De Havilland Canada DHC-8-311, G-BRYS

AAIB Bulletin No: 2/99 Ref: EW/C98/9/4 Category: 1.1

Aircraft Type and Registration:	De Havilland Canada DHC-8-311, G-BRYS
No & Type of Engines:	2 Pratt and Whitney Canada PW-123 turboprop engines
Year of Manufacture:	1992
Date & Time (UTC):	29 September 1998 at 0745 hrs
Location:	On approach to Runway 34 at Aberdeen
Type of Flight:	Public Transport
Persons on Board:	Crew - 4 - Passengers - 48
Injuries:	Crew - None - Passengers - None
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	51 years
Commander's Flying Experience:	4,800 hours (of which 200 were on type) Last 90 days - 200 hours Last 28 days - 40 hours
Information Source:	AAIB Field Investigation

The crew reported for duty at 0530 hrs to operate a return flight from Manchester to Aberdeen. The commander was operating as the Pilot Flying (PF) with the first officer as the Pilot Not Flying (PNF). The 22 year old first officer had 458 hours flying experience on type. It was normal for the aircraft to be flown, for the most part, with the auto pilot engaged. On this occasion the commander briefed the first officer that he would probably fly the aircraft manually more than normal as he was due to carryout a company base check in a weeks time and wanted to practice his manual flying skills. The aircraft, which was serviceable with no recorded defects in the technical log, departed 'off chocks' at Manchester at 0629 hrs and climbed to its cruising altitude of FL180 without incident.

The cruise phase of the flight was flown with the auto pilot engaged in ALT HOLD (Altitude Hold) and L NAV (Lateral Navigation) modes. Aberdeen Runway 34 was in use and so the commander briefed for a manually flown 'radar vectors to ILS' approach. The current ATIS for Aberdeen gave the surface wind as calm with few clouds at 200 feet, scattered clouds at 800 feet and broken cloud at 1,200 feet.

At 0735:30 hrs, during the manually flown descent to FL90 on a radar heading of 050°, the aircraft was transferred to Aberdeen approach control whereupon the controller instructed the crew to resume their own navigation for the 'ADN' VOR. The crew, however, requested to route direct to an 8 mile centre fix position for Runway 34. The controller transmitted "THAT'S APPROVED IT'LL BE RADAR ADVISORY SERVICE OUTSIDE CONTROLLED AIRSPACE". At this stage the commander decided to re-engage the autopilot in the L NAV mode. The crew were then given the QNH of 1004 mb and QFE of 997 mb and asked by the controller if they could "SELF ESTABLISH (on the ILS localiser) AT EIGHT MILES". The crew confirmed the request and at 0743 hrs were cleared to descend to an altitude of 3,200 feet and asked to reduce speed to 180 kt. Moments later they were cleared to descend to 2,000 feet and "REPORT LOCALISER ESTABLISHED". At 0745:50 hrs the crew reported localiser established and were cleared to descend on the ILS and change to the tower frequency.

The next call from the crew was still on the approach frequency when they reported at 4.5 DME. The approach controller was surprised to hear the aircraft still on his frequency but replied "YOU'VE COME OFF THE ILS BY THE LOOK OF THINGS YOU'RE TWO MILES TO THE EAST, ARE YOU SHOWING ESTABLISHED?" The crew replied "NEGATIVE...WE'RE JUST TURNING BACK ON" to which the controller replied "YOU HAPPY TO CONTINUE THE APPROACH?" The crew confirmed that they were and were transferred again to the tower frequency.

The crew made contact on the tower frequency at 0746:50 hrs reporting at 3.5 DME. The tower controller immediately transmitted "...CONFIRM YOU ARE VISUAL". (Coincident with the end of this transmission was an internal call from the radar controller to the tower controller of "I'VE WARNED HIM ALREADY!") The crew transmitted 'NEGATIVE' to which the tower controller replied "YOU'RE CLEARED TO LAND RUNWAY THREE FOUR SURFACE WIND CALM". The crew however immediately responded by transmitting '...GOING AROUND'. This was acknowledged by the tower controller who cleared them to climb to an altitude of 3,000 feet and maintain runway heading. At 0748 hrs the aircraft was transferred back to the radar frequency.

