission was granted and an airfield fire vehicle, equipped with a radio, was provided as an escort. During the inspection the runway edge lighting was turned up to maximum intensity. Following his inspection the pilot told his colleague that he was able to see four white runway centreline marks and was "comfortable with the visibility for a takeoff".

The pilot met his passengers in the hangar where the aircraft was parked, was shown a receipt for the uplift of 987 litres of fuel by the ground handler, and confirmed that the aircraft tanks were full. As the planned departure approached the AFISO contacted the pilot who instructed him to put a 30 minute delay on the flight plan. During this delay the pilot organised his flight documentation in the cockpit and secured the luggage in the rear hold. At the same time his colleague ensured that four books of approach plates and a life raft were placed on board. Subsequently the pilot delayed the flight plan for a further 30 minutes followed by an additional 25 minutes to achieve a departure time of 1325 hrs.

Three of the passengers boarded the aircraft in the hanger. It was then towed, by the ground handler, and parked on the hard standing. Whilst doing so he noted the passenger's seating positions. A male passenger then boarded the aircraft and occupied the front right pilot's seat. Throughout the boarding the pilot had been in the maintenance manager's office making a telephone call. He also had a brief discussion with a manager regarding the poor visibility and explained to him that during the take-off roll he would visually maintain the runway centreline as the aircraft accelerated and rely on someone else to readout the airspeed; a technique he had carried out before in the simulator.

The pilot boarded the aircraft and sat in the front left pilot's seat. The duty engineer connected the ground power and, following a normal start on both engines, disconnected the ground power from the socket in the root of the right wing, aft of the propeller. It is normal practice to start the engines with the propeller controls at their fully forward position. The levers are then retarded to the feathered position in order to reduce propeller wash whilst ground power is disconnected from the rear of the right engine nacelle. This was confirmed not only by the absence of propeller wash experienced by the engineer as he disconnected the ground power, but also by the sound recorded from the cockpit area microphone on the Cockpit Voice Recorder (CVR).

At 1340 hrs the pilot was cleared to enter and backtrack Runway 08. In accordance with the airfield's low visibility procedures two fire vehicles 'Fire 1' and 'Fire 2' were positioned to the north of the runway. The fire officer in 'Fire1' saw the aircraft line up at the 08 threshold, heard the engine power checks being carried out and heard on his cab radio the AFISO transmit 'FARNBOROUGH CLEARS VP-BBK ON DEPARTURE RIGHT TURN TRACK TOWARDS GOODWOOD, CLIMBING ALTITUDE 2,400 FEET; SQUAWK AIRWAYS 7254, FREQUENCY FARNBOROUGH RADAR 134.35'. The pilot read the clearance back correctly. This was followed by a take-off clearance, which the pilot acknowledged and informed ATC that he would call 'rolling' and 'airborne'. The fire officer in 'Fire 1' heard the engine power increase and saw the aircraft commence its take-off roll. The pilot called 'rolling' abeam his position, approximately 200 metres from the start of the take-off run, and disappeared into the fog a few seconds later. The second fireman in 'Fire 2', positioned some 900 meters from the 08 threshold, did not hear the aircraft approaching due to the noise of his vehicle engine but saw the aircraft airborne as it passed him. He reported that the takeoff appeared to be normal although he did not notice the position of the landing gear or flaps before it disappeared into the fog.

A flying instructor who was standing at the base of the control tower saw the aircraft pass abeam his position. He heard the aircraft approaching and whilst he could not make out its shape he saw one of the aircraft lights some 350 metres away at an estimated height of 50 to 70 feet above Runway 26 threshold. The AFISO in the tower heard the aircraft pass but did not see it.

Two witnesses standing by the perimeter fence at the threshold of Runway 26 initially heard the aircraft approaching them making an unusual sound 'similar to a lorry'. When they saw it they noted that both propellers were turning and that it was slightly north of the runway centreline with the wings level in a shallow climbing attitude. The aircraft passed over them and banked gently 30° to the left before disappearing into the fog. Moments later they heard 'two bangs' from the direction that the aircraft had been travelling.

The AFISO instructed the pilot to change frequency to Farnborough but received no acknowledgement. Having checked with Farnborough ATC that the aircraft had not called them he tried again to establish contact and when he was not unable to do so he put into effect the airfield crash procedures. The airfield rescue and fire fighting service (RFFS) responded immediately and, with the co-ordination of the AFISO and directions from members of the public, located the crash site in a factory complex. They proceeded to fight the resulting fire before being joined by local fire appliances. The factory was closed and deserted at the time of impact and thus there were no further casualties on the ground.

Cockpit voice recorder

The aircraft was fitted with a 30-minute solid state CVR. Carriage of this equipment, however, was not mandatory as the aircraft was being operated in the private category. The CVR, which had suffered external structural deformation and fire damage, was recovered and replayed satisfactorily. The surviving memory module retained a complete audio recording of the accident flight from prior to engine start up, to final impact.

The recording showed that the pre-flight checks were carried out solely by the commander, the aircraft was cleared to enter and back track Runway 08 prior to takeoff and the commander advised ATC that he was going to follow low visibility procedures for the departure. During taxi the commander checked the brakes and the operation of the rudder boost system; designed to compensate for induced yaw following an engine failure. As part of the take-off briefing he instructed the occupant of the right-hand seat to call out the airspeed during the take-off roll at intervals of 10 kt up to 70 kt and thereafter at 5 kt intervals. The aircraft lined up on Runway 08 and, having briefed the passengers to expect some vibration, the commander carried out power assurance checks by increasing engine power in stages.

The commander observed that he had full power and began the take-off roll and stated that the 'autofeather' was armed. The right seat occupant began announcing airspeeds from 40 kt at 5 kt intervals. At 70 kt the commander advised ATC that he was rolling. Following this radio transmission and at 85 kt airspeed calls were resumed again in 5 kt intervals. Approximately 20 seconds after brake release, as '110 kt' was announced, the noise of the propellers, recorded from the cockpit mounted area microphone, began to change. For the next four and a half seconds, further airspeed calls of '115 kt', '120 kt' and '125 kt' were recorded. There then followed a delay of 6.5 seconds, during which the commander uttered two muted exclamations, before the next airspeed of '130 kt' was announced. The right seat occupant made only two further announcements of '135 kt' and '140 kt', the latter occurring five seconds before impact. Four seconds before impact the sound of the stall warning was recorded and, for the last three seconds of the recording, the sounds made by the engines / propellers changed rapidly, first decreasing and then increasing in pitch. The CVR stopped operating at the moment of impact due to the removal of power.

