SERIOUS INCIDENT

Aircraft Type and Registration:	DHC-8-402 Dash 8, G-ECOE	
No & Type of Engines:	2 Pratt & Whitney Canada PW150A turboprop engines	
Year of Manufacture:	2008 (Serial no: 4212)	
Date & Time (UTC):	11 January 2018 at 1632 hrs	
Location:	Belfast City Airport	
Type of Flight:	Commercial Air Transport (Passenger)	
Persons on Board:	Crew - 4	Passengers - 44
Injuries:	Crew - None	Passengers - None
Nature of Damage:	None	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	60 years	
Commander's Flying Experience:	14,122 hours (of which 464 were on type) Last 90 days - 91 hours Last 28 days - 39 hours	
Information Source:	AAIB Field Investigation	

Synopsis

After takeoff from Belfast City Airport, shortly after the acceleration altitude and at a height of 1,350 ft, the autopilot was engaged. The aircraft continued to climb but pitched nose-down and then descended rapidly, activating both the "DON'T SINK' and "PULL UP" TAWS (EGPWS) warnings. The commander disconnected the autopilot and recovered the aircraft into the climb from a height of 928 ft. The incorrect autopilot 'altitude' mode was active when the autopilot was engaged causing the aircraft to descend toward a target altitude of 0 ft. As a result of this event the operator has taken several safety actions including revisions to simulator training and amendments to the taxi checklist.

History of the flight

Introduction

The crew were to complete a four-sector duty period; the first two sectors were from Glasgow Airport to Belfast City Airport and then return to Glasgow. The aircraft commander had been called in from standby and travelled by taxi from Aberdeen to Glasgow Airport where he met the co-pilot. They had not operated together before, and both had limited experience of Belfast City Airport. They briefed for the flight and, due to the weather being forecast to deteriorate at Belfast, they agreed that the commander would act as Pilot Flying (PF) for the first two sectors.

The first sector was uneventful, and the aircraft landed on Runway 22 at Belfast City. While it taxied clear of the runway, the co-pilot carried out the 'after-landing' checks which included setting the autopilot selected altitude to zero. The aircraft was parked on stand, five minutes ahead of schedule.

The weather at 1620 hrs was: wind from 110° at 4 kt, good visibility, clouds FEW at 800 ft, BKN at 1,000 ft, temperature +5˚C, dew point +4˚C and QNH 1023 hPa.

The incident flight

The commander carried out the external turnaround checks whilst the co-pilot programmed the Flight Management System (FMS) for the return flight. There were changes to the payload and this required a new load sheet to be produced. The commander stated that to save time before pushback he had set the autopilot Flight Director (FD) modes to Go-Around (GA), Heading (HDG) and Altitude Select (ALT SEL) but without first setting a selected altitude. When ATC issued the clearance, he set the selected altitude to the 3,000 ft cleared. He stated that 3,000 ft was set on the Primary Flight Displays (PFD), but neither of the crew noticed that the autopilot modes were set to HDG and Altitude Hold (ALT), and this condition was confirmed by the recorded FDR parameters. The vertical FD bar had also moved from the nose-up GA position to the aircraft symbol, corresponding to a pitch attitude of about 0°.

The crew briefed for the departure and also a Delayed Engine Start (DES) taxi but did not discuss where the second engine was to be started. The revised load sheet was completed and provided. At push back, the aircraft was three minutes behind schedule.

As the aircraft was pushed back the right engine was started. After engine start, FLAP 5 was selected. As the aircraft taxied towards holding point A1, it was cleared to enter Runway 22 to backtrack and position for takeoff. The aircraft entered the runway, and shortly after the co-pilot started the left engine; it is normal practice to have started the engine prior to entering the runway.

