SERIOUS INCIDENT

Aircraft Type and Registration:	Eurocopter EC155B1, OY-HJJ	
No & Type of Engines:	2 Turbomeca Arriel 2C2 turbine engines	
Year of Manufacture:	2003 (Serial No: 6662)	
Date & Time (UTC):	6 November 2013 at 2023 hrs	
Location:	Clipper Gas platform, North Sea	
Type of Flight:	Commercial Air Transport (Passenger)	
Persons on Board:	Crew - 2	Passengers - 8
Injuries:	Crew - None	Passengers - None
Nature of Damage:	None	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	41 years	
Commander's Flying Experience:	2,240 hours (of which 1,160 were on type) Last 90 days - 120 hours Last 28 days - 44 hours	
Information Source:	AAIB Field Investigation	

Synopsis

Shortly after takeoff from an off-shore platform at night, the helicopter entered a series of extreme pitch excursions which resulted in the airspeed reducing below 20 kt, followed by a descent. The flight crew were eventually able to recover to normal flight. The helicopter had descended to within approximately 50 feet of the sea surface. It was found that the helicopter's flight path was consistent with inappropriate control inputs. The investigation concluded that a combination of technical and organisational factors had pre-disposed the flight crew to believing that the helicopter was not performing correctly, which led them to depart from normal operating parameters. This resulted in the crew rapidly becoming disorientated to the extent that their ability to control the helicopter safely was compromised. Several safety actions have been taken by the helicopter operator.

History of the flight

The helicopter was operating a personnel transfer flight to the Clipper gas production platform in the southern North Sea. It departed on the outbound flight from Norwich Airport at 1925 hrs with two flight crew and five passengers on board. The 1848 hrs weather report from the platform gave a wind of 190º at 14 kt, FEW clouds at 500 ft and SCT cloud at 1,100 ft. The visibility was reported as 6,675 m with recent light drizzle; QNH was 996 hPa.

The outbound flight was unremarkable. The weather on arrival was slightly worse than forecast, with a visibility of 3,000 m, FEW clouds at 400 ft and SCT clouds at 800 ft. The actual wind was largely unchanged. The commander, acting as Pilot Flying (PF), flew the majority of the sector including the approach. However, the physical characteristics of the helideck and the prevailing wind direction necessitated that the co-pilot, who flew the majority of the sector as Pilot Not Flying (PNF), take control for the landing.

Ten passengers boarded the helicopter for the return flight to Norwich. The calculated takeoff mass was 37 kg below the calculated performance limited takeoff mass of 4,870 kg. However, when the commander, acting again as PF, attempted to lift the helicopter from the helideck, he could achieve only a low hover with the power available. He therefore had to land back on the helideck.

During the first takeoff attempt, an amber TRIM caution illuminated on the Caution Advisory Display (CAD), with an associated amber C legend on each pilot's Primary Flight Display (PFD). This indicated that a problem existed with the collective channel of the Automatic Flight Control System (AFCS). The crew carried out a reset of the AFCS which cleared the caution, although it reoccurred several times (along with other AFCS related indications, as described in more detail later in this report) while the helicopter was on the helideck. The commander briefed the co-pilot that automatic control of the collective might not be available after takeoff.

One passenger and his luggage were off-loaded and the crew prepared for a second attempt at takeoff. The second attempt to take off also encountered performance issues, even though the calculated takeoff mass was now 134 kg below the performance limited maximum. The commander decided to land again to off-load a further passenger, reducing the total to eight. A combination performance issues and the need to deal with repeated AFCS cautions prolonged the departure. With generally poor weather in the operating area, the crew became concerned that the fuel state was reducing towards minimum for their flight to Norwich.

After 28 minutes on the helideck, the commander carried out a successful takeoff and, as the helicopter accelerated, he engaged the autopilot in Go-Around (GA) mode. Almost immediately, the crew sensed that the helicopter was not transitioning to a climb as they expected, but was in fact still descending and accelerating. With the autopilot still engaged, the commander made manual control inputs in an attempt to ensure the desired climb profile was followed. Recorded flight data showed that the helicopter transitioned to a climb but that pitch attitude continued to increase steadily to 18º nose-up and the airspeed reduced to near zero. Soon afterwards, with the helicopter still in a nose-high attitude and at low speed, the co-pilot, in response to a request for assistance from the commander, made an input on the collective lever which resulted in an over-torque. The nose-up pitch continued to increase, reaching 23.5º nose-up before recovery action was taken. In recovering from the pitch excursion, the helicopter reached a 36º nose-down pitch attitude with the subsequent high rate of descent being arrested approximately 50 ft above the sea surface. A further nose-high pitch excursion followed, during which the helicopter reached 20º nose-up. The commander subsequently recovered the helicopter to normal flight parameters and established a climb to cruise altitude. The crew reported initial difficulties engaging autopilot modes during the climb, but normal functionality was recovered prior to a safe approach and landing at Norwich, 47 minutes after takeoff.

Flight crew reports

The flight crew were interviewed separately on the morning of 8 November 2013.

AFCS abnormal indications

Both pilots described repeated indications of abnormal AFCS operation before the final takeoff, which occurred while the helicopter was on or just above the helideck. Although the pilots differed somewhat in their recall, in general terms both described repeated amber TRIM captions on the CAD, with an associated C legend on their PFDs. These captions generally appeared just as the collective lever was first moved upwards for liftoff.

According to the pilots' reference cards, these indications represented '*loss of collective trim or stick position sensors*'. The associated actions were applicable only in flight, and consisted of notes that flight could continue, but that certain autopilot functions would not be available. The crew therefore responded to the cautions by carrying out repeated re-sets of the AFCS, which in each case were successful. The commander also noted that he had to adjust the collective friction control as the lever felt stiff to move and did not seem to move smoothly.