Spectral analysis

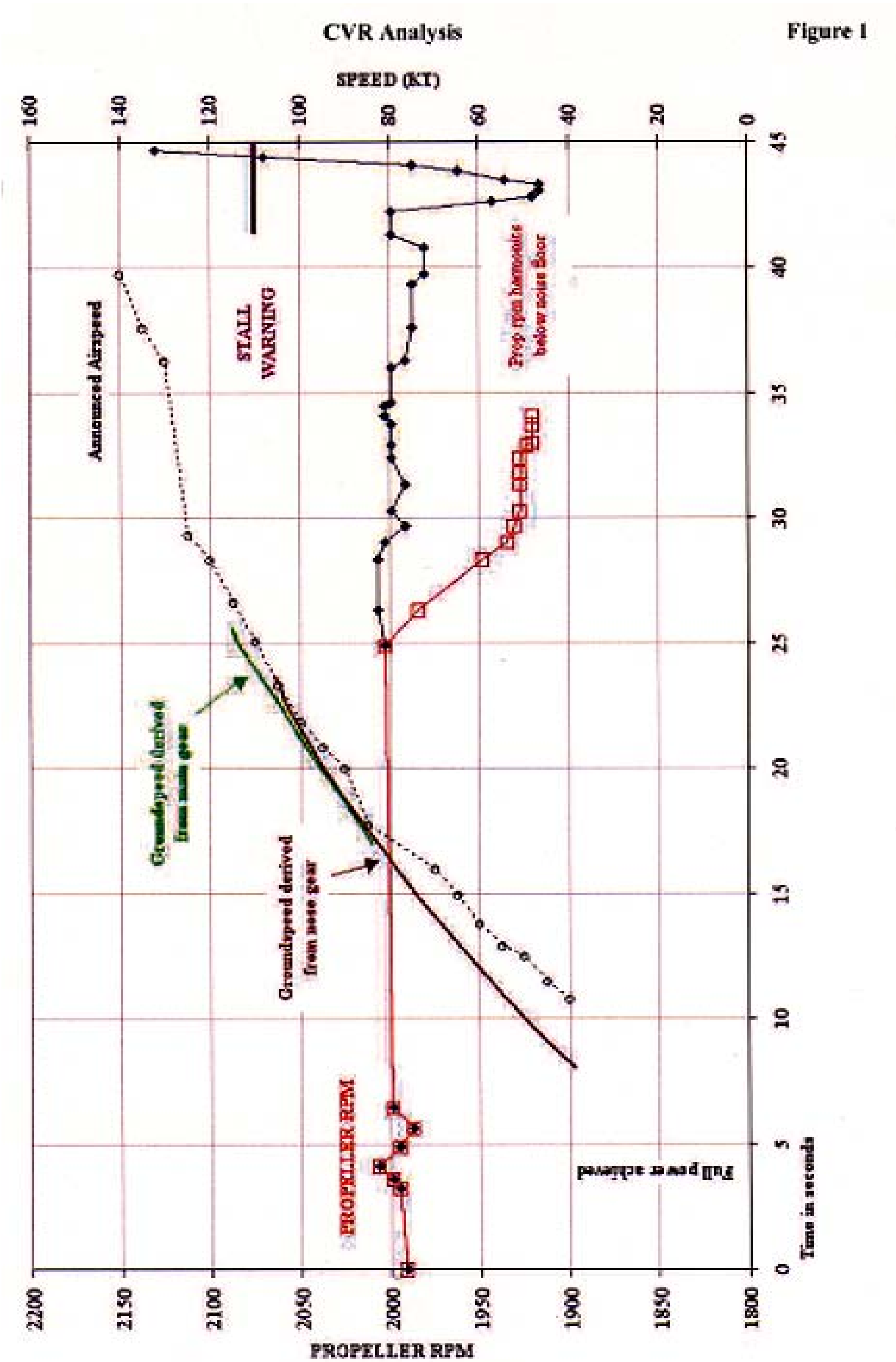
In addition to providing a record of speech on the flight deck, spectral analysis of the four recorded channels on the CVR yielded further information. It was possible, through the use of frequency/time plots to isolate the frequencies associated with both main and nose gear tyre rotation during the take-off roll. Propeller blade passing frequency (and hence propeller rotational speed) was present throughout the recording from the time the engines were started. Due to the monaural nature of the recordings it was not possible to distinguish between the left and right propellers. Furthermore, it was not possible to isolate frequencies associated with rotation of either engine as they were above the upper frequency range of the CVR at all times other than during engine start.

Noting the change in tyre rotational speed and with knowledge of the tyre diameters it was possible to derive an aircraft ground speed during takeoff. Moments where the sounds of nose wheel and then main wheels stopped were considered likely to correspond to aircraft rotation and becoming airborne respectively. It was noted that the derived ground speed correlated well with the announced airspeed calls, particularly above 80 kt where aircraft airspeed indicators are accurate.

The spectral analysis showed that the propeller rotational speeds were symmetrical at 2,000 rpm during the take-off roll. However, where the nature of the sound changed, it was observed that one of the propellers started to reduce in speed; decaying to approximately 1,925 rpm over a period of five seconds before stabilising at that value. The frequencies associated with this lower speed propeller were discernible for the next five seconds before reducing in amplitude (but remaining constant in frequency) until they could not be distinguished from background noise. This reduction in amplitude may be attributable to a reduction in the air mass flow rate through the propeller disc.

During the period of decaying speed of one propeller, the frequencies associated with the other propeller indicated a slight rise in rotational speed to 2,007 rpm for four seconds, before reducing to marginally below 2,000 rpm and then stabilising back at the take-off speed.

During the last 10 seconds of flight, frequencies associated with the lower speed propeller could not be observed and so it was not possible to determine rotational speed. The frequencies from the other propeller could be distinguished and a speed derived. From the plot of parameters calculated using spectral analysis, shown in Figure 1, it can be seen that the speed of this propeller reduced towards 1,900 rpm at a point 2.5 seconds before impact and then increased rapidly. The final, derived value of rotational speed was in excess of 2,125 rpm and occurred at impact.