When the aircraft came onto his frequency the radar controller asked if there had been a problem. The crew explained that they had tried to turn onto the ILS using the Flight Management System (FMS) but that appeared not to have worked. The controller then instructed the crew to turn right onto a heading of 080°. The aircraft initially turned to the left before reversing its turn to the right. The radar controller then asked if they could maintain 3,000 feet. The crew confirmed that they could but the radar controller re-emphasised 3,000 feet as the cleared altitude. Data recorded on the Flight Data Recorder (FDR) showed that the aircraft had in fact climbed to 3,800 feet and then descended to 2,700 feet before eventually levelling at 3,000 feet.

Minutes later the radar controller transmitted "...I ADVISED YOU (during that approach) THAT YOU SEEMED TO BE GOING AWAY FROM THE ILS YOU SAID YOU WERE TURNING BACK (but) ONCE I'D PUT YOU BACK TO TOWER YOU APPEARED TO GO EVEN FURTHER AWAY FROM THE ILS". The first officer replied "WE ACTUALLY RECEIVED SOME GPWS SPURIOUS WARNINGS IT STARTED SHOUTING TERRAIN TERRAIN AT US.....". The controller responded 'UNDERSTAND THAT I THINK YOU GOT QUITE CLOSE TO THE MAST PROBABLY."

The remainder of the radar vectored instrument pattern and subsequent ILS and landing were flown without further incident.

Radar information

Information recorded from the Aberdeen radar and plotted on a 1:50,000 scale map of the area showed the aircraft's ground track and mode 'C' altitude during the approach. After initially intercepting the ILS inbound course, albeit slightly to the left, the aircraft deviated to the east of the runway centreline achieving a maximum displacement of 2 km before converging towards the airfield. This track took the aircraft close to Aberdeen city centre and 650 metres laterally and 82 feet vertically from a radio transmitter mast (648 feet amsl) situated in the Cummings Park district of the city.

Weather

The 0750 hrs weather report for Aberdeen gave the surface wind as calm with a visibility 3,500 metres in mist. The cloud cover was few at 200 feet, scattered at 600 feet and overcast at 1,200 feet. The temperature and dew point were +12°C/+11°C respectively and the QNH was 1004 mb.

A report from the Meteorological Office at Bracknell stated that the synoptic situation at 0800 hrs showed a slack pressure gradient established over East and North Scotland. The 0600 hrs upper air sounding data suggested that there was a surface inversion with a top of 700 feet and temperatures of +12.5°C/+6°C. An isothermal layer also existed with a base of 3,200 feet and temperatures of +6.5°C/+5°C and a top of 4,200 feet with temperatures of +6°C/+1°C. The surface wind was calm and variable 5 kt or less at 2,000 feet.

A Boeing 757 had carried out an ILS ahead of the incident aircraft and landed on Runway 34 at 0738 hrs. The incident aircraft turned to establish on the ILS centreline at 0745:40 hrs, some 7 minutes after the B757 had landed. The possibility of a wake vortex encounter causing the Dash 8 to roll to the right with a bank angle of 30° and deviate from the localiser was therefore considered. Although the light wind regime and the isothermal layer at 3,200 feet could have encouraged the prolonged existence of wake vortex generated turbulence, a study of the Dash 8's recorded flight data confirmed that the aircraft's roll was not caused by wake vortex effects.

Flight Data Recorder (FDR) information

Recorded flight data showed the active modes of the autopilot/flight director system as well as parameters such as radio height, altitude, heading, roll angle, engine torques and localiser and glideslope deviation. Using this data it was possible to analyse the events that occurred during the approach.

The aircraft descended from its cruising flight level in the vertical speed (VS) and L NAV (lateral navigation) modes. The commander stated that he disconnected the auto pilot in the descent to fly the aircraft manually as briefed. The instruction from ATC to self position on the ILS, according to the commander, took him by surprise and as a result he re-engaged the auto pilot and it remained engaged as the aircraft descended to capture (ALT C mode) the selected altitude of 2,000 feet at a selected speed of 170 kt. The turn onto the final inbound ILS course was flown with L NAV still engaged. The commander stated that he had already pre-set his heading bug to the inbound course of 344°.

The aircraft completed the turn onto the inbound course as expected whereupon the commander momentarily selected HDG (heading) on the mode control panel and then pushed the V/L (VOR or Localiser) and NAV buttons for localiser capture. He did not however set the ILS inbound QDM of 344° on his course selector. The first officer reported that the commander's course selector was set 90° removed from the inbound course and that this was only corrected after the aircraft had deviated from the runway centreline. Localiser capture mode became active almost immediately with the localiser beam bar slightly off-set to the right by 0.27 of a dot. Instead of making the expected small correction necessary to regain the localiser centreline (ie zero dot displacement) and tracking the ILS the autopilot applied increasing right bank to an angle of 29.88°.