From the pilots' combined accounts, it is possible that there was also an ACTUATOR caption on the CAD which may have illuminated briefly, after one of the resets, before clearing. The cause of this condition was described in the reference cards as '*loss of series actuator*'. The associated actions for this condition, which again were related only to flight, consisted of assuming manual control and carrying out a reset of the AFCS. The commander also thought (and confirmed by later comment on the voice recording) that an amber COLL LINK (collective link) legend had appeared on his PFD in association with a CAD caution. Both pilots were certain that resets had been successful and that no abnormal indications were present when the helicopter eventually took off.

Takeoff and accelerating transition

With the helicopter climbing vertically and maximum takeoff power applied, the commander committed to the takeoff by moving the cyclic control forward to commence the transition. He was concerned about the hitherto unexpected poor performance, and selected a greater nose-down pitch attitude than normal in order to ensure that the helicopter cleared the helideck as swiftly as possible; flight data showed the helicopter reached an 18º nose-down attitude. The commander recalled thinking that the helicopter's cyclic control felt unusual, and that pitch control was more sensitive than usual. He was aware of a descent and thought the performance was still not as expected.

At about 40 kt, in response to a standard "airspeed alive" call from the co-pilot, the commander reduced power to maximum continuous in accordance with normal procedures. He thought the helicopter had levelled or began a shallow climb by about 55 kt airspeed. However, the commander still felt that performance was poor and so, possibly slightly earlier than usual, he engaged the autopilot GA mode, which was confirmed by correct indications on his PFD. However, he soon felt that the helicopter was not responding as expected, which was to climb away at the current airspeed. Instead, he believed it pitched nose-down slightly and was still descending and accelerating. In an effort to arrest the perceived speed excursion and assist the autopilot to transition to a normal climb, he thought he may have temporarily made an aft input on the cyclic control.

The co-pilot had a similar impression and recalled calling "still descending". The commander did recall making an aft cyclic input at this stage. The autopilot remained engaged in the GA mode, and the commander was aware of overriding it for a short while. He recalled seeing the pitch attitude increasing to about 20º nose-up and a significant rate of climb, although he perceived the helicopter to be still descending with maximum power applied. He heard the automatic aural alert 'ONE HUNDRED FEET' and called for the co-pilot (who was aware of the pitch excursion and had been calling out parameters) to assist him. The commander believed that this occurred at about the lowest height reached during the incident.

The co-pilot saw the pitch attitude increasing and thought the commander was making control inputs in the correct sense, although they appeared exaggerated, resulting in a degree of 'over controlling'. He was aware of the reduced height (he thought about 50 ft) and airspeed reducing through about 20 kt. He thought the commander wanted him to assist on the controls, so placed his hands on them and made a forward input on the cyclic and an upward movement of the collective lever. The commander retained control but reduced power slightly before establishing what he believed was a normal accelerating transition. He did recall disengaging the autopilot at some stage in the event, but was unsure exactly when. The co-pilot recalled a further pitch oscillation before recovery to normal flight was achieved.

The commander reported that the helicopter's cyclic control felt unusual throughout and that it was akin to flying the helicopter in a degraded control mode, whereby only basic stability augmentation is available. Although not a normal condition, it was one which he practised routinely in the simulator. The co-pilot, from his observation of the commander's control inputs, was of the same opinion. The commander recalled disengaging the autopilot, but thought it was probably late in the sequence of events.

The commander reported difficulty in engaging some autopilot modes during the subsequent climb until ALT mode (altitude hold) was selected for cruise flight. A successful 3-axis coupled[1] ILS was flown at Norwich.

Footnote

[1] 'Coupled' refers to the process of coupling the autopilot to one or more upper modes.

Helicopter description

The Eurocopter EC155B1 is a twin-engined helicopter that can carry up to 13 passengers with 2 crew (Figure 1). It has an AFCS, also known as the autopilot (AP), that can control the four axes of pitch, roll, yaw and collective.

Figure 1
Eurocopter EC155B1 OY-HJJ

Automatic Flight Control System (AFCS)

System overview

The helicopter's AFCS is intended to improve stability and handling qualities with 'basic modes' functioning continuously in normal operation. Additionally, a number of 'upper modes', which are guidance modes, are selectable by the pilots as desired. The 'upper modes' include airspeed hold (IAS), altitude hold (ALT), vertical speed hold (VS) and go-around mode (GA).

Controls and indications

'Upper modes' are engaged and disengaged by pushbuttons on a control panel or on the cyclic and collective controls. Indications of mode engagement status are displayed on each pilot's PFD (green for engaged modes). Indications of failures, transient conditions or degraded modes are also displayed on the PFD, sometimes accompanied by caution messages on the CAD. Reference or target values are displayed on the PFD and navigation display (ND), and a failure of the autopilot to achieve a reference value for any reason is also indicated on the PFD. Indication that a control is being moved manually while upper modes are engaged is indicated to the flight crew by the engaged mode legend on the PFD flashing green/amber.

The commander recalled seeing indications of correct GA mode engagement. However, neither he nor the co-pilot were aware of any other AFCS related indications on their PFDs during the incident.

AFCS Go-Around (GA) mode

Engagement of the GA mode is achieved by pressing a button on the collective lever. In this mode the autopilot initially maintains the airspeed at time of engagement and a vertical speed of 1,000 ft/min up or current vertical speed, whichever is higher. The airspeed and vertical speed can then be adjusted by the pilot if desired. Unless other modes were selected beforehand, GA mode would automatically revert to separate IAS and VS modes after 15 seconds. In GA mode or IAS / VS mode, the autopilot controls vertical speed through the collective control and airspeed through cyclic pitch control.