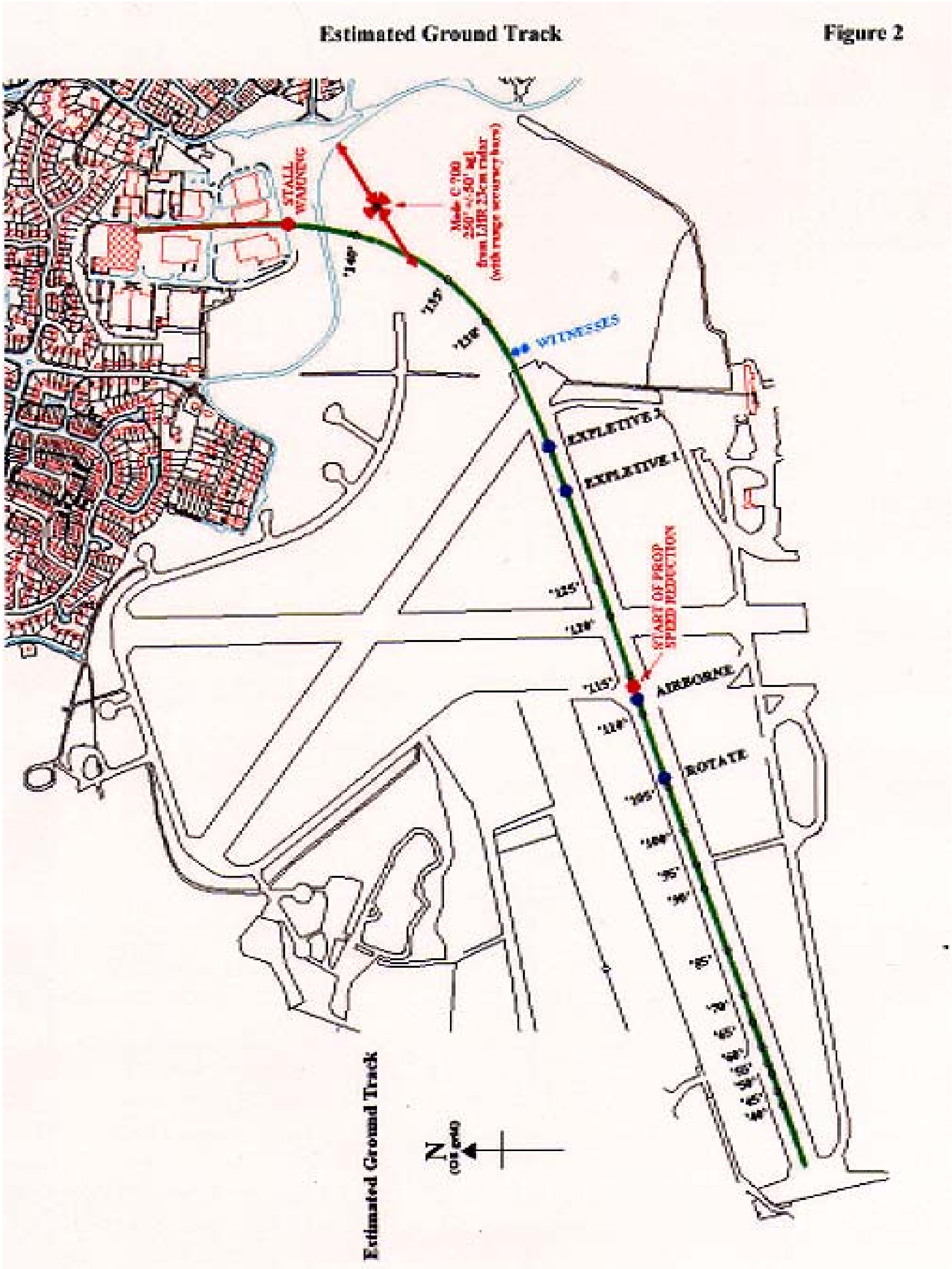
The only time that frequencies associated with rotation of the engines were observable was during engine start as turbine speed increased. No evidence of engine run down, with frequencies reducing to within the recorder bandwidth, was observed during the analysis.

Human factors

An experienced aviation psychologist and expert in 'Human Factors' provided an interpretation of the CVR in relation to the comments made by the pilot and any distraction or disorientation he may have suffered. He reported that shortly after the reduction in propeller rpm the pilot's respiration rate and depth increased indicating a significant increase in his workload. The uttering of an expletive suggested that he had noticed the occurrence of an adverse event and a further expletive, two seconds later, seemed to confirm that something was not right with the aircraft. With the probable reduction in power on one engine the pilot appears to have been working at or close to his limit with little if any spare information processing capacity available.

Aircraft track

From information recorded on the CVR, one 'Mode C' radar return recorded from the Heathrow 23 cm radar, witness evidence, and flight trials using an Islander aircraft, the track of the aircraft over the ground was derived. This, overlaid with the aircraft's airspeed, is shown in Figure 2.



The accident site

The aircraft crashed in a light industrial area that consisted of a number of single storey modern industrial units and two storey office units which were bordered to the north by the large residential area of Yateley and to the south by open common land and Blackbushe Airport. The initial impact site was approximately 10 metres below the level of the airfield. The aircraft wreckage came to rest inside a large single storey industrial unit.

The aircraft initially impacted the ground with its left wing tip. This initial impact was in an area of small shrubs that edged the pavement on the western side of a service road that was approximately 27 metres from the rear entrance of an industrial complex manufacturing rubber components. At the time of the initial impact the aircraft was banked approximately 60° to the left with the nose pitched down approximately 15°. It was descending at around 1000 ft/min and on a heading of about 355°(M) and at a speed of approximately 145 kt. The landing gear was extended and three of the four wing flaps sections were partially extended.

Following the initial impact the aircraft slewed to the left and slid sideways in a northerly direction for 39 metres before impacting the side wall of the main factory unit. In the middle of this side wall were two substantial vertical steel structural roof supports. These ruptured the right wing and severed the aircraft's fuselage structure into three sections. The wreckage, which penetrated the factory unit coming to rest amongst machinery, was then partially buried under that machinery, factory shelving, storage cupboards and items from the factory unit's structure. Fuel from the ruptured right wing ignited and a substantial fire ensued which consumed the majority of the aircraft after it came to rest.

Ground marks made by both propellers showed that both were being driven by the engines at the time of the initial impact.

Wreckage examination

The aircraft suffered a high degree of break-up during the impact sequence and the subsequent fire destroyed much of the structure and hence the available evidence. That which remained relatively intact, however, was subject to a prolonged and detailed examination.

