DHC Dash 7-102, VP-CDY

AAIB Bulletin No: 11/99 Ref: EW/C98/11/5 Category: 1.1

Aircraft Type and Registration:	DHC Dash 7-102, VP-CDY
No & Type of Engines:	4 Pratt & Whitney PT6A-50 turboprop engines
Year of Manufacture:	1983
Date & Time (UTC):	28 November 1998 at 0947 hrs
Location:	Ashburton, Devon
Type of Flight:	Test flight
Persons on Board:	Crew - 2 - Passengers - None
Injuries:	Crew - Fatal - Passengers - N/A
Nature of Damage:	Aircraft destroyed
Commander's Licence:	Canadian Airline Transport Pilot's Licence (with Cayman Islands validation)
Commander's Age:	75 years
Commander's Flying Experience:	Approximately 15,000 hours (of which approximately 4,000 were on type) Last 90 days - 30 hours Last 28 days - 9 hours
First Officer's Licence:	Canadian Airline Transport Pilot's Licence (with Cayman Islands validation)
First Officer's Age:	66 years
First Officer's Flying Experience:	17,200 hours (of which 1,700 were on type) Last 90 days - 90 hours Last 28 days - 28 hours
Information Source:	AAIB Field Investigation

History of the flight

Prior to the flight the commander had filed a flight plan which indicated that after take off the aircraft would transit from Guernsey to the Berry Head VOR at FL 100. It was then planned to manoeuvre in the Plymouth area whilst conducting a performance related test flight. The commander called for start clearance at 0902 hrs and, after a short taxi, the aircraft was cleared for take off at 0918 hrs.

After take off Guernsey ATC handed the aircraft over to the London Air Traffic Control Centre (LATCC) at 0930 hrs. As the aircraft approached Berry Head at FL 100 the commander requested FL 60. The aircraft was cleared for this descent and then handed over to Exeter ATC at 0943 hrs. Exeter ATC confirmed the aircraft requirements for a block of airspace between FL 60 and FL 100 and offered a radar advisory service. The aircraft was then vectored onto a northerly heading to keep it clear of departures from Plymouth Airport.

As the aircraft approached FL 60 the commander requested further descent to FL 50, which was approved. The air traffic controller at Exeter then noticed that the altitude readout from the aircraft radar transponder indicated FL 47. He called the aircraft to confirm the local sector safe level of 3,500 feet but received no reply; this call was timed at 0947 hrs. From FDR timings the crew would not have heard this call. At the same time the transponder information disappeared from the radar screen and the primary radar return was no longer visible. The controller made repeated calls to the aircraft but received no reply. He arranged for LATCC to inform the Distress and Diversion cell whilst he notified the local emergency services.

A large number of eye witnesses saw the aircraft in its final descent before impacting the ground; twenty two of these witnesses were interviewed. All agreed that the sky was clear and bright with only a few of them describing small amounts of light cumulus clouds. No one saw any other aircraft in the area and all were certain that there was no smoke or fire issuing from the aircraft or its engines whilst it was in the air. Most witnesses described the aircraft in a spin or a spiral descent, generally to the left, although some described the motion as like a falling leaf. Four witnesses, who all had a clear view of the aircraft throughout, described the aircraft completing a two or three turn spin/spiral to the left. Those witnesses who were in a position to hear clearly the sound of the engines confirmed that the engines were making a loud noise as if at a high power setting. The impact with the ground was followed immediately by a post crash fire.

History of the aircraft

The aircraft had been manufactured in 1983 and supplied new to the initial operator, based in Norway. It remained there until 1996 when it was acquired and re-registered by an Egyptian operator. The aircraft remained in Egypt for approximately 18 months; it is understood that during the latter part of this period the local operator encountered financial difficulties and the aircraft ceased flying. The aircraft was then re-possessed by a leasing company together with another DHC 7 also operating in Egypt. The new owners arranged for both aircraft to be ferried to Guernsey where an aircraft engineering company were tasked to recover all maintenance issues to enable the aircraft to re-enter service. Both aircraft were re-registered in the Cayman Islands. Maintenance and operational procedures were thereafter carried out in accordance with Cayman Islands regulations. These are based largely on those of the UK CAA and/or the US Federal Aviation Administration.