Technical description of the AFCS

The AFCS consists of an Automatic Pilot Module (APM) which controls the helicopter via four series actuators and four parallel actuators. The series actuators provide small but rapid control inputs on the roll, pitch and yaw axes (two on the roll axis). The parallel actuators, also known as trim actuators, provide slower control inputs over the full control range. These control the roll, pitch, yaw and collective axes and also provide control feel. The pilot can override the parallel actuators by force or can press the relevant trim release button to disengage them.

The APM receives a number of inputs from air data systems, gyroscopes, cyclic positions sensors, a yaw lever position detector and a collective lever position detector (CLPD). The CLPD is mounted to the airframe below the left collective and has a link that connects to the collective push-pull tube. As the collective is moved, the link moves and its linear displacement is converted to an angular displacement which is measured by an RVDT[2] and a potentiometer installed inside the CLPD (Figure 2). The RVDT provides collective position to the APM, while the potentiometer serves to monitor the RVDT. If the two disagree a TRIM and C caption will be illuminated in the cockpit, as well as a COLL LINK caption. If these captions remain on, the collective channel will not be available to the AFCS.

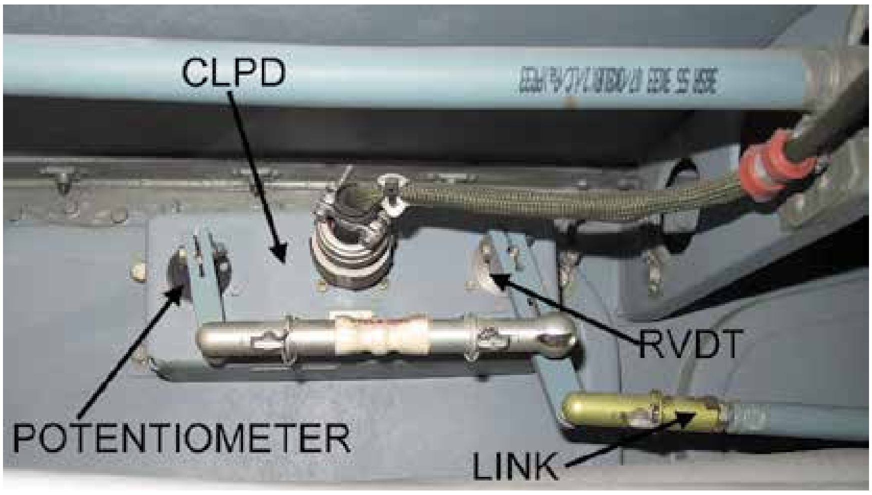

Figure 2

Collective Lever Position Detector (CLPD)

Footnote

[2] Rotary Variable Differential Transformer, used for accurate measurement of angular displacement.

Recorded flight data

The helicopter was fitted with a combined cockpit voice recorder and flight data recorder that contained one hour of cockpit recordings and over 12 hours of flight data respectively. This was removed from the helicopter following the incident for the data to be downloaded and analysed. Electrical power to the flight recorder was not isolated after landing, so the unit continued to record until the helicopter's main power was turned off. Consequently, for the voice recordings, activities on the helideck and the first part of the takeoff were over-written. The main flight data parameters for the incident are shown at Figure 3.

Recorded flight data

Recorded flight data showed the transition commencing with a progressive forward movement of the cyclic control and a corresponding decrease in pitch attitude from the hover attitude of 2 to 3º nose-up to 18º nose-down (Figure 3 - time 39400 seconds). The cyclic then moved back to just forward of neutral and nose-down pitch started to reduce. As the helicopter accelerated and power was reduced to maximum continuous (not shown), the pitch attitude was still significantly below 10º nose-down. The helicopter's flight path changed from level flight to a descent. At about 70 kt, as the helicopter pitched up through 10º nose-down, the cyclic control moved further back to about the neutral position and the rate at which the helicopter was pitching up increased, although it continued to descend with a maximum rate of 860 ft/min for two or three more seconds before a climb was established. At this point, as the pitch attitude passed 0º, and at 76 kt airspeed, autopilot GA mode was engaged (time 39409).

About two seconds after mode engagement, with vertical speed increasing towards (and eventually exceeding) the target of 1,000 ft/min, the collective and engine torque began to reduce under the control of the autopilot collective channel as it tried to limit the vertical speed to 1,000 ft/min. Vertical speed reached a maximum of 1,500 ft/min.

The cyclic control remained at about neutral as the pitch continued to increase. Although the autopilot GA mode remained engaged, force 'breakout' sensors on the cyclic control detected continued pilot manual control inputs, primarily in pitch but also in roll, which continued until the point of eventual recovery. The helicopter continued to pitch up and climb, reaching 18ºº nose-up pitch at about 240 ft radio height[3] and with speed reducing through about 45 kt. At this point, total engine torque, which had reduced to below 50% (time 39415), started to increase again, reaching about 80% over 6 seconds.

With increasing forward cyclic inputs, the pitch attitude then decreased over the next 8 seconds (although with oscillations) to reach 10º nose-up, by which time the helicopter had climbed to 400 ft radio height with airspeed reducing to below 20 kt. The collective lever was raised, to give about 88% torque. About two seconds later, there was a noticeable forward movement of the cyclic and the collective was further raised (believed to be the inputs made by the co-pilot). Engine torque increased briefly to 109%, representing the point at which the over-torque occurred. Radio height at this point was about 410 ft.

Footnote

[3] Radio height is recorded at a low sample rate of once per four seconds.