Engines

The cockpit engine and propeller control levers together with their friction systems were examined but because of the nature of the break-up of the aircraft, the post-impact fire and the design of the mechanisms it was not possible to determine their positions at impact.

The engines were subjected to a detailed strip examination at the manufacturer's facility in Canada. The examination revealed internal evidence to indicate that both engines were producing significant and similar degrees of power at impact. Neither engine displayed any indications of any pre-impact fault or failure that would have precluded normal engine operation. A number of the engine and propeller control units were bench tested and found to function satisfactorily. A number of items could not be bench tested because of impact and post-impact fire damage. These items were strip examined and no evidence was found to indicate a pre-impact failure or fault that would have prevented normal operation.

Propellers

Both propellers were subjected to a strip examination at the engine manufacturer's facility. Although a precise blade angle or estimate of engine power could not be made there was sufficient evidence to indicate that at impact the engines were powering the propellers. There were no indications in either propeller mechanism to suggest that they may have been in an abnormal pitch position, such as flight idle, reverse pitch or feather, at impact. There was no evidence seen in either propeller mechanism to indicate a pre-impact fault or failure that would have prevented normal operation.

Flight controls

A detailed examination of what remained of the aircraft structure revealed that all the flying control surfaces were correctly attached at impact and there was no evidence of any pre-impact flying control system failure or restriction.

The control surface trim systems were examined but due to the nature of the aircraft break-up during impact and the fact that the trim systems were cable operated it was not possible to determine their impact positions.

The four screw actuators together with their teleflex drives, flap motor and gearbox and the flap tracks and rollers were examined. The left inboard wing flap screw actuator was found to be at the flap retracted position whereas the other three flap screw actuators were at the 7° flap extended position. No mechanical failure or defect was found to account for the differences in the positions of the screw actuators. There was evidence to indicate however, that towards the end of the impact sequence when the teleflex drives to the screw actuators had become disconnected by aircraft break-up, that a large sustained force had been applied to the rear of the left inboard flap. The combination of this force and disconnection of the flap teleflex drive to the screw actuator had allowed the screw actuator to back-drive to the retracted position. The cockpit flap selection lever was found to be in the 'FLAPS UP' position at impact and the flap position gauge, which was relatively undamaged, showed a reading consistent with the electrical power switched off.

Landing gear

Examination of the hydraulic landing gear extension/retraction system showed that the landing gear was extended at the time of impact. The cockpit landing gear selector lever was found in the 'DOWN' position and the landing gear lever ground lock, which was undamaged and free to operate, was found to be engaged. With electrical power OFF the landing gear lever ground lock defaults to the engaged position. The 'weight-on-wheels' switch that provides electrical power to the landing gear lever ground lock was tested and found to be in the 'weight-off-wheels' position and to function satisfactorily. The electrical solenoid that operates the landing gear lever ground lock was also tested and found to function satisfactorily.

Warning indications

A large number of light bulbs were recovered from numerous system warning and indication captions that were located in the cockpit. These included the 'Warning' and 'Caution-Advisory' annunciator panels and the landing gear position indicator lights. Examination of the bulb filaments did not show any evidence of 'hot stretch' that could have indicated that the bulb had been illuminated at impact. However, specific bulbs, such as the three green landing gear 'DOWN' and locked lights, that would have been illuminated, showed no evidence of hot stretch of their filaments either. It is therefore concluded that the impact forces were not of the magnitude required to cause hot bulb filaments to stretch.

Gyroscopes

The three aircraft gyros, one attitude and two compass, that were located in the forward avionics bay, were examined and found to indicate an attitude and heading consistent with that of the aircraft at impact.

Structure

The main cabin door was found, relatively undamaged, within the main wreckage site. The door's OPEN/LOCK handle was found to be in the UNLOCKED position and due to impact distortion impossible to move to the LOCKED position. Detailed examination of the door and the door frame showed evidence however that it had been correctly located with the latch bolts extended and engaged in the door frame striker plates at the time of the impact. The impact distortion that prevented the 'OPEN/LOCK' handle being placed into the LOCK position was removed and the door mechanism found to functioned satisfactorily. The electrical micro switch, located within the door in the area of the door handle, that triggered a warning in the cockpit of a door 'UNLOCKED' condition, was found capable of producing a cockpit warning with the door handle in the 'LOCKED' position. There had been no previously reported occurrences of spurious 'DOOR UNLOCKED' warnings and the door mechanism and warning system functioned satisfactorily when tested during routine maintenance carried out prior to the accident flight. It is therefore considered that the fault observed with the operation of the door UNLOCKED micro switch, was the result of distortion of the door occurring during the impact sequence.

Because of the severe post impact fire it was not possible to determine if an external panel or engine cowling had become loose or if there had been a bird strike or a pre-impact fire. To date no aircraft parts have been found between the take-off point and where the initial impact occurred.

Aircraft maintenance

The aircraft had undergone a period of maintenance immediately prior to the accident flight. This consisted of a comprehensive inspection, a corrosion check, the overhauling of both propellers, repair of the inboard flap screw actuation mechanisms, a radio equipment check and general aircraft husbandry. The aircraft manufacturer's maintenance requirements and procedures were complied with during all of these maintenance operations. Where possible the areas where maintenance work had been carried out were examined and all were found to have been carried out correctly. During the maintenance activity a number of engine ground runs were conducted following the fitment of the two overhauled propeller units. Prior to these ground runs the frictions applied to the cockpit engine and propeller control levers were slackened off. Immediately prior to the maintenance the owner provided the maintenance organisation with a list of defects that needed to be rectified. All of these defects were rectified and none were significant to the accident scenario.

Aircraft information

Engine and propeller controls

The engine and propeller control levers are conventionally situated between the two pilots with two power levers with individual friction devices adjusted by a screw knob at the base of the quadrant, below their respective lever. The two propeller levers are to the right of the power levers with one friction adjustment governing the freedom of movement for both levers. The 'Pilots Operating Handbook' details the 'Before Takeoff (Runup) Checks' and item No 6 in that checklist states that the 'Engine Control Friction Locks' should be set prior to takeoff.

To the right of the propeller levers are two engine condition levers which are used as fuel cocks and can select normal or high engine idle speeds. The left lever in each case controls the left engine function and the right lever the right engine.