The aircraft remained out of service at Guernsey airport for approximately one year whilst it underwent an extensive programme to ensure that all maintenance required during the previous two years had been fully implemented. This was found to be necessary because the extent of the work carried out during its period in Egypt was not clearly defined by the supporting documentation. The maintenance company eventually decided to carry out (or, in some instances, repeat) all activities required by the maintenance schedule during the period after the aircraft left the operational control of the initial operator. The aircraft was not flown between the time of its arrival in Guernsey and the initial test flight.

The aircraft owners were then issued with a special flight authorisation by the Cayman Islands Civil Aviation Authority (CICAA) to operate the aircraft in the private category for the purpose of flight testing. Following successful completion of the test flight it was intended to issue a Certificate of Airworthiness.

Background to the flight

The initial test flight was flown on 25 November 1998, within Channel Island's airspace and was satisfactory except that the aircraft did not achieve the requisite climb performance. It was established that No 3 engine was not producing the rated power. This engine was changed and an abbreviated test flight was planned for the 28 November 1998; it was intended that this flight would only cover those elements related to aircraft performance. Because of the prevailing meteorological conditions on 28 November the crew elected to conduct this test flight within UK airspace. In order to do so in a foreign registered aircraft, without a valid Certificate of Airworthiness, the operator should have obtained from the UK CAA an exemption from the provisions of Article 8(1) of the Air Navigation (No 2) Order 1995. Although an initial request had previously been discussed the required supporting documentation was not made available to the CAA and therefore no such exemption had been issued. The aircraft should not therefore have conducted the test flight in UK airspace.

The flight test was to be conducted using a standard flight test schedule for the aircraft that had been approved by the CICAA. The first element of the test flight was to be a 3-engine climb, at the appropriate V_2 speed, with a recommended initial altitude of FL 50. The required configuration for the test was:

Landing gear	Up
Flaps	25°
No 1 engine	Shutdown, propeller feathered
Intake deflectors	Retracted
Engine bleeds	Off
Operating engines	Take off power
Airspeed	V_2 speed, appropriate to weight

Once established at the required parameters the climb was to be maintained for a period of 5 minutes whilst relevant data were recorded.

Meteorological conditions

The synoptic situation at 0900 hrs on the 28 November 1998 indicated that a cold front, with associated poor weather, was lying north/south over the Channel Islands and central England and was moving steadily eastwards. When the aircraft took off from Guernsey the reported weather was: surface wind 290û/17 kt, 5,000 metres visibility in rain, cloud scattered at 300 feet, broken at 700 feet and broken at 1800 feet, the surface temperature and the dew point were coincident at +10ûC. The forecast conditions for the Plymouth area were visibility 25 km, cloud few between 2,500 feet and 5,000 feet with no significant weather. An aftercast obtained from the Meteorological Office at Bracknell for 1000 hrs validated the forecast and indicated that the wind at 5,000 feet was 280û/25 kt with a temperature of -3ûC. The eyewitnesses all agreed that the weather was very clear, bright and cool in the area of the crash site.

Pilot experience and training

The commander had been one of the experimental test pilots involved with the development of both the Dash 7 and Dash 8 aircraft. After retiring from test flying with the aircraft manufacturer he was employed by an organisation that provided pilots for ferrying and production test flights of de Havilland aircraft. Prior to the test flight on 25 November he had last flown a Dash 7 on 17 October 1998 on a transit flight in the US. However, he had more recently flown on the Dash 8 and had conducted production flight tests on 3, 19 and 23 November 1998 on this type.

The first officer (FO) was employed by the same organisation and was also experienced on this type of aircraft. His last recorded flight in a Dash 7 was in June 1998 when he completed a number of ferry flights in a ten day period for a total of 36 hours. He had more recently flown the Dash 8, his last recorded flight on this type had been on 23 November 1998 when he had conducted a production flight test with the same pilot that he flew with on 25 and 28 November 1998.

These two pilots had flown together previously on many occasions. When conducting flight tests it was the commander's normal practice to occupy the right seat from where he would direct the flight, record data, set the required engine power and manage communications with ATC. This then allowed the handling pilot, in the left seat, to concentrate on flying the aircraft. This practice was followed on this flight.

Accident site

The aircraft crashed on the southern slopes of Dartmoor at an elevation of approximately 500 feet amsl. From examination of the wreckage it was evident that it had struck the ground with a high descent rate and a low forward speed whilst rotating rapidly to the left. At the time of the impact the aircraft was in an erect, nose-down, left wing low attitude.