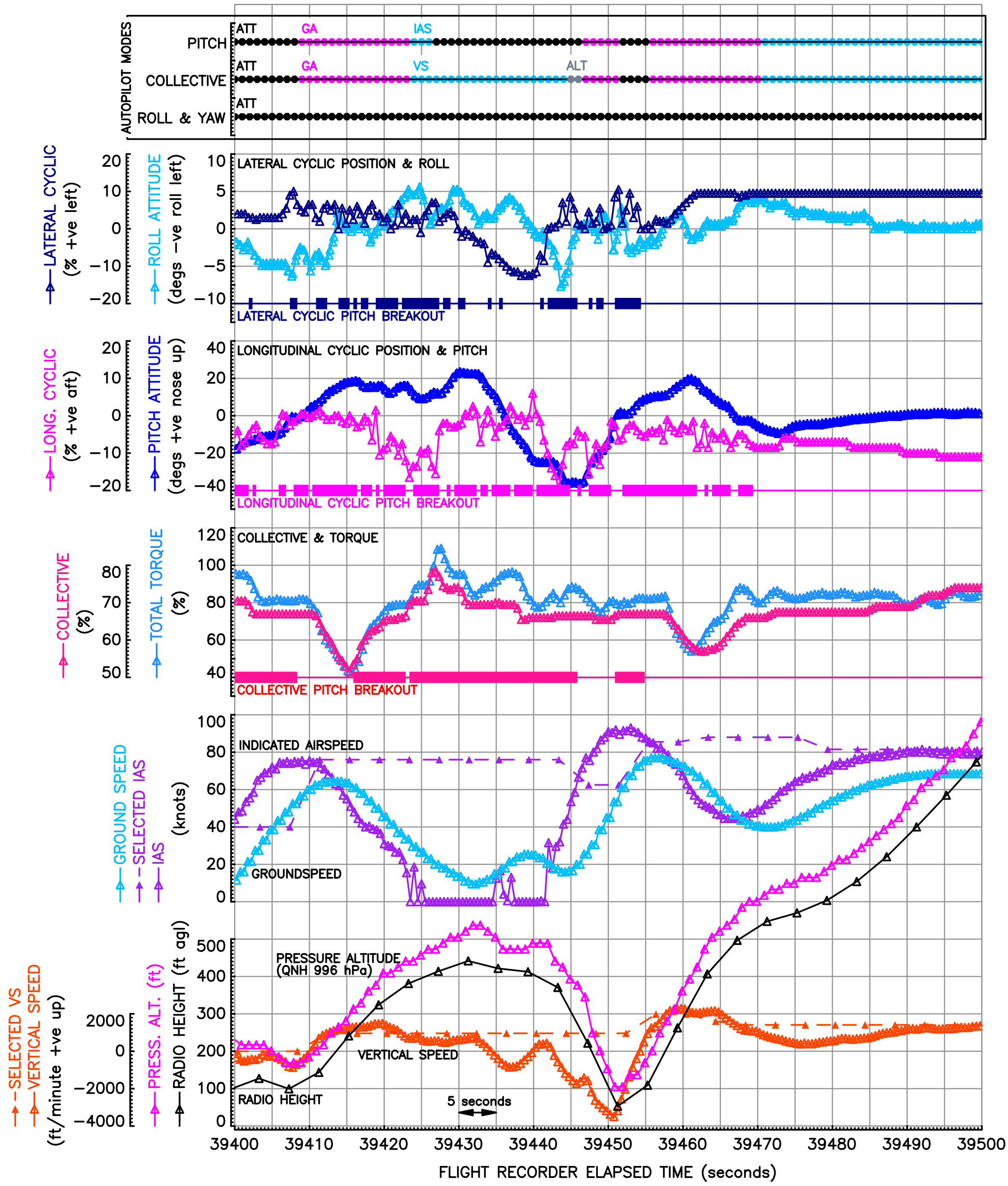

Figure 3

Salient recorded flight data for the incident to OY-HJJ

With data indicating zero airspeed[4], the cyclic control then moved significantly aft again, initially to just forward of the neutral position, and pitch attitude started to increase again (time 39426). This was coincident with operation of the cyclic trim release button (not shown), which allowed the pilot to disengage the trim actuators temporarily on the cyclic control, allowing it to be repositioned to a new datum without the artificial load applied (the commander remembered repositioning the cyclic rearwards, although he thought this occurred earlier in the sequence, in response to his initial perception that the helicopter was not responding correctly to GA mode engagement). The helicopter reached 25º nose-up pitch over the next 3 seconds (time 39430). It remained at this value for a further 3 seconds, with the helicopter at 460 ft radio height and indicating zero airspeed, before a noticeable forward cyclic input was made. The helicopter then pitched nose-down and started to descend.

The helicopter reached 24º nose-down pitch in about 7 seconds. After a brief pause at this value, the helicopter responded to increasing forward cyclic input by pitching down further, to 36º nose-down. This was accompanied by a rise in airspeed and descent rate calculated from the pressure altitude as 2,900 ft/min at a height of about 100 ft. After about a second, the helicopter pitched up again, reaching zero pitch angle just before it reached the lowest recorded radio height of 53 ft.

There followed a similar pitch up excursion, to 20º nose-up, but with a more obvious and controlled recovery. This time, the airspeed did not fall below 40 kt and the helicopter maintained a climb throughout.

AFCS mode behaviour

When the commander engaged GA mode, it engaged as expected. Current airspeed (76 kt) became the autopilot speed target, with a vertical speed target of 1,000 ft/min up. As vertical speed increased towards the target and then exceeded it, collective and engine torque reduced, as would be expected. The GA mode remained engaged for 15 seconds before reverting to IAS and VS modes. However, as IAS decayed to zero, due to the aft cyclic inputs, the IAS mode disengaged automatically, being replaced with a basic attitude mode; the VS mode remained engaged.

There was a brief GA mode re-engagement as the helicopter descended towards its lowest altitude, but both pitch and collective channels disengaged simultaneously after 2 or 3 seconds, probably the deliberate disengagement by the commander. A further 2 seconds later, the mode was again engaged. As with the first engagement, the helicopter was by this time climbing under pilot input and collective and engine torque again reduced as the vertical speed increased. The GA mode remained engaged, reverting to IAS and VS modes for the subsequent climb. Pilot manual input continued in cyclic pitch but ceased as the recovery and climb became established.