The aircraft was fitted with an 'autofeather' system that, in the event of engine torque dropping below 260 ft lbs, automatically feathers the propeller reducing the drag caused by what is known as a 'disking prop'. If the power lever is moved aft a micro switch relay opens and the 'autofeather' is disarmed. The force required to move the power lever and the propeller control lever aft, with the friction fully off, is 0.6 lbs and 2 lbs respectively

Pilot's Operating Handbook and FAA approved Airplane Flight Manual

The Pilot's Operating Handbook contains a section on 'Propulsion System Controls'. The entry relating to 'Friction Locks' is reproduced below:

FRICTION LOCKS

Four friction locks are located on the power quadrant of the pedestal. When they are rotated counterclockwise, the propulsion system control levers can be moved freely. As the friction locks are rotated clockwise, the control levers progressively become more resistant to movement, so that they will not creep out of position.

Weight and balance

The basic weight and index of the aircraft was 8,531.4 lb with a moment arm of 186.88 inches. To this figure was added 778 lb; the actual and estimated weights of the pilot and passengers using the relevant moment arm for each person from evidence of their known seating positions. Personal items and aviation related documents, with due consideration given to items consumed by fire and those soaked in water/fuel, were estimated to weigh 300 lb with a moment arm of 325 inches. A dinghy, similar to the type placed on the floor behind the pilot on the day of the accident, weighed 28 lb. A full fuel load weighs 3,645 lb, however, at take off an estimated 150 lb had been used for the taxi and engine run-up checks therefore the fuel on board at take-off was approximately 3,495 lb with a moment arm of 190 inches.

The aircraft weight at takeoff was thus calculated to be 13,132 lb with a centre of gravity (CG) of 190.5 inches. The maximum certificated take-off weight for the aircraft was 12,500 lb and CG limits for the aircraft are only available up to that weight. Linear extrapolation of the CG envelope, for investigation purposes only, showed that the CG would have been within the extended envelope.

Airfield information

Blackbushe airport has a tarmac main runway orientated 26/08, 1,342 metres in length and 46 metres wide. White runway edge lighting is installed at 60 metre intervals with some larger distances at runway or taxiway intersections. At the time of the accident the lighting was serviceable and set at maximum intensity. White centreline markings, 30 metres long and separated by 30 metre gaps, are painted on the runway surface.

Weather

The following TAFS and METARS for Farnborough, 4 nm south-east of Blackbushe, were issued for the period relevant to the accident:

1200Z 23/12/00 EGLF 231214Z 231320 10005KT 0400 FG OVC001 TEMPO 1320 1200 BR OVC003 PROB30 TEMPO 1520 4000 BR BKN005

1320Z 23/12/00 EGLF 231320Z 12003KT 0500 FG OVC000 02/02 Q1009

1350Z 23/12/00 EGLF 231350Z 00000KT 0300 FG OVC000 02/02 Q1009

The visibility at Blackbushe, passed to the pilot by telephone and on the radio, was consistently 500 metres. The pilot assessed the runway visibility from his car, sometime between 1100 hrs and 1130 hrs, stating that he could see four runway centreline markings. The length of the centreline markings and the gaps between them were each measured as 30 metres. The distance from the end of a marking to the end of the gap after the fourth centreline marking is therefore 270 metres. However, it was noted that when seated in a car it was difficult to see the fifth centreline marking even on a day when visibility was good.

Approximately two hours had elapsed and the temperature had dropped between the time the pilot made his assessment of RVR and the time of his takeoff. Witnesses positioned at the Runway 26 threshold stated that the visibility had deteriorated and was at best 310 metres at the time of the accident.

Low visibility operations

The pilot of the accident aircraft held an FAA ATPL and undertook regular recurrent training. He was familiar with low visibility operations and practised them on a regular basis in the simulator. Whilst this flight was a non-public transport flight, the pilot's qualifications and training were to an equivalent standard to that of a commercial pilot operating a public transport flight. Examination of the requirements and guidance for pilots carrying out low visibility departures included in the Air Navigation Order, the UK AIP and JAR-OPS 1 are therefore deemed relevant.

Article 40 of the Air Navigation Order deals with, *Non-public transport aircraft - aerodrome operating minima.* This Article includes a requirement for CAA approval to be obtained before conducting non-public transport flights involving take-off when the relevant RVR is less than

150 metres. Although it may appear that no absolute minima are prescribed for low-visibility takeoffs when the RVR is between 150 and 400 metres, the visibility minima for private flying are in most cases applied by restrictions in the pilot's licence privileges, to take into account different levels of training and qualification, and the classification of the airspace. The minima specified by the pilot's licence privileges are removed only when the pilot holds an appropriate and valid Instrument Rating. However. in all cases it is the responsibility of the operator and commander of the aircraft to decide the minima to be used.

The UK AIP defines a 'Low Visibility Takeoff' as: 'A takeoff where the runway visual range is less than 400 metres'. The takeoff of VP-BBK therefore can be considered to have taken place within this definition as the visibility observed at the upwind end of the runway was less than 400 metres. Whilst the take-off minima published in the AIP 'Aerodrome Operating Minima' section are mandatory for commercial air transport flights, non-commercial air transport operators are strongly recommended, but not required, to operate in accordance with the advice in order to achieve adequate levels of safety. The AIP also states that the RVR minima used may not be lower than either of the values given in Table 2 or Table 3. From the tables the applicable minimum for such an aircraft conducting a public transport flight from a runway with edge lighting and/or centre-line marking is 250 metres. It does not state however if the visibility is for one or two pilot operations for aerodrome operating minima are normally only differentiated according to the number of pilots in respect of landing minima ie for the purpose of an approach ban.

The relevant text from JAR-OPS1 is reproduced below:

9. TAKE-OFF MINIMA

9.1 General

Take-off minima must be expressed as visibility or RVR, taking account all relevant factors for each aerodrome planned to be used and the aeroplane characteristics. Where there is a specific need to see and avoid obstacles on departure and/or for forced landings, additional conditions (eg ceiling) must be specified. Take-off shall not be commenced unless the weather conditions at the aerodrome of departure are equal or better than the applicable minima for landing at that aerodrome unless a suitable take-off alternate aerodrome is available. When the reported meteorological visibility is less than that required for take-off, or when meteorological visibility reports or RVR are not available, a take-off may only be commenced if the commander can determine that the RVR/visibility along the take-off runway is equal to or better than the required minimum.

9.2 Visual Reference

The take-off minima must be selected to ensure sufficient guidance to the control of the aeroplane in the event of both; a discontinued take-off in adverse circumstances, and a continued take-off after failure of the critical power unit.