A sustained ground fire largely destroyed the wreckage. This destruction prevented a fully effective wreckage examination from being carried out. Nevertheless it was established that the aircraft was structurally complete and all doors were attached at impact. The ailerons, elevators, and associated tabs were all attached, as were both surfaces of the articulated rudder. The ground and roll spoilers are presumed to have all melted in the ground fire.

It was confirmed that the No 1 propeller was feathered and not rotating with significant energy at impact. All four blades remained attached. The remaining three propellers had all been rotating under some degree of power. Their 12 blades were all accounted for at the site in positions consistent with having been correctly attached at the time of the impact.

Examination of the flap mechanism confirmed that the flaps were fully and symmetrically retracted. All three landing gear units were also retracted. The intensity of the fire had melted the turn-barrels in the connections of the flying control cables so it was not possible to confirm continuity of control runs. Nevertheless all cables in areas of lesser fire damage were found to be correctly connected.

The left and right caution light panels, mounted above the windscreen, were recovered, having suffered only limited damage. A bulb filament analysis was carried out. This revealed no conclusive evidence of bulb filament stretch in any of the bulbs illuminating the 84 captions. Given the fact that one engine was shut down with its propeller feathered, a number of related captions should have been illuminated as the aircraft struck the ground. It is presumed from the absence of any filament stretch that the impact and break-up sequence resulted in disruption of power supplies to the CWP before significant deceleration forces were applied to the panels. This is reasonable given the fact that the caution light panels on this aircraft type are positioned high up in the flight-deck and their supply cables are routed below floor level. There was therefore no characteristic filament stretch on those bulbs associated with the systems driven by No 1 engine and there was no useful information as to whether any other captions were illuminated indicating unexpected system failures.

Medical and pathological information

Both pilots sustained fatal multiple injuries in the ground impact. No evidence was found of any drugs, alcohol or other toxic substances which may have caused or contributed to the cause of the accident. Both pilots had valid medical certificates. The commander, who occupied the right hand seat of the aircraft, had undergone a major operation in October 1997 but had recovered well from this. There was little of note in the FO's medical history other than slightly raised blood pressure that had been well controlled with mild treatment. The FO occupied the left seat of the aircraft. There was nothing in either pilot's medical history to suggest that either might have become incapacitated.

Aircraft performance

Immediately prior to the flight 2,420 litres of fuel was added, so that the total fuel on board was then calculated to be 10,000 lb. The operating weight of the aircraft was 27,923 lb, which included the basic weight of the aircraft plus two pilots; thus the calculated ramp weight (fuel weight + operating weight) was 37,923 lb. The maximum certificated ramp weight was 44,100 lb. Allowing for engine start, taxi, take off, climb and transit the calculated weight at the start of the performance climb was 36,963 lb from which a V_2 speed of 80.5 KIAS was calculated for the required configuration. At the same aircraft weight the stall speed quoted in the aircraft flight manual was 90 KIAS with the flaps up and power at flight idle.

Flight recorders

The aircraft was fitted with a Sundstrand Universal Flight Data Recorder (UFDR) and a Sundstrand AV557 Cockpit Voice Recorder (CVR). Both recorders were recovered from the wreckage and returned to the AAIB for replay and analysis. There was no significant fire damage to either recorder, although the UFDR was found detached from the rack within the wreckage and the anti-vibration mounts for crash protection were broken.

Cockpit voice recorder

The CVR contained a 30 minute duration recycling magnetic tape; this was removed and replayed. The recording on the tape was not from the accident flight and related to the period when the aircraft was being operated in Egypt. It was not possible to determine when the CVR had failed. The recording was intermittent and an examination of the unit revealed that the bearings within the tape motor were seized. The condition of the unit suggested that the recorder had probably been running intermittently for some time before the ultimate failure. The bearings were of an older standard from that currently used on this type of CVR; the newer standard of bearing was introduced to rectify this specific problem. The CVR tape would not have run when power was applied and the built-in-test-equipment (BITE) circuit should have detected this failure. The BITE is operated from the cockpit by means of a test switch on the CVR panel.

The aircraft was being operated in the private category on the Cayman Islands Register and therefore, under existing regulations, no flight recorders were required to be fitted. However, recorders were fitted to the aircraft as it had been previously operated in the transport category, for which they were required. The absence of any useful data from the CVR relating to the crew activity severely hampered the investigation. However the data from the FDR enabled an accurate and detailed reconstruction of the accident flight.