Footnote

[4] The recorded airspeed is unreliable below 20 kt.

Data comparison with earlier flights

The flight recorder contained data for 17 earlier takeoffs, being a mix of shore-based and platform departures. The weight and balance conditions for each flight were not established, nor were environmental conditions, so only a general comparison between the earlier flights and the incident flight was made. Nevertheless, the following observations were made:

1. The nose-down pitch attitudes for initial transitions were all between -5º and -9º.
2. The cyclic pitch control position in the early stages of transition always remained significantly further forward than on the incident flight and never as far back as the neutral position. The most rearwards position was typically achieved just after maximum nose-down pitch, and appeared to be a short term corrective input. Cyclic positions then moved gradually forward with increasing airspeed.
3. The average pitch attitude at 70 kt on transition was 4.4º nose-down.
4. The final pitch attitudes for most transitions were only 2º to 4º above the initial pitch attitude, with only small variations in actual cyclic pitch positions.
5. Stabilised climb pitch attitudes varied between +2º and -2º, depending on airspeed, the actual values remaining largely stable.
6. There were no other instances of manual inputs occurring with autopilot upper modes engaged, either on earlier flights or later on the accident flight. All observed returns of manual inputs in cyclic pitch were consistent with the phase of flight.
7. Autopilot GA mode was used on takeoff on 53% of previous flights.

Cockpit voice recordings

The recording started with the commander's call to the co-pilot for assistance. Immediately afterwards, the over-torque warning chime sounded and it was evident that it had been noticed by the commander. The co-pilot announced that the speed was zero, and called out the applied power. Eight seconds later he announced "FOUR TWENTY FEET RADALT, SPEED COMING UP". Four seconds later he called "WE'RE DESCENDING", repeating the warning immediately after, although the commander did not acknowledge the calls. The aural voice alert "ONE HUNDRED FEET" sounded three seconds after, and the co-pilot said "CHECK HEIGHT". The commander made a short exclamation. The next call was the co-pilot calling out airspeed and attitude as the helicopter climbed through 200 ft, after reaching its lowest point.

Subsequent conversation between the pilots included discussion about apparent problems engaging autopilot heading mode (although it did subsequently engage) and what had occurred on takeoff. Each pilot voiced confusion over what had occurred, and each appeared to identify the point that GA mode was engaged as being a key area: the commander said that the helicopter didn't respond as he thought it would do and the co-pilot remarked that the helicopter was still descending.

Loss of relevant voice recordings

Voice recordings from the ground phase and early flight phase were overwritten because power to the flight recorder was not isolated immediately after landing and shutdown, allowing the unit to continue to run. The operator included the following in its Operations Manual part A, paragraph 2.5.13, being an extract from JAR-OPS procedures:

> *'To prevent the data of the FDR/CVR to be erased, the power supply to the FDR/CVR should be disconnected until the data has been preserved.'*

It was apparent at interview that, in the absence of further guidance or explicit instructions to flight crews, the commander believed that isolation of the recording equipment was an engineering function.

Helicopter examination

An autopilot self-test was carried out by the crew after landing and there were no faults. Additional self-tests were carried out by the operator's engineer and by the AAIB, and again there were no faults. Interrogation of the APM did not reveal any fault codes for the incident flight.

Examination of the collective control system revealed that the potentiometer inside the CLPD had become loose. When the collective was moved the body of the potentiometer moved slightly. The CLPD was removed which revealed that one of the three tongues which secured the potentiometer to the casing had become loose (Figures 4 and 5). This tongue should have engaged into the slot at the base of the potentiometer, but it had become loose and rotated out, enabling the body of the potentiometer to rotate slightly during collective movement. The other two tongues were still securely engaged in the slot.

Figure 4
Inside the CLPD

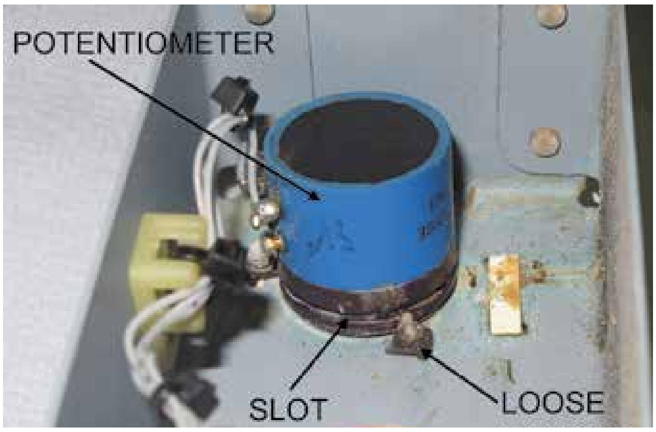

Figure 5

Close-up of potentiometer inside CLPD

The APM and CLPD were removed from the helicopter for further examination and replacement parts were installed. The operator carried out further checks on the flight control system and AFCS and no faults were found. All control movements were found to be smooth without binding. The over-torque checks were also completed with no faults found. The helicopter then underwent a test flight during which no anomalies or AFCS faults occurred; this flight included a departure with GA engagement in a similar flight condition to the incident flight. The helicopter was subsequently released back to service.

Further faults following OY-HJJ's release back to service

On OY-HJJ's third flight in operational service, during pre-taxi checks, the ACTUATOR caption illuminated on the CAD accompanied with C and R captions on the PFD. These cleared when the AP was reset. During the last phase of the flight, while raising the collective in the flare, the TRIM caption with C illuminated. Additionally, the pilot reported that the collective was harder to move than normal. The collective system was inspected and tested for full movement and no faults were found. Two flight tests were carried out, during which the TRIM and Y captions illuminated. The yaw parallel actuator was replaced and a further test flight was carried out without incident. During departure of the next operational flight, the TRIM and Y captions illuminated as well as YAW on the AP control panel. These occurred multiple times and were cleared by switching the yaw channel on and off six times. The helicopter was subsequently withdrawn from service for further investigation with the assistance of the helicopter manufacturer.