Within 10 seconds the aircraft heading had altered to 005° (21° to the right of the ILS QDM). The commander realising that the aircraft was not capturing the localiser selected heading and speed modes. The aircraft continued to turn to the right for the next 8 seconds onto a heading of 020° before slowly turn back to the left. By now the aircraft was 0.6 of a dot above the ideal glideslope and 1.0 dot to the right of the localiser heading 36° to the right of the inbound course. The commander reduced the engine torques to zero and, as the automatic flight system was still in speed

mode, the aircraft commenced a descent at 170 kt. 7 seconds later the localiser indicated full scale deflection to the left (2.5 dots) and the aircraft was heading 016°, still deviating from the inbound course. At 1,874 feet agl the commander disengaged the autopilot. He continued to fly a decent turning slowly to the left eventually to parallel the inbound course by the time the aircraft reached a radio height of 870 feet (agl). For the next 11 seconds the aircraft continued to descend reaching, at its lowest point, a radio height of 430 feet (agl). By this time the commander had initiated a go-around. Engine torques were increased to approximately 108% and the aircraft pitch attitude increased to +13.6° to climb still in heading and speed modes. The go-around mode (GA) was not activated.

The autopilot was re-engaged in the active heading and speed modes as the aircraft climbed through a radio height of 1,930 feet agl. It remained with these modes active as the aircraft climbed to and exceeded its cleared altitude of 3,000 feet. The aircraft reached 3,800 feet before the engine torques were reduced causing the aircraft to descend again. At an altitude of 3,330 feet in a descent the commander selected vertical speed mode and 59 seconds later the aircraft eventually captured the cleared altitude of 3,000 feet. The autopilot remained engaged during the subsequent radar vectored ILS approach until it was disconnected at 286 feet agl on finals.

Ground proximity warning system (GPWS)

The aircraft is fitted with a Sundstrand Ground Proximity Warning System that automatically and continuously monitors the aircraft's flight path with respect to terrain at all radio heights between 50 and 2,450 feet. If the projected flight path will imminently result in impact, the system issues a warning to the flight crew. Warnings are given whenever the aircraft penetrates the warning envelope of any of the five flight modes relative to terrain. Warnings for modes 1 to 4 indicate that the aircraft is either dangerously close to the terrain or not in the proper configuration and immediate action must be taken. Corrective action for these modes consists of executing and maintaining an immediate pull-up by adding climb power and assuming the best climb angle. Mode 2A covers excessive (terrain) closure rate (gear and flaps retracted). Closure rate with terrain is a function of aircraft rate of descent, shape of the terrain overflown and forward speed (ground speed) of the aircraft. The initial warning in the case of a GPWS mode 2A activation is an audio warning of 'TERRAIN TERRAIN' which, if the closure rate increases and/or the radio altitude reduces, is followed by the audio warning 'PULL UP'.

Using data recorded on the FDR, it was possible to determine the aircraft's rate of descent compared with its radio height. Analysis of the recordings showed that although the instantaneous rate of descent varied considerably, the average rate of descent from 1,600 agl to 1,100 feet agl started at 2,000 feet per minute (fpm) and increased to 2,200 fpm. As the aircraft descended to 700 feet agl the rate of descent increased to 3,000 fpm and at 600 feet agl increased to 3,200 fpm putting the terrain closure rate within the 'TERRAIN TERRAIN' boundary of the GPWS Mode 2A envelope.

Digital integrated flight control system

The aircraft is equipped with a Sperry SPZ-8000 Digital Integrated Flight Control System that provides automatic flight and the execution of flight director guidance, autopilot, yaw damper and trim functions. The automatic path mode commands are generated by the Flight Guidance Computer which integrates the attitude and heading reference, air data and the Electronic Flight Instrument System (EFIS) into a complete aircraft control system that provides the stabilisation and control required.

The localiser mode provides for automatic intercept, capture and tracking of the front course localiser beam to line up on the centreline of the runway in use. Prior to engagement the pilot has to tune the navigation receiver to the localiser frequency, set the course pointer on the HSI to the ILS QDM and set the heading cursor on the HSI to the desired heading to perform a course intercept.