Flight data recorder

The UFDR was replayed successfully and standard calibrations were used to convert the data into engineering values. Errors were found in the calibration of airspeed when comparing the recorded values with data from the previous test flight where the flight test observer had noted the indicated airspeed during each test. These tests had covered the entire speed range, from low speed stalls to the maximum operating speed, V_{mo}. These data were therefore used to determine a datum correction to be applied to the recorded values of airspeed. A datum correction was also applied to the rudder position conversion. The lateral flight control system consists of conventional cable operated ailerons operating in conjunction with hydraulically powered spoilers. The aileron position is not recorded on the UFDR and the Left Spoiler transducer was not functioning.

There are a number of tolerances to be considered in the recording of airspeed. A Flight Data Acquisition Unit (FDAU) senses all the various outputs of the aircraft and formats them to be recorded by the FDR. The FDAU uses the same Air Data Computer (ADC 2) source as the co-pilot's instruments to measure airspeed. This is converted by the FDAU from the transducer as a D.C. signal, the tolerance for the transducer in the range 80 to 200 kt is ±3·5 kt. Normally a standard calibration is used to convert the voltage, recorded on the FDR as a number of bits, into a value of knots. In this case the indicated values from the previous flight have been used to provide the calibration; this can introduce errors between the logging of the data by the observer, and the FDR data points. The error is probably of the order of ±2 kt. The airspeed values recorded by the observer are also subject to instrument errors. As no calibration of the instrument was performed the errors are not known, but probably could also be of the order of ±2 kt.

Interpretation of data

Approach to the 'stall'

Figure 1 shows the relevant data from the FDR as the aircraft was descending from 10,000 feet. At around 7,000 feet the No 1 engine was shutdown. The other three operating engines were at a low power setting. The autopilot was engaged and the flaps were up. The aircraft was then levelled at 5,000 feet. The final 45 seconds of data is shown in Figure 2. As the autopilot attempted to maintain level flight, the pitch attitude increased and the airspeed reduced at a rate of about 1·5 kt. At about 95 KIAS, with the autopilot still engaged and the elevator and the pitch trim continuing to provide a positive pitch-up demand, the pitch attitude started to decrease. The maximum pitch attitude achieved was 8°.

The approach to a stall is normally identified by natural buffet and in the case of this aircraft a stick shaker was fitted to supplement this cue. The stick shaker should operate at least 2 to 4 kt above the 1g stall speed to warn the pilot of the low speed and impending stall. The operation and speed at initiation had been checked on the previous test flight when deliberate stalls were performed in two configurations; flap 15° gear up and flap 45° gear down. The operation of the stick shaker is not directly recorded by the FDR. What is evident on the FDR recording is a high frequency, low amplitude vibration recorded by the normal and lateral accelerometers indicative of airframe buffet or stick shaker operation. The onset of the vibrations occurred at about 97 KIAS. Coincident with this was a slight forward movement of the elevator, prior to this the elevator and pitch trim were consistently moving nose up together. The autopilot was not disconnected until 6 seconds later.

Subsequent aircraft behaviour

The power was then increased on all three operating engines and the autopilot was disconnected. The elevator was 12° and the pitch trim 16.4°, both positive (pitch up) demands. (The maximum nose up trim available from the autopilot was 18° and using manual trim it was 20°). The airspeed was 89 KIAS. The power continued to increase on the three operating engines and the aircraft began to roll to the left to a maximum of 80° angle of bank and this was opposed by the use of up to 54° right spoiler. The pitch attitude reduced to 54° nose down. Power was than reduced on the operating engines. The maximum rate of rotation about the yaw axis was 60°/sec. The right rudder input increased from 4° to 9°. With flaps retracted the movement of the rudder is limited such that the maximum deflection is 10.5° ±0.5°. With flaps extended the maximum rudder is 23° ±0.5°left and 19.5° ±0.5°right.

Some of the witnesses described the aircraft being in a spin or a spiral dive. In a spin the stalled aircraft enters autorotation and describes a helical path as it descends. Generally there are rotations in all three axes (pitch, roll and yaw). The spinning behaviour of the aircraft will be dependent on the individual type with each type behaving differently. In a spiral dive the aircraft is not stalled, its airspeed increases or is very high and it has a large bank angle with a high value of normal acceleration.