To address the collective TRIM with C fault, the bearings in both collective mixing units were replaced although they showed no binding during tests. The fault in the yaw channel was traced to a bellcrank in the aft end of the tailboom which had a worn guide that could cause binding in the yaw controls. The bellcrank was replaced and the helicopter was returned to service but the TRIM with C captions illuminated again.

Further investigation revealed that wiring around the collective control was tight so this was re-routed. In addition, the grounding block 10N2 was found to be soiled with dirt and oil. This grounding block serves to ground three wires for the YAW TRIM discretes.

The resistance between the yaw parallel actuator plug and these three ground pins was measured and found to be high. The ground wires were removed from the block and found to be slightly corroded, so were cleaned and replaced. In the operator's experience corrosion on wirepins for discrete signals could cause false captions on the CAD.

Given these findings, the TRIM with Y caption was probably caused by either the worn bellcrank in the tailboom or the corroded wires in the 10N2 grounding block, or a combination of both.

As a further preventative measure the collective, roll, pitch and yaw parallel actuators were replaced.

Examination of the stationary swashplate revealed chafing where the main servo rod end was attached to the swashplate (left image in Figure 6). This area of the swashplate should have been protected by a 'stirrup guide' (right image in Figure 6), but this guide was missing. Because the servo rod is a hydraulic actuator, any resistance, due to chafing between the rod end and swashplate, would not have been felt in the pilot controls and would not have affected the AFCS. The swashplate was replaced with a new part with a stirrup guide fitted.

Following the aforementioned rectification action the helicopter was returned to service with no further reported AFCS faults.

Figure 6

Left image: fixed swashplate from OY-HJJ with missing stirrup guide;
Right image: stirrup guide on another swashplate

Autopilot module examination

The APM was removed from the aircraft and sent to the helicopter manufacturer for testing under the supervision of the BEA[5]. The APM should have recorded fault codes in its non-volatile memory (NVM) in relation to the AP captions witnessed by the flight crew, but no such fault codes were stored. The manufacturer connected the APM to another helicopter and repeated the interrogation of the NVM but no fault codes were stored. The manufacturer's investigation into the cause of the lack of fault code recording is continuing.

Footnote

5 The BEA is the Bureau D'Enquêtes et D'Analyses – the French equivalent of the AAIB.

Maintenance history

OY-HJJ was manufactured in 2003 and bought by the current operator in 2007. At the time of the incident it had accumulated 4,962 hours and 8,595 cycles. There was no significant recent maintenance or significant deferred defects. The CLPD and the potentiometer inside the CLPD had not been replaced since the operator acquired the helicopter in 2007. Maintenance documentation from the helicopter's previous owner could not be obtained, so it could not be established if the potentiometer had been installed by the manufacturer or by the previous owner's maintenance organisation. The helicopter manufacturer stated that this was their first known occurrence of a loose potentiometer in the CLPD.

The stationary swashplate (also known as the non-rotating star) had been installed on OY-HJJ in June 2011. This swashplate had been repaired and overhauled by the helicopter's maintenance and repair organisation (MRO) in February 2011. During overhaul the stirrup guide was not replaced, and this was due to the repair worksheet not including an instruction to replace this guide. The helicopter manufacturer has initiated an internal investigation and has published a revised repair worksheet which includes an instruction to install the stirrup guide. It also intends to publish a Safety Bulletin to require operators of the EC155 to inspect the stationary swashplate for stirrup guide fitment.

Flight crew information

The commander joined the operator as a co-pilot in July 2012 with 1,780 hours total flying time. He completed type conversion training with his previous company and had flown 570 hours on type. His most recent recurrent simulator check was completed successfully on 4 October 2013. The commander's training records reflected successful completion of all required training with no weaknesses noted.

The co-pilot joined the operator in September 2012. He had also previously qualified on type, with 1,300 hours total and 550 hours on type. His most recent recurrent simulator check was completed successfully on 13 July 2013. Like the commander, his training records reflected successful completion of all required training with no weaknesses noted.

On the day of the incident, the two pilots reported for their duty at 1515 hrs. Both pilots had returned to duty after scheduled days off and each considered himself well rested and fit.

Helicopter performance

Helicopter mass

The helicopter was weighed by the manufacturer in 2007 at the time of its delivery to the operator. In 2011, it was dry-leased to a company in Africa, where it was re-painted and re-weighed. On return to the operator in 2013, a new weighing record was produced on the basis of the 2011 weighing record. However, there was a misunderstanding over the configuration of the helicopter at the time of its weighing in 2011; the cabin seating had not been included in the new figures, whereas the operator believed that it had been. When the helicopter was re-weighed after the incident, it was found to be 82 kg heavier than that stated on its weighing record.

In line with the provisions of JAR-OPS 3[6], the operator's OM Part A stated:

> *'The mass and centre of gravity (C of G) of each Company helicopter shall be established by actual weighing before it is used for the purpose of commercial air transportation. All helicopters are to be reweighed thereafter at intervals of four years.'*

JAR-OPS 3 further stated:

> *'Helicopters transferred from one JAA operator with an approved mass control programme to another JAA operator with an approved programme need not be weighed prior to use by the receiving operator unless more than 4 years have elapsed since the last weighing.'*

The company to which OY-HJJ was dry leased did not meet the above criteria, so a re-weighing would have been required on the helicopter's return in 2013. At that time, as part of the operator's application to the Danish Transport Authority (DTA) for an Airworthiness Review Certificate (ARC), the 2011 weighing report was among documents presented to a DTA official for inspection. The operator regarded the issue of the ARC as an acceptance by the DTA of its non-compliance with JAR-OPS 3. However, there was no documented evidence of such.