During a normal intercept of the localiser the lateral beam sensor (LBS) monitors localiser deviation, beam rate and true air speed (TAS). At the computed time the LBS will trip and capture the localiser signal. At this point the flight guidance computer drops the heading select mode and generates the proper roll command to bank the aircraft towards the localiser beam centre. With the aircraft almost lined up on the localiser beam centre the computer will automatically change to the LOC TRACK 1 and LOC TRACK 2 submodes.

Course select error signals are routed to the flight guidance computer from the HSI and represent the difference between actual aircraft heading and desired aircraft course. The course error signal is modified by TAS signals to achieve approximately the same aircraft turn radius for a given command regardless of aircraft's altitude and airspeed. The radio (localiser) signal, also routed to the flight guidance computer, is modified to cater for the aircraft approaching the localiser transmitter and beam convergence. The localiser signal is filtered, amplified and summed with the course error signal.

At the point of ILS beam capture, which in this incident was with the aircraft already heading towards the airfield and slightly offset to the left of the localiser, the flight guidance computer generated a roll angle based on ILS beam position, beam closure rate and course error. The course was 90° removed from that which should have been set, hence a maximum course error signal was generated causing the flight guidance computer to demand a roll, up to the roll angle limit of 30°, in order to intercept a course that was in conflict with the ILS deviation signal.

ICAO guidance material

ICAO Document 8168 OPS/611 Volume 1 covers Aircraft Operations - Flight Procedures. Paragraph 3.5.4 deals with the final approach segment - precision approach - ILS. It states that:

> 'The final approach segment begins at the final approach point (FAP). This is a point in space on the centreline of the localiser where the intermediate approach altitude/height intersects the nominal glide path. Generally glide path interception occurs at heights from 300 m (984 feet) to 900m (2,955 feet) above runway elevation. On a 3° glide path interception occurs between 6 km (3 nm) and 19 km (10 nm) from the threshold. The width of the ILS final approach area is much narrower than those of non-precision approaches. Descent on the glide path must never be initiated until the aircraft is within tracking tolerance of the localiser.
>
> ILS obstacle clearance surfaces assume that the pilot does not normally deviate from the centreline more than half a scale deflection after being established on track. Thereafter the aircraft should adhere to the on-course, on-glide path position since more than half course sector deflection or more than half course fly-up deflection combined with other allowable system tolerances could place the aircraft in the vicinity of the edge or bottom of the protected airspace where loss of protection from obstacles can occur'

Operations manual (OM)

The operator's OM includes, under the heading of normal procedures, a section on 'crew co-ordination'. It states that both crew are responsible for ensuring that the aircraft is levelled off at the assigned level, and any divergence from either the horizontal or vertical profile of an instrument approach must be brought to P1's attention without delay.

Flight Training Manager's newsletter

A month before the incident the operator's Flight Training Manager issued a newsletter which included reference to the use of the FMS in relation to navigating to a 10 nm final approach fix

position. It stated that it was possible for pilots to make an error in inputting details of the fix position and therefore it was unsafe to use this facility in any circumstances other than when the aircraft was receiving a full radar service.

Approach charts

The 'ILS/DME 34' approach chart for Aberdeen, used by the pilots, only showed terrain contours and did not show the position of obstructions. The pilot would therefore only be aware that the safety height in the area to the east of the runway centreline was 1,800 feet. By convention obstructions below 500 feet above aerodrome level (aal) are not shown on this type of chart as safe clearance is assured if the 1,800 feet safety altitude is respected. The mast to the east of the centreline, which is 648 feet amsl (433 feet above the aerodrome elevation of 215 feet), is only depicted on the 'Radar Vectoring Area' chart for Aberdeen. All the masts of significance near to the airfield are shown on the ILS DME RWY 34 chart included in the UK AIP.

Manual of Air Traffic Services (MATS)

The Manual of Air Traffic Services Part 1 Chapter 2 includes a paragraph detailing when an aircraft shall be instructed or advised by the radar controller to carry out a missed approach. The relevant paragraph is reproduced as follows:

> An aircraft shall be instructed to carry out a missed approach in any of the following circumstances:
>
> (a) on instructions from approach/aerodrome control;
>
> (b) when no landing clearance is received before 2 miles from touchdown (or such other range agreed with aerodrome control);
>
> (c) when it appears to be dangerously positioned on final approach.
>
> An aircraft is to be advised to carry out a missed approach in any of the following circumstances:

(a) if it reaches a position from which it appears that a successful approach cannot be completed;

(b) if it is not visible on the radar display for any significant interval during the last two miles of the approach;

(c) if the position or identification of the aircraft is in doubt during any portion of the final approach.