In the case of this accident, after the aircraft stalled, the elevator and pitch trim continued to demand a nose up pitching moment, thus maintaining the wings in a stalled condition. When power was increased on the three operating engines the asymmetric thrust ultimately provided a rolling moment. It is not possible to say whether the aircraft was then in a spin. No tests have ever been carried out on the Dash 7 to investigate the spinning behaviour. The recorded positive normal acceleration would suggest the aircraft was in a spiral dive although the airspeed remained low, consistent with a spin. Very low values of airspeed, below 30 kt, were recorded during this manoeuvre. Analysis from manufacturers previous flight test recordings during stalls show that these low values of recorded indicated airspeed are an effect of the errors in the aircraft pitot system and are therefore invalid. When the engine power was subsequently reduced the normal acceleration and the effect of the thrust asymmetry would also have reduced. This resulted in the yaw rate reducing in the final few seconds of recorded data.

Final recorded data values from the FDR

The final value of pressure altitude recorded was 1,440 feet; this was about 900 feet above the height of the ground at the accident site. The FDR data ends almost one second after this final value of altitude is recorded. The final data shows the aircraft descending at a calculated rate of descent of 180 feet/s (10,800 feet/min). The final recorded heading was 307° with a pitch attitude of 36° nose down and a roll attitude of 37° to the left.

The absence of any further data is due in part to the method of operation of the UFDR. The UFDR stores data into one of two memory stores, each holding approximately one second of data. When one memory if full, the data flow is switched to the other store. While data is being fed to this other store, the tape is rewound and the previous second of recorded data is checked. A gap is left on the tape and the data from the first store is written to the tape, and the first memory is emptied. The whole 'checkstroke' operation takes much less than one second to complete so that once the other store is full, data is switched back to the first store, and the other store is written to the tape using the 'checkstroke' operation again. The procedure is then repeated. Thus the UFDR tape is not running continuously. When power is lost from the recorder the data held in volatile memory, which has not been recorded on the tape is lost. The recorder manufacturer states that this can result in the loss of up to 1.2 seconds of data before impact.

Previous test flight

Data from the FDR was also available from the previous test flight, including stalls at flaps 15° and 45° and a 3-engine climb, which was the manoeuvre that the crew were setting up to repeat on the accident flight. The aircraft performed the stalls on the previous flight at about 14,500 feet with the autopilot disconnected, Figure 3 and Figure 4 show the data from these tests. The measured results, noted by the crew in the Flight Test Schedule, together with the FDR values are listed below**:**

Flap 15°	Scheduled Speed KIAS	Achieved Speed KIAS	FDR Recorded Values KIAS
Stick Shaker	79	80	80 (airframe buffet recorded by G's)
Stall	73	74	72 (at the point where the nose dropped)
Flap 45°			
Stick Shaker	67	69	71
Stall	58	64	65

The aircraft then descended to 8,400 feet with the autopilot still disconnected. The No 1 engine was shutdown as the aircraft passed through 9,000 feet at 140 KIAS. The flap was selected to 25° one minute later as the aircraft levelled at 8,400 feet with the airspeed reducing through 120 KIAS. As the flap angle reached the 25° position, 25 seconds later with an airspeed of 86 KIAS, power was increased on the three operating engines. The pitch attitude increased and an airspeed of 81 KIAS was maintained during the five minute climb to 10,770 feet. In order to counter the asymmetric thrust up to 10° right rudder was applied during the climb. Figure 5 shows the start of the climb.

Simulator evaluation

The final manoeuvre flown by the crew, which was the deceleration to the stall at FL 50, was evaluated in a Dash 7 full flight simulator. The aerodynamic data utilised for this area of the simulator's flight envelope was derived from flight test data. No attempt was made to analyse the behaviour of the simulator after the point of stall since no valid aerodynamic data was available for this regime. Throughout the evaluation the simulated aircraft weight, the centre of gravity and environmental conditions were set to match those at the time of the accident.

Before flying the deceleration to the stall the basic parameters and system modelling of the simulator were assessed. A series of stalls was manually flown with flaps in, landing gear up and power at flight idle with the aircraft initially trimmed at 120 KIAS. It was noted that the stick shaker activated at 98 KIAS and the stall, characterised as a benign, positive nose-drop, occurred at 90 KIAS; the stall speed for quoted in the Flight Manual for the same conditions, was also 90 KIAS. At the stall the control column was close to the aft limit, relaxation of the rearward pressure ensured a prompt stall recovery. A further stall was evaluated at flap 25 and the stall speed was 65 KIAS, this was also in agreement with the published data.