Approaching the turning circle at the threshold of Runway 22, the commander confirmed the takeoff clearance was "THREE THOUSAND WITH ALT SEL"; the selected FD modes were set to HDG and ALT. A few seconds later, the aircraft reached the beginning of the runway and the commander started to make a 180° right turn to position for takeoff. This coincided with the completion of the taxi checklist. The various radio calls, cabin secure and after-start checks meant that there was a high level of flight deck activity at this time, which added to the level of urgency as the crew also believed that there may have been another aircraft on the approach. The commander then referred to the Flight Mode Annunciator (FMA) modes, stating "GO-AROUND, HEADING, ALT….WHY ISN'T IT ALT SEL….THAT'S BETTER, YEAH", which coincided with the co-pilot selecting the ALT SEL mode.

Whilst the aircraft was turning, the crew carried out the 'line up' check list, which was interrupted by ATC providing the takeoff clearance. When the final item on the check list was reached which was to check the FMA and Caution and Warning Panel (CWP), the commander stated the FD modes were set to "GO-AROUND, HEADING AND ALT SEL". However, the selected modes were subsequently found to be have been set to ALT, HDG and ALT SEL.

A few seconds later the crew commenced the takeoff roll. Shortly after becoming airborne the landing gear was retracted and the FD lateral navigation (LNAV) mode was selected; the aircraft pitch was initially maintained at about 15° nose-up[1] before being reduced to about 10° nose-up.

After reaching the acceleration altitude (1,000 ft aal) the flaps were retracted, which was shortly followed by the autopilot being engaged. The aircraft was now in IMC and at a height of 1,350 ft agl and its airspeed was 163 KIAS. Following the autopilot engagement the aircraft started to gradually pitch nose-down at a rate of about 1.2° per second from a height of 1,500 ft agl. During the next 15 seconds, whilst the crew were completing the 'after takeoff' checklist, the aircraft descended at an increasing rate with the pitch attitude reducing from about 10° nose-up, to 8° nose-down.

At a height of about 1,300 ft agl, an EGPWS Mode3[2] "DON'T SINK" caution was activated. The commander responded almost immediately, disconnected the autopilot and applied nose-up pitch to arrest the rate of descent, which had reached a maximum of 4,300 ft/min. Engine power was also simultaneously reduced, with the airspeed having increased to 235 KIAS. The aircraft continued to descend for a few more seconds, during which a EGPWS "PULL UP" warning was triggered. The aircraft then transitioned to a climb, having reached a minimum height of 928 ft agl and a maximum airspeed of 241 KIAS (V_{MO}[3] below 8,000 ft amsl is 245 KIAS); the crew subsequently reported that they had become visual with the ground during the recovery.

As the aircraft climbed, the commander stabilised the pitch attitude to about 8° nose-up and the airspeed at 200 KIAS, with engine power gradually increased to the climb setting.

When the aircraft was at about 1,900 ft agl, the autopilot was re-engaged, however, the aircraft started to gradually pitch down and the commander disconnected the autopilot, stating "IT'S GOING TO ALT HOLD AGAIN, IT'S GOING TO PITCH DOWN". The commander then selected the FD indicated airspeed (IAS) mode, which deselected the ALT mode, and set the target airspeed to 210 kt. The autopilot was then re-engaged and the commander confirmed to the co-pilot that everything was now normal, with the aircraft subsequently levelled at 3,000 ft. Shortly after, ATC inquired if everything was okay, having observed the aircraft on radar descend and deviate slightly from the planned track. The co-pilot responded, stating that they had experienced a problem with the autopilot, but that it was now resolved.

The aircraft continued to Glasgow where it made an uneventful landing. After landing, the crew briefly discussed the incident, but neither were certain why the aircraft had descended when the autopilot had been initially engaged.

Footnote

1 This higher pitch attitude allows the IAS to gradually increase without exceeding the flap limiting speed and leaving the GA mode provides a good pitch reference in the event of engine failure.
2 Altitude loss after takeoff.
3 V_{MO} is the maximum operating speed for the aircraft.

Aircraft information

Automatic Flight Control System (AFCS)

The aircraft is equipped with an AFCS that includes an FD function that provides lateral and vertical guidance to fly the aircraft, either manually or automatically, and a single autopilot that couples the FD guidance for automatic control of the aircraft. FD guidance is presented on the pilots PFD as vertical and lateral bars.