When the helicopter was drained of fuel for weighing, it was also established that a calibration error in the right hand fuel system resulted in an extra 38.5 kg of fuel being carried in the right hand tank than was indicated to the flight crew. The combined effect of these two factors was to produce an error or 120.5 kg in the calculated takeoff mass; the helicopter being heavier than the flight crew believed.

The reason for the fuel calibration error was subject to separate investigation. The helicopter operator undertook to analyse historical flight information to establish if and when the helicopter may have been unwittingly flown outside the applicable mass and balance limitations.

Helicopter performance

Using a performance table appropriate for the Clipper platform, the flight crew derived a performance limited maximum takeoff mass of 4,870 kg. For their initial departure, takeoff mass was calculated to be 4,833 kg, 37 kg below this maximum, while the second takeoff attempt, with 9 passengers, was calculated to be 134 kg below maximum. The final takeoff, with 8 passengers on board and an appropriate fuel adjustment, was calculated to be at 4,573 kg, or 297 kg below the performance limited takeoff mass.

During the investigation, takeoff performance figures were recalculated using the revised, higher weight. This established that the first two takeoff attempts were above the

Footnote

[6] JAR-OPS Part 3 prescribes requirements applicable to the operation of any civil helicopter for the purpose of commercial air transportation by any operator whose principal place of business is in a JAA Member State.

performance limited takeoff mass, by 114 and 17 kg respectively (the second attempt may have been slightly under the maximum if fuel burnt while on the heli-deck is taken into account).

The final takeoff mass (including an adjustment for additional fuel burnt) was 146 kg below the maximum. The helicopter remained below the absolute maximum all-up mass of 4,920 kg throughout. Actual centre of gravity position was calculated to be at 3.92 m aft of datum, which was slightly forward of mid position and within prescribed limits.

Company information

Takeoff profile

The normal takeoff profile detailed in the operator's Operations Manual (OM) was based on one developed by the helicopter manufacturer with a view to reducing exposure to risk during the takeoff phase. The procedure was termed PC2DLE: *Performance Class 2 – Defined Limited Exposure*. It entailed a vertical climb using no more than maximum takeoff power to a decision point 20 ft above the helideck, at which point the helicopter was rotated to a maximum of 10º nose-down (the Eurocopter Complimentary Flight Manual for the EC155B1 gave this as 15º nose-down, the reduced value being a company maximum). As the helicopter reached takeoff safety speed of 40 kt, power was to be reduced to maximum continuous, the nose-down attitude reduced and a smooth accelerating climb initiated.

The company's training philosophy on AFCS use after takeoff was that autopilot upper modes would only be selected via the autopilot mode selector panel, and only once the helicopter's flight path was stable. GA mode was not regarded as a normal mode to be used after takeoff. However, it was known that other operators of the type routinely used GA mode after takeoff, and that pilots joining from those operators may revert to using it during normal takeoffs. The commander was one of these pilots, and it was evident at interview that he regarded GA mode as a valid mode for use after takeoff. The operator's OM did not prohibit the use of GA mode for takeoff, it only stated:

> *'Climb may be flown manually or in 3 or 4 axis CPL mode. Normally 4 axis coupled.'*

In a Notification to Pilots issued after the incident, the operator issued specific instructions that the GA mode may only be used during a missed approach and not during takeoff. Engagement of upper modes was not to be made below 70 kt and 200 ft, and only in a 'wings level' climb of not more than 1,000 ft/min.

Procedure, deviation and attention calls

In its OM Part B (applicable to the EC155B1), the operator detailed its requirements for standard communication calls between pilots under normal and abnormal conditions. *Procedure* calls were applicable to routine procedures on a particular helicopter type. *Attention* calls were primarily for use in the approach phase, to enhance safety and guard against an undetected pilot incapacitation; they required a clear response from the PF, with a requirement that the PNF take control of the helicopter if the PF twice failed to respond to a call. *Deviation* calls by the PNF were intended to alert the PF to deviations from the normal or intended flight path.

The OM Part B did not stipulate any requirements for the PF to acknowledge deviation calls, or state what actions the PNF should take if the deviations continued. The OM Part A (General) did include a 'Two Communication Rule'. This was also intended to guard against incapacitation, stating that a crew member should suspect incapacitation any time a pilot did not respond appropriately to a second call associated with deviation from normal procedures or flight profile.

After the incident, the operator revised its instructions to crews, requiring a positive response from the PF in case of a deviation call being made. Additionally, it required the PNF to take control in case of an incorrect or absent response to any standard call during a critical phase of flight.

Operator's internal recommendations

Following its own investigation into the incident, the helicopter operator made a number of internal safety recommendations. Areas addressed included: guidance and advice to flight crews regarding automation and the AFCS, improved flight crew training programmes, the introduction of defined flight parameters to assist PNF monitoring and the Flight Data Monitoring programme, a review of the PC2DLE based company takeoff procedure and measures to improve the company's procedures for mass and balance arrangements.

Analysis

Prior to departure from the platform, the flight crew received a number of abnormal AFCS indications. These captions were not captured in the APM's NVM, the cause of which is subject to ongoing investigation by the helicopter manufacturer. There was no evidence that these captions reoccurred during the incident and the AFCS was assessed to have operated correctly during this phase of the flight. After the CLPD was replaced, the COLL LINK caption did not recur; it was probably caused by the loose potentiometer inside the CLPD providing a different collective position reading to the RVDT. The cause of the loose potentiometer inside the CLPD could not be determined, but the helicopter manufacturer had not received any other reports of loose potentiometers. Since the potentiometer is only used to monitor the RVDT, the worst-case effect of a loose potentiometer is a loss of the collective AFCS channel with accompanying captions.