The No 1 propeller was then feathered and the engine shut down, the automatic flight control system (AFCS) was engaged and the simulator stabilised in a descent to 5,000 feet with the 3 operating engines set to approximately 150 feet lb torque. The AFCS levelled the simulator at 5,000 feet and, as the speed reduced, the AFCS operated correctly in applying nose up trim. This was readily apparent as the trim wheel, painted in alternating black and white segments, clearly rotated in a nose up direction. At the point of stall the elevator had trimmed close to the maximum nose up limit. The simulator stalled at 90 KIAS and when the AFCS was disconnected a push force of about 30 lb was required to unstall the aircraft. It should be noted that there was no logic within this autopilot that automatically caused it to disengage in the event of stick shaker operation or at the stall. The autopilot can only be deselected by the crew. The simulator performed in a similar manner to that depicted by the recorded data from the aircraft FDR.

Analysis

A sustained ground fire had largely destroyed the wreckage. However, it was established that the aircraft had been structurally complete. The No 1 propeller was feathered and the flaps were fully and symmetrically retracted. There was no evidence of any mechanical malfunction.

The two pilots had flown together previously on many occasions. On this flight the commander occupied the right seat from and made all radio transmissions. It was his normal practise to direct the flight, set the required engine power and to record data. This then allowed the FO, who occupied the left seat, to concentrate on flying the aircraft.

The commander initially asked ATC for a block of airspace from FL 60 to FL 100 and then requested a base of FL 50. This was entirely consistent with the intention to perform a 3-engine climb. It would be normal practice to configure the aircraft for the next test point during the descent to the planned base altitude, as had been done on the previous flight. On this occasion however, the flap was not selected to 25° but remained fully retracted. In accordance with the configuration requirements for the 3-engine climb the No 1 the propeller was feathered and the engine was shutdown. With the autopilot engaged and the 3 operating engines at a low power setting the aircraft levelled at FL 50 and the speed reduced. During this speed reduction the crew should have noted the trim wheel rotating as progressive nose up trim was being applied by the autopilot. It is possible that the non-handling pilot may have interpreted this as a manual trim input by the handling pilot. There would also have been clear aural and tactile warnings, via the stick shaker, that the aircraft was approaching the stall.

Although both pilots were familiar with the test schedule the aircraft was not correctly configured for this particular test. Furthermore, the autopilot was retained down to the point of the stall and there appears to have been no adequate response to the stick shaker. If the crew were unaware of the flap configuration error then the stall warning may have surprised them but for a crew of their experience to fail to react correctly to the compelling intervention of the stick shaker is most unusual. However, the possibility of some distraction cannot be discounted. The available evidence therefore suggests that normal crew operation and co-ordination was lacking during this phase of flight. In the absence of a working CVR it is not possible to state why this occurred.

The aircraft stalled with the autopilot still engaged. Power was increased on the three operating engines and two seconds later the autopilot was deselected. The application of asymmetric power ultimately caused the aircraft to roll rapidly to the left and this motion was countered by the application of right rudder and right spoiler. The elevator was then moved to the full nose up demand position. With the exception of decreasing application of right spoiler the controls remained in these positions until just prior to impact when the engine power was reduced.

The flight control inputs and the changes to engine power suggest that both pilots were involved in the aircraft operation throughout the descent to the ground. The progressive and sustained rudder inputs together with the constant application of full aft control column also suggest that the same pilot retained authority over these flight controls. However, some of the crew actions were unusual. The non-handling pilot would have been ready to apply take-off power on the three operating engines in order to initiate the climb but the application of asymmetric power at the stall inevitably led to autorotation and was therefore inappropriate. The application of opposite rudder by the handling pilot was a normal pilot response but the application of full aft control column following the stall is inexplicable, irrespective of whether the pilot subsequently believed that he was in a spin or a spiral dive. Analysis of the manufacturer's flight test data during prolonged stalls provided no evidence of any elevator overbalance due to aerodynamic loads on the lower surface of the elevator. Moreover, in this instance, following the application of asymmetric power the aircraft adopted large bank angles that would have further reduced any aerodynamic load on the lower elevator surface. It is therefore considered most probable that the control column was placed in the fully aft position by the pilot. The nose-up elevator trim, applied by the autopilot before its disconnection, would have produced unexpected control forces when positioning the control column for recovery such that the normal release of back pressure would have been ineffective. However, this does not explain the subsequent application of full aft control column. It is possible that the rapid autorotation that followed the application of asymmetric power at the stall caused the handling pilot to become disorientated. The high longitudinal control forces that had been generated by the application of full nose up trim by the autopilot prior to the stall may then have exacerbated his difficulties.