Autopilot engagement and associated selection of FD modes, that include HDG, ALT SEL and ALT, are made using push buttons on the Flight Guidance Control Panel (FGCP) that is located on the upper instrument panel (Figure 1). The FD GA mode is selected by buttons on the power levers.

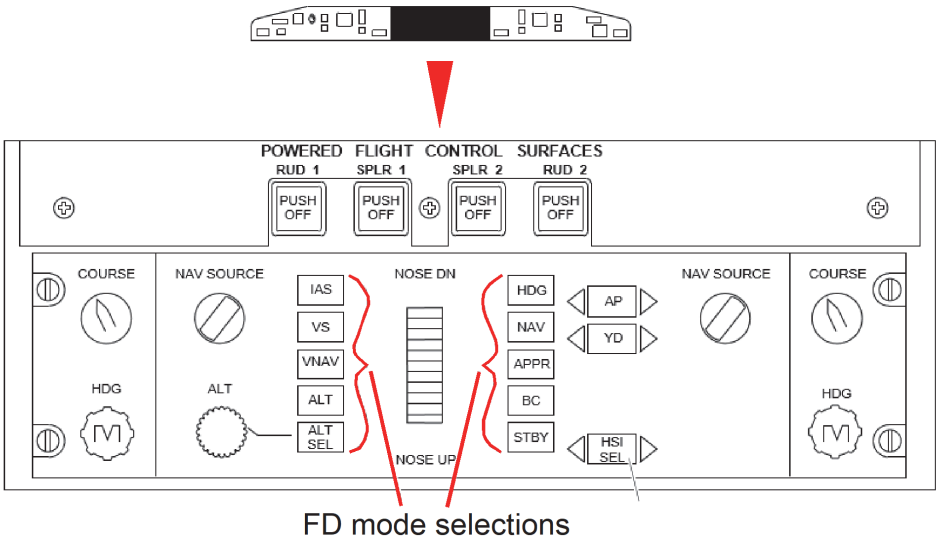

Figure 1

FMGC Panel

Selection and engagement status of the autopilot and FD modes are permanently indicated on the FMA block located at the top of the commander and co-pilot PFDs. Active FD modes are displayed in green text and armed modes are displayed in white text.

The ALT SEL mode provides FD commands to acquire and maintain the selected altitude that is set on the FGCP and displayed on the PFD. When the aircraft approaches the selected altitude, the FD automatically transitions to the altitude capture mode (ALT*), which provides guidance to level off. When the selected altitude has been captured, the FD automatically transitions to the ALT mode.

The ALT mode provides FD commands to maintain a target altitude. If the ALT mode is activated automatically, using the ALT SEL mode, the target altitude is set to the altitude set on the FGCP and displayed on the PFD.

If the ALT mode is activated manually using the push button on the FGCP, the target altitude is set to the aircraft's current altitude, rounded to the nearest 100 ft.

The AFCS logic enables the ALT and ALT SEL modes to be simultaneously selected when the aircraft is on the ground or in flight. The ALT mode will be the active mode and ALT SEL will be the armed mode.

The GA mode sets the FD vertical bars to a fixed pitch angle of about 10° nose-up, and the HDG mode commands the FD lateral bars to maintain the target heading selected on the FGCP.

Incorrect setting of the FD guidance modes prior to takeoff

Selection of the ALT mode when the aircraft is on the ground sets the FD vertical bars to a pitch attitude of about 0° and the target altitude to the aircraft's current altitude, ie the airfield elevation amsl. Selection of the ALT SEL mode, when the ALT mode is also selected, does not alter the target altitude unless the ALT mode is deselected.

If the HDG, ALT SEL and ALT modes are selected on the ground, subsequently as the aircraft climbs after takeoff above the target altitude, the FD vertical guidance bar will progressively move to a nose-down pitch attitude. Upon engagement of the autopilot, the aircraft will pitch down to follow the FD vertical guidance bar to descend to the target altitude. For this incident this target altitude would have been set to about 0 ft amsl.