The TRIM with 'C' caption could also have been caused by the loose potentiometer. However, this caption recurred after CLPD replacement, so it may also have been caused by the restriction caused by the tight wiring around the collective control which was later discovered (and may have also caused the later ACTUATOR with c captions on further flights). The tight wiring may also explain why the commander reported that the collective felt stiff to move. No reason for the commander's report of the cyclic controls feeling unusual could be determined, nor for the ACTUATOR caution. The helicopter manufacturer stated that the ACTUATOR caution can sometimes briefly appear following an autopilot reset, and the crew's accounts support this explanation.

Despite the technical issues experienced by the crew, the helicopter nevertheless appeared serviceable and within applicable operating limitations immediately before the final takeoff. The flight crew were both early in their duty period, properly qualified and well rested. However, the takeoff was preceded by performance, technical and weather issues which would have combined to place an additional pressure on the flight crew for what was already a demanding takeoff profile.

Almost immediately after takeoff, both pilots perceived that the helicopter was not performing correctly and that the AFCS was not responding as expected, neither of which is borne out by the flight data. Their perception of the helicopter's flight path rapidly diverged from what was actually occurring, to the extent that their ability to control the helicopter within safe limits was compromised. The only unusual event that occurred between the helicopter lifting from the helideck and the onset of the crew's perception errors was the initial pitch down, which was significantly greater than both the operator's stipulated maximum and typical values seen elsewhere on the recorded flight data. It is thus likely that the initial pitch down, together with the lack of external visual cues, was the triggering event for this incident.

Flight data showed that the effect of the exaggerated nose-down attitude, when combined with the power reduction which started at 40 kt, was to cause the helicopter to descend, at a point in the transition when the crew would normally be expecting to establish in a climb. This descent continued until about the time the commander engaged GA mode, and is apparently what prompted him to start making aft cyclic inputs. The commander's assessment that the helicopter was not performing correctly was a factor in his decision to engage the autopilot slightly early, but it also meant that the autopilot was engaged before a stable, climbing flight path was achieved. This situation would have taken the autopilot a finite time to resolve, which probably conflicted with the commander's perception of the time available, hence the desire to 'assist' the autopilot with a manual control input.

As the helicopter pitched up the rate of climb increased quickly, causing the autopilot to reduce collective and engine torque significantly. This may have contributed to the crew's perception of a continued descent, which was so powerful that both pilots believed the helicopter to have descended directly to its lowest point, despite their instrumentation indicating a very different flight profile.

Recorded flight data showed that the AFCS system performed as expected, but was overridden by manual control inputs throughout much of the incident. As no other instances of manual input with autopilot upper modes engaged were detected in the recorded data, and the indications ceased coincident with recovery, the indications were believed to be valid. As far as could be determined, there were no cockpit indications of abnormal AFCS operation during the incident. Indications alerting the crew to the abnormal situation are presumed to have occurred, but were not recalled. However, the crew clearly believed that the autopilot was not functioning correctly, both during and after the event. This is most likely due to the repeated abnormal AFCS indications which occurred whilst on the helideck, which would have predisposed them to this view.

The concept of deviation calls in standard procedures is intended to alert all crew members to a developing undesirable situation. In this case, the situation developed so rapidly after takeoff that the pilots quickly became overloaded, to the extent that even basic flight parameters were incorrectly perceived. The opportunity for standard calls to prevent the situation developing was therefore limited, and only early in the incident, at a time for which there was no voice recording. However, the voice recording does show some verbal communication taking place during the most extreme manoeuvres, which probably contributed to the crew's successful recovery of the situation.

The commander's decision to select an exaggerated nose-down attitude was made out of concern for the helicopter's apparently poor performance. This arose because of the weighing and fuel gauging errors which had existed undetected for some time. Their direct effect was to cause the flight crew to believe that the helicopter was underperforming and therefore were a major influence on the commander's subsequent actions. The provisions of JAR-OPS 3 in respect of the weighing requirements would, if followed, have removed this contributory factor and the incident may not have occurred.

Safety actions

Following the incident, the operator carried out a review of the instructions and guidance given to flight crews in its Operations Manual and the content of recurrent simulator training programmes. The following safety actions were carried out:

1. Pending amendment of the Operations Manual, a Notice to Crew (NTP) was issued, covering:
   a. A revised, more conservative method of applying wind corrections to performance calculations,
   b. A limit on the number of resets that may be carried out on a malfunctioning or degraded system, with the requirement that autopilot resets must be followed by a successful system self-test,
   c. A prohibition on the use of GA upper mode after takeoff,
   d. Additional company requirements for engagement of autopilot upper modes after takeoff,
   e. An expansion of the Procedure, Deviation and Attention call-outs to introduce a formal response from PF and widen the requirement for PNF to take control of the helicopter in case of an incorrect or missing response by PF.
2. Recurrent simulator training programmes were expanded to include:
   a. A review of autopilot upper modes, including the potential for excessive deviations arising from manual control inputs while upper modes are engaged,

b. A greater emphasis on manual handling skills,

c. Increased frequency of 'recovery from unusual attitude' training.

The missing stirrup guide in the stationary swashplate resulted in chafing damage to the swashplate, but this was not related to any of the AFCS captions. The helicopter manufacturer has revised their repair worksheet to include instructions to fit the stirrup guide and intends to publish a Safety Bulletin requiring operators of the EC155 to inspect the stationary swashplate for stirrup guide fitment.

BULLETIN CORRECTION

Prior to publication it was noted that this report was incorrectly classified as an INCIDENT.

The occurrence was in fact classified as a **SERIOUS INCIDENT**.

BULLETIN CORRECTION

The report incorrectly stated the location as **Clipper South Gas Field, North Sea.** The correct location is **Clipper Gas platform, North Sea**.

The online version of the report was on corrected on 8 August 2014.