Requirements for the carriage of flight recorders

Flight recorders have proved to be invaluable in accident and incident investigation. Investigations should not be constrained by different requirements for the same type of aircraft based upon their category of operation. The need to derive safety information from any occurrence is just the same. Given a normal requirement for flight recorder(s), then these should be fitted whatever the operating category of a particular aircraft. Current UK CAA regulations require aircraft operating in the Aerial Work, or Private Category for which an individual certificate of airworthiness was first issued on or after 1 June 1990 whose maximum total weight exceeds 27,000 kg to be equipped with flight recorders. For aircraft of a lesser weight, such as the type involved in this accident, the requirement to fit recorder(s) only applies to aircraft in the Transport Category.

ICAO Annex 6, Part II, International General Aviation - Aeroplanes, contains Standards and Recommended Practices in relation to General Aviation (ie aircraft operating other than commercial air transport and aerial work) aircraft. The ICAO definition of Standards is a provision, which is 'necessary for the safety or regularity of international air navigation and to which contracting states will conform.' The definition of a Recommended Practice is a provision, which is 'desirable in the interest of safety, regularity or efficiency of international air navigation and to which contracting states will endeavour to conform'. Chapter 6.10.3 includes a Standard requiring those aircraft for which the individual C of A was first issued on or after 1 January 1989, and with a maximum certificated take-off weight of over 27,000 kg to be equipped with FDRs. For aircraft with a maximum certificated take-off weight in excess of 5,700 kg and less than 27,000 kg the carriage of an FDR is a Recommendation.

Chapter 6.10.4 includes a Standard requiring aircraft for which the individual C of A was first issued on or after 1 January 1987, and in excess of 27,000 kg to be equipped with a CVR. For aircraft in the lesser weight category again the carriage of a CVR is a Recommendation. For aircraft with a C of A issued on or after 1 January 1990, it is also a Recommendation that the duration of the CVR be extended from 30 minutes to 2 hours.

It is recommended that the CAA should amend the Air Navigation Order requiring aircraft whose maximum certificated weight exceeds 5,700 kg but is less than 27,000 kg and which operate in the Aerial Work or Private Category, as well as in the Transport Category, to be equipped with flight recorders. This will reflect the Recommended Practices contained in ICAO Annex 6 Part II Chapter 6.10. [Recommendation 99-29]

The accident aircraft was not registered in the UK, although the Cayman Islands tend to reflect UK regulations. The ICAO Annexes are designed to ensure that national airworthiness authorities achieve the minimum standard. Although existing regulations did not require the accident aircraft to be fitted with any type of flight recorder, the fortuitous presence of a working FDR contributed greatly to the investigation of this accident. Flight recorders are primarily designed for accident and incident investigation, although they serve other purposes as well. It is considered that the ability to have recorded data from every occurrence involving classes of aircraft such as the Dash 7 is so important that consideration should be given to raising the relevant existing Recommended Practices in Annex 6 to Standards. It is therefore recommended that the Department of the Environment, Transport and the Regions (DETR), Civil Aviation, should urge ICAO to revise Annex 6 Part II, Chapter 6.10 such that aircraft in the weight category between 5,700 kg and 27,000 kg are required to be equipped with flight recorders, without regard to their operating category. [Recommendation 99-30]

Safety recommendations

The following safety recommendations are made:

Recommendation 99-29

The CAA should amend the Air Navigation Order requiring aircraft whose maximum certificated weight exceeds 5,700 kg but is less than 27,000 kg and which operate in the Aerial Work or Private Category, as well as in the Transport Category, to be equipped with flight recorders. This will reflect the Recommended Practices contained in ICAO Annex 6 Part II Chapter 6.10.

Recommendation 99-30

The Department of the Environment, Transport and the Regions (DETR), Civil Aviation, should urge ICAO to revise Annex 6 Part II, Chapter 6.10 such that aircraft in the weight category between 5,700 kg and 27,000 kg are required to be equipped with flight recorders, without regard to their operating category.