9.3 Required RVR/VIS

For multi-engined aircraft, whose performance is such that in the event of a critical power unit failure at any point during take-off the aircraft can either stop or continue the take-off to a height of 1,500 feet above the aerodrome while clearing obstacles by the required margins, the take-off minimums established by an operator must be expressed as RVR/VIS values which are not lower than those given in the table below except as provided in note 3.

Table 1: Take-off RVR/Visibility

FACILITIES	*RVR/Visibility (see note2)*
Nil (day only)	500m
R/W edge lighting and/or centre-line marking	ABC-250m; D-300m (seen note1)

R/W edge & centre-line lighting	ABC-200m; D-25m
R/W edge & centre-line lighting & multiple RVR information	ABC-150m; D-200m (see note 3)

Note 1: For night operations at least runway edge & runway end lights required

Note 2: The reported RVR/VIS value representative of the initial part of the take-off run can be replaced by pilot assessment.

Note 3: The required RVR must be achieved for all relevant RVR reporting points with the exception given in note 2.

9. Low Visibility Take-off (LVTO)

A Take-off where the RVR is less than 400m

NOTE: LOW VISIBILITY PROCEDURES FOR TAKE-OFF AT AERODROMES THAT ARE NOT APPROVED FOR CAT II & III OPERATIONS

Until such time as the concept of Low Visibility Take-off procedures is established for aerodromes not authorised for Cat II or Cat III operations, the following temporary guidance is deemed to fulfil JAR-OPS1 requirements.

An operator should make every reasonable effort to verify that Low Visibility Procedures for take-off are established at the aerodrome where Low Visibility Operations (operations in visibility of less than 400 metres) may take place. Until further notice it may be accepted that these procedures ensure that only one aircraft at a time is allowed on the manoeuvring area and that vehicle traffic on the manoeuvring area is controlled and restricted to the absolute minimum.

9.7 Multi-engined aeroplanes.

For those aircraft whose performance is such that they cannot comply with the performance conditions in para 9.3 in the event of a critical power unit failure, there may be a need to re-land immediately and to see and avoid obstacles in the take-off area. Such aeroplanes maybe operated to the following take-off minima provided they are able to comply with the acceptable obstacle clearance criteria, assuming engine failure at the height specified. The take-off minima established by an operator must be based upon the height from which the one engine inoperative net take-off flight path can be constructed. The RVR minima used may not be lower than either of the values given in Table 1 above or Table 2 below.

TABLE 2: Assumed engine failure height above the runway versus RVR/VIS

Take-off RVR/Visibility-flight path	
Assumed engine failure height above the take-off runway	*RVR/Visibility*
<50 ft	*200m*
51 to 100 ft	*300m*
101 to 150 ft	*400m*
151 to 200 ft	*500m*
201 to 300 ft	*1,000m*
>300 ft	*1,500m (see note 1)*

Notes:
(1) 1,500m is also applicable if no positive flight path can be constructed.
(2) The reported RVR/VIS value representative of the intial part of the take-off run can be replaced by pilot assessment.
(3) When the reported RVR or meteorological visibility is not available the commander shall not commence take off unless he can determine that the actual conditions satisfy the applicable take-off minima

While it was not possible to determine the exact visibility at the time of takeoff it was >270 metres and <500 metres. As such the departure was conducted in visibility greater than the minima of 250 metres determined in JAR-OPS1 and the UK AIP.

Medical

Post mortem examination of the pilot showed there was no evidence of any natural disease, alcohol, drugs or any toxic substance which may have caused or contributed to the accident. The accident was considered to be non-survivable.

Pilot's background

Licencing

The pilot held a United Kingdom Civil Aviation Authority (CAA) Private Pilot's Licence (PPL) for single engine land planes, valid until 28 April 2002, with a valid Radio-Telephony (RT) Operators Licence. His class two medical certificate was valid until 1 June 2001.

His Federal Aviation Administration (FAA) Airline Transport Pilot Licence (ATPL) requirements were completed on 18 October 2000. This permitted him to exercise the privileges of his Instrument Rating (IR) and Type Rating for Beech 200 aircraft. The FAA 'First-Class' medical certificate required for his ATPL was issued on 3 May 2000 and was valid until 30 November 2000. After that date the medical certificate, although still a 'First Class' certificate, would have continued validity as a 'Second-Class' medical certificate. This would have downgraded the privileges of his ATPL to those of a Commercial Pilot Licence (CPL). This would still have allowed him to fly Beech 200 aircraft.

As the accident aircraft was registered in Bermuda, the pilot was required to hold a Bermuda Department of Civil Aviation Certificate of Validation issued for Pilot in Command of Beech 200 aircraft. This was issued on 2 July 1999 and expired on 1 July 2000. The Bermuda Department of Civil Aviation did not permit pilots holding foreign licences, in this case an FAA ATPL, to fly Bermuda registered aircraft without a Bermuda Certificate of Validation.

Experience and training

The pilot owned and frequently flew the Beech 200 King Air as well as a Piper PA-46 Malibu Mirage. He had received training from the manufacturer on both aircraft and had undertaken six monthly refresher training on the Beech 200 with an organisation in the USA. It was usual for him to fly his Beech 200 to the USA when undertaking that training and the last occasion was from 17 to 19 October 2000. The pilot consistently achieved a high standard of performance both during training and when carrying out type and instrument experience tests. He had previously demonstrated low visibility departures both in the simulator and on one occasion with a friend who regularly flew with him.

In November 2000 the pilot flew approximately 13 hours in the Beech 200 and 9 hours in the PA-46. He delivered the Beech 200 to the maintenance organisation at Blackbushe airport on 20 November 2000 and continued to fly the PA-46 recording approximately 22 hours flying before the accident.

The Beech 200 and the PA-46 were equipped to a very high standard and both were cleared for IFR operations. The PA-46 attitude indicator was an electro-mechanical type with the angle of bank indictor at the top of the display. Thus when the aircraft was banked to the left the needle indicating the angle of bank moved to the left. In contrast the Beech 200 was fitted with a three screen, Electronic Flight Instrument System (EFIS). Attitude indicator and flight director information were displayed on the top screen in front of the pilot. The angle of bank indicator worked in the opposite sense to that fitted to the PA-46. Thus when the aircraft banked to the left the pointer moved to the right. This was also the case with the standby attitude indicator positioned to the left of the main attitude indicator display.