Missed approach instructions shall include the level to which the aircraft is to climb and, if necessary, heading instructions to keep the aircraft within the missed approach area. The aircraft shall be instructed to contact approach control or, by arrangement, to remain with the radar controller.

Air Traffic Services (ATS), CAA Safety Regulation Group, has realised through discussions with controllers that there appears to be some confusion within the industry regarding the material as published above. Although the guidance is contained within the Approach Radar Chapter of MATS Part 1, they suggest that it is appropriate for any controller who believes that an aircraft is dangerously positioned on final approach to instruct it to carry out a missed approach. An aircraft can be considered as 'dangerously positioned' when it appears to be poorly placed either laterally or vertically. Controllers should issue missed approach instructions if, for example, they observe a Mode 'C' readout indicating that an aircraft is dangerously low and in close proximity to terrain or obstructions. It is not possible to quantify 'dangerously positioned' in the terms of distance or height nor provide a definitive list of circumstances in which go-around instructions shall be issued. Controllers must use their professional judgement and assess the information available to them. A supplementary Instruction to MATS Part 1 is to be issued in the near future amplifying this matter.

Follow-up action

As a result of this incident the company issued instructions in the form of two Flight Crew Notices (FCN). The first detailed the procedure to be adopted when using the Flight Management System (FMS) to track towards a 'centre fix' for an ILS intercept. The notice is reproduced below:

A recent incident highlighted the possibility of incomplete ILS capture when de-selecting FMS and engaging NAV/APP Mode on the Flight Director when established on the ILS centreline. Experience has shown that there is a tendency for the system to suffer momentary fluctuations before settling down to give valid ILS indications. In order to minimise resulting aircraft oscillations the following procedure is to be adopted when intercepting the ILS centreline.

The FMS may be used to navigate to a given ILS intercept way point, however, the FMS shall be deselected, and the Flight Director HDG and NAV mode engaged, to enable conventional ILS capture, AT LEAST 5 nautical miles prior to the intercept point.

This will enable the PF to identify the ILS, select the correct approach QDM, and allow the crew to complete the APPROACH checks prior to ILS capture. It will also ensure a smooth intercept of the ILS.

The second FCN (issued on 8 December 1998) emphasised the need to ensure that the course cursor (on the HSI) has been correctly set to the ILS inbound QDM during the Approach Checks.

Summary

Although the commander had briefed that he would fly the approach manually he re-engaged the autopilot during the intermediate descent and it remained engaged until disconnected by him at 1,874 feet agl on the first approach. The FMS, used in the 'L NAV' mode initially, navigated the aircraft successfully to establish on the correct inbound heading slightly to the left of the extended centreline of Runway 34. The course set on the commander's HSI, at the time of ILS localiser capture, was 90° removed from the correct inbound ILS QDM of 344°. Therefore, when the flight control system captured the localiser signal it applied 29° of right bank in order to cater for 90° of course error.

The commander quickly realised that the aircraft was manoeuvring away from the desired track although at the time he was not aware of the reason why. He attempted to regain the centreline by selecting 'HDG'. This selection however only served to turn the aircraft slowly to the left an amount insufficient for an expeditious re-capture of the localiser. By this time the aircraft was above the glide path and, although the aircraft was 1 dot to the right of the localiser and on a heading that would increase its deviation, he commenced a descent using the autopilot in the speed mode. He allowed the descent, flown partly by the autopilot and subsequently manually, to continue to a radio

altimeter height of 430 feet agl even though the localiser was displaying a full fly left indication. The GPWS Mode 2A terrain warning was triggered during the go-around manoeuvre.

The commander did not activate the go-around mode hence the flight control system remained in the already active speed mode. The commander subsequently allowed the aircraft to climb 800 feet above the cleared altitude before reducing engine torques which caused the autopliot, in order to maintain the selected speed, to pitch the aircraft into a decent towards the cleared altitude of 3,000 feet. The aircraft however again failed to level at the cleared altitude, descending below it by 300 feet. Eventually the aircraft levelled at 3,000 feet and the subsequent radar vectored ILS approach was flown without incident.