Technique

A friend, who had flown with the pilot on a number of occasions, outlined the technique used by him for takeoff and initial climb. When possible the pilot tookoff with flap retracted and the flight director in heading mode. He increased power against the brakes ensuring that take-off power was set to maximum when the brakes were released. His left hand held the control column with his right holding the engine power levers. The aircraft was allowed to accelerate and fly off the runway with the pilot then assisting the rotation with aft control input. The pilot normally used both hands on the control column at rotation. Once a positive rate of climb was established the landing gear was retracted. It was reported that the pilot tended to 'hand-fly' the aircraft up to 3,000 feet before engaging the yaw damper and autopilot. It was also reported that the pilot, for convenience, had produced his own A4 laminated checklist which he had been seen using regularly. Fragments of this checklist were found within the accident wreckage.

Flight Trials and research

A series of simulator and flight trials were carried out, both in the UK and with the assistance of the manufacturer in the USA. Controllability in asymmetric flap conditions, critical asymmetric power configurations, takeoff performance and power lever migration were explored.

Power lever migration

Tests were carried out, both on the ground and in flight, to examine power lever migration with the friction selected fully off. Take-off power of 2,230 ft lbs was set and 2,000 propeller rpm (governed) was selected. When the pilot removed his right hand from both power levers on the ground, they migrated aft initially very quickly to 1,000 ft lbs and then more slowly with the torque falling to 400 ft lbs. The left propeller lever moved more rapidly aft on each occasion and on different test aircraft. This was possibly due to the fact that the control cable to the left engine is shorter and subject to less friction than the cable controlling right engine.

On the ground when the power lever moved the propeller rpm reduced immediately to 1,900 rpm but then fell further to 1,600 rpm. In flight the left propeller rpm reduced to 1,800 rpm with the IAS at 110 kt representative of the speed at which the accident aircraft rotated from the runway and the speed at which the propeller rpm was seen to initially decay.

A large positive force was required on the right rudder pedal to contain the yaw to the left created by the asymmetric power. A number of test runs were performed with more friction on the right power lever which prevented the right-hand engine power reducing so increasing the asymmetric effect. In the worst case scenario, take-off power was set on the right hand engine and zero torque on the left hand engine with that propeller unfeathered and effectively disking. Having contained the yaw with full right pedal which required an estimated force of 30 - 40 lbs, the pilot released the right pedal and the aircraft rolled to 60° left bank and 20° nose down pitch in 3.5 seconds. In order to recover the aircraft to level flight, the right hand power lever had to be closed smartly.

It was found during further tests that with the pilot only slightly reducing right pedal pressure the rate of roll was slower but the large angle of bank up to 60° was still achieved, the aircraft nose dropping as the angle of bank increased. If power was not reduced on the right hand engine at 60° angle of bank the aircraft was reluctant to return to wings level but seemed to hang at the bank angle with the speed increasing.

Asymmetric flap

A Beech 200 aircraft was flown in the same asymmetric flap configuration as indicated by evidence found in the wreckage (left outboard, right outboard and inboard flaps at 7° and the left inboard flap retracted). It was found that the aircraft only required a small right bank input on the control column to counter the left roll tendency, akin to a 5 to 10 kt crosswind, on take off. The remainder of the test flight was flown in that configuration without difficulty.

Flap selector

During the flight trials it was noted that when reaching down between the two pilot's seats to adjust the rudder trim, it was possible to inadvertently knock the flap selector switch down, selecting the first stage of flap.

Simulator tests

Take-off profiles, flown in a Beech200 simulator with the aircraft weight set at 13,000 lb, were carried out with all engines operating and in the single engine failure case both with and without the failed engine propeller feathered. In all cases the aircraft performed satisfactorily and climbed away safely.

Analysis

Engineering

Evidence from the engineering investigation established that the aircraft had not suffered an engine failure and inspection of the propeller pitch control mechanisms and governors revealed no evidence of failure. It is therefore concluded that both the engines and propellers were probably functioning correctly at the time of the accident.

Licencing

There is no reason to believe that the Bermuda department of Civil Aviation would not have issued a Bermudan validation to the commander's FAA ATPL had an application been made. It is considered therefore, that the licencing situation was solely an administrative oversight by the commander. Licencing was considered not to be a factor in this accident.

Performance

The aircraft take-off weight was estimated to be 632 lb above the maximum take-off weight permitted of 12,500 lb. During the takeoff the one and only mode 'C' readout, recorded by Heathrow radar, showed that the aircraft had performed satisfactorily for even though the aircraft was in a steeply banked left turn it had climbed to 250 feet ±50 feet above the airfield some 13 seconds after rotation. Furthermore simulator tests showed that despite the overweight condition it was possible to control the aircraft and contain any asymmetric condition. Whilst the aircraft weight at takeoff exceeded the maximum certificated take-off weight for this airframe, other variants of the Beech 200, with identical airframe structure and installed power to the accident aircraft, are certificated with a maximum take-off weight of 14,000 lb. It is therefore considered that aircraft weight was not a factor in this accident.

Flap position

The pilot had briefed the front seat passenger to call out the airspeeds during takeoff. He had done as instructed throughout the flight and the accuracy of these 'callouts' was confirmed by correlation with the landing gear wheel noise derived from the CVR. It was therefore confirmed that the aircraft rotated and lifted off at speeds consistent with a flaps retracted takeoff. The flaps however were found in the wreckage to be asymmetric with the left inboard flap screw actuator in the fully up position and the remaining three flap screw actuators at the 7° position. The 7° position is not permanently selectable and can only be achieved momentarily during flap travel.

The investigation considered it possible that if the pilot reached down between the seats for the rudder trim wheel, which is located below the flap selector, he could have inadvertently knocked the flap selector down. Or conversely having inadvertently knocked the flap lever down he had re-selected it to the up position. It could not be determined whether the flaps were lowering or retracting at the time of the impact but there was conclusive evidence to confirm that the asymmetric flap configuration had occurred as a result of the impact. Even with the 7º asymmetric flap (the aircraft flap system includes a protection system to ensure that asymmetry does not develop to more than 6º) flight trials showed that the aircraft, which only required a small right bank input on the control column to counter the left roll tendency, could be flown in that configuration without difficulty.

Propeller rpm

Information gathered from the CVR showed that, at rotation, the rpm of one of the propellers dropped from 2,000 rpm to 1,925 rpm. The sound of the propellers coming out of synchronisation could clearly be heard on the CVR recording from the cockpit area microphone and would certainly have been audible to the pilot. This distinctive sound was also described by the two witnesses at the upwind end of the runway. The engineering investigation established however that the aircraft had not suffered an engine failure and that the propeller pitch control mechanisms and governors were functioning correctly, therefore the circumstances leading to this rpm reduction have to be considered.

When the propellers were set up during the post maintenance ground runs the engineer slackened off the frictions in order to give him better control of the engine and propeller parameters. He was unable to recall exactly how the frictions were left following the ground runs. The 'Pilots Operating Handbook' details the 'Before Takeoff (Runup) Checks' and item No 6 in that checklist states that the 'Engine Control Friction Locks' should be set. The pilot is believed to have produced and used his own 'A4 size' laminated checklist. Only small fragments of the lower part of the checklist were recovered from the wreckage, the remainder having been consumed by the fire. It could therefore not be ascertained whether his checklist contained item No 6. Notwithstanding the above it is possible that the frictions were either not adjusted or not set sufficiently. It is therefore also possible that as the pilot removed his right hand from the power levers, at the end of the take-off roll to place it on the control column, the left hand power lever migrated back rapidly to a low power setting. The right hand power lever may also have migrated but to a lesser degree.

Control

The yaw to the left, brought about by the asymmetric power, would have been relatively easy to control whilst external references, such as the runway centreline markings and runway edge lighting, were visible. Continuing to control the aircraft in IMC however would have required more concentration and application of the correct amount of rudder. To contain the yawing moment as the airspeed increased, would have required the pilot's focussed attention on the primary flight instruments. Furthermore as the speed increased the effect of the 'disking' propeller would have had the tendency to increase the yaw with the secondary effect of increasing the rate of roll. At this point with full right rudder and maximum opposite aileron applied the aircraft bank angle would have stagnated at an estimated 60° angle of bank with the nose pitched down. This is consistent with the attitude of the aircraft at impact.

Faced with this situation the pilot had several options. Firstly, if he had realised that power asymmetry had been brought about by power lever migration he could have moved both levers to their fully forward position to balance the thrust. Secondly, if he had believed the left engine had failed, he could have reduced the drag from the left propeller by feathering it. Thirdly, if he was unsure as to the reason for the power reduction from the left propeller he could have retarded the right power lever, balanced the thrust and accepted the resulting overall power reduction and resulting loss of performance. This would have led to a speed reduction and the possibility of a stall as the aircraft pitch was increased to reduce the rate of descent. Spectral analysis of the CVR appears to support the later option in that three seconds before impact a reduction in rpm, possibly as the right power lever is moved aft, can be seen. This is followed by an increase in rpm as one, or possibly both power levers are advanced in an attempt to avoid ground contact.

Disorientation

Additionally, having realised that an asymmetric power situation existed it is reasonable to assume that the pilot would have looked across and down to his right to check the centrally positioned engine and propeller instruments. If he move his head in doing so it is possible that the balance organs within his inner ear could have created the sensation that the aircraft was banking and turning to the right. This naturally would cause the pilot to incorrectly bank the aircraft to the left to recover to what he perceived to be level flight. The turn to the left seen by witnesses was described as controlled and as the aircraft disappeared into the fog the rate of roll was normal and passing through approximately 30° angle of bank.

Further adding to his disorientation could have been confusion with the angle of bank indicator. The pilot's mental model of the aircraft's position would have been of a wings level climbing attitude. The attitude indicator however would have shown an increasing left bank and descent. The angle of bank indicator would have been displaced to the right and not the left as he had been used to when recently flying his PA-46. Flight director indications could have led to further confusion. The disbelief in the response from control inputs may have been the reason for the expletive uttered by the pilot at this time. The degree to which the basic horizon presentation would have been more compelling to the pilot than the angle of bank pointer displayed on the attitude indicator however can not be known. Undoubtedly in this situation, with a rapidly increasing workload in IMC and with some still unidentified technical event, the pilot would probably have been very confused. If he had been able to concentrate solely on the main attitude indicator and given his knowledge of low visibility takeoffs and recent instrument flying experience, he should have been able to successfully transition to instrument flight and climb the aircraft to a safe height. He appears to have accomplished this initially, for he maintained the aircraft alignment with the runway until just before the threshold of Runway 26 where he was seen to be slightly left of the runway centreline. As the aircraft passed the 26 threshold however it was seen to commence a gentle and apparently controlled turn to the left. This was about the time that the pilot would have been making the transition from visual to instrument flight.

Finally, moments before impact the pilot would have been aware of the aircraft's rapid closure with the ground. It is not surprising therefore that he probably pulled hard back on the control column to arrest the rate of descent activating the stall warning that could be heard on the CVR recording.

Conclusion

Whilst the CVR does not provide any comments by the pilot as to the problems he was experiencing, spectral analysis of the CVR recording indicates that a significant difference in propeller rpm occurred at rotation when the pilot would normally have removed his right hand from the power levers. There was no evidence of a malfunction in either engine or the propeller control systems thus it is probable that migration of a power lever(s) occurred due to insufficient friction being set on the power lever friction control. The fiction control had been slackened during recent maintenance and it was possible that it was not adjusted sufficiently by the pilot during his checks prior to takeoff. His simulator training had included engine failures but as far as could be established, the pilot had not encountered or been trained for the situation of power lever(s) migration during takeoff. With his level of experience the pilot should have controlled the resultant asymmetric thrust and in reasonable conditions continued the takeoff to a safe height where analysis of the problem could have been carried out. In the event the takeoff was carried out in extremely low visibility conditions leading to the pilot's total loss of any ground references within seconds of lift off. Having controlled the aircraft initially the lack of visual reference with the ground, possible confusion with attitude instrument bank angle display, physical disorientation brought about by cockpit activity and confusion as to the exact nature of the problem led the pilot to lose control of the aircraft at a low altitude. The unusual attitude developed by the aircraft and the reason for the power asymmetry may have been recognised by the pilot several seconds before impact however there was insufficient height available for him to effect a safe recovery. The transition from visual to instrument flight in the low visibility conditions existing at the time of departure was considered to be a major contributory factor in this accident.

Recommendations

As a result of the investigation the following safety recommendation is made:

Safety Recommendation 2003-17

The Raytheon Aircraft Company should ensure that reference to the correct adjustment of power lever friction is suitably emphasised in the Beech 200 Aircraft Operating Manual (AOM) and the consequences of insufficient adjustment are not only highlighted in the AOM but also included in the recommended Beech 200 type training syllabus.