Figure 2 shows the FMA and FD vertical bar positions displayed on the PFD when the FD modes are selected in accordance with the operator's procedures prior to takeoff (GA, HDG and ALT SEL) and those selected during the incident takeoff (HDG, ALT SEL and ALT). Other than the FMA indicating that the ALT mode has been armed on the ground, there are no other indications to identify that the target altitude has been set to the airfield elevation amsl.

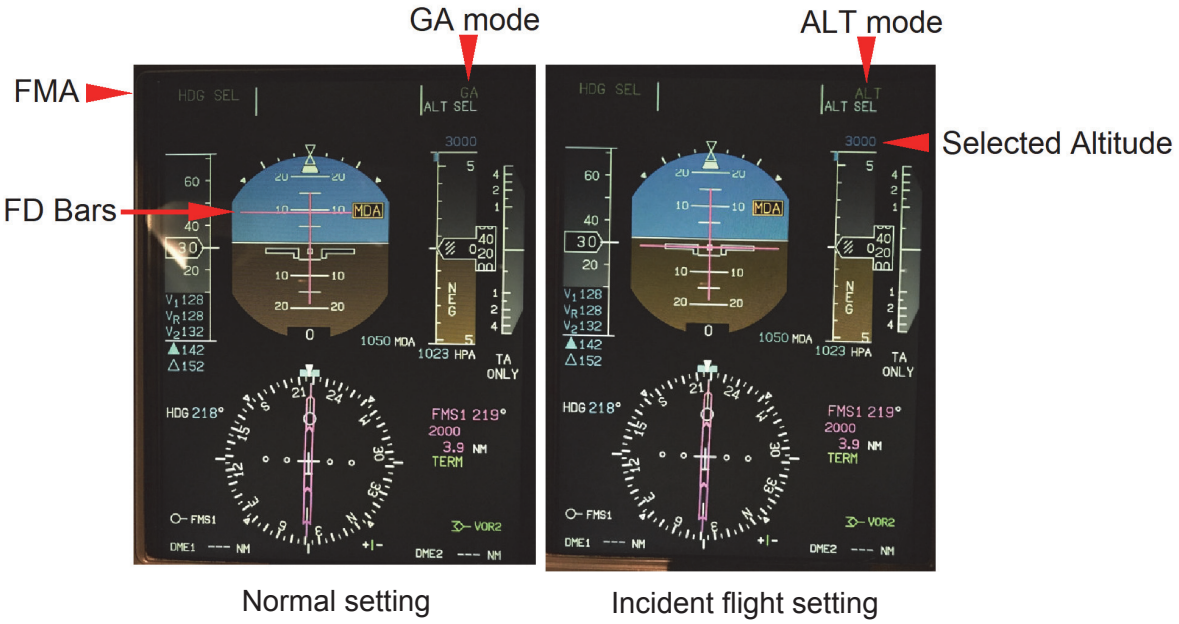

Figure 2

PFD indications when GA, HDG and ALT SEL (left PFD)
and HDG, ALT SEL and ALT (right PFD) are selected for takeoff

Sources of information

A record of the incident flight was available from the aircraft's 120 minute duration CVR and the 25 hour FDR. Information was also obtained from the two pilots. The CVR recording commenced at 1554 hrs when electrical power was applied to the aircraft as the crew prepared the aircraft for the flight, and the FDR recording commenced when the anti-collision light was selected by the crew, shortly before the first engine was started at 1624 hrs. The FDR parameters included the engagement status of the autopilot and FD modes, which included GA, HDG, ALT SEL and ALT. Figure 3 shows pertinent parameters during the incident takeoff.

As the FDR was not recording during the crew's preparations prior to the first engine start, it was not possible to validate the sequence in which the PF reported that he had initially set the FD modes and selected altitude. There was no reference by the crew to the selection of the FD modes on the CVR recording during this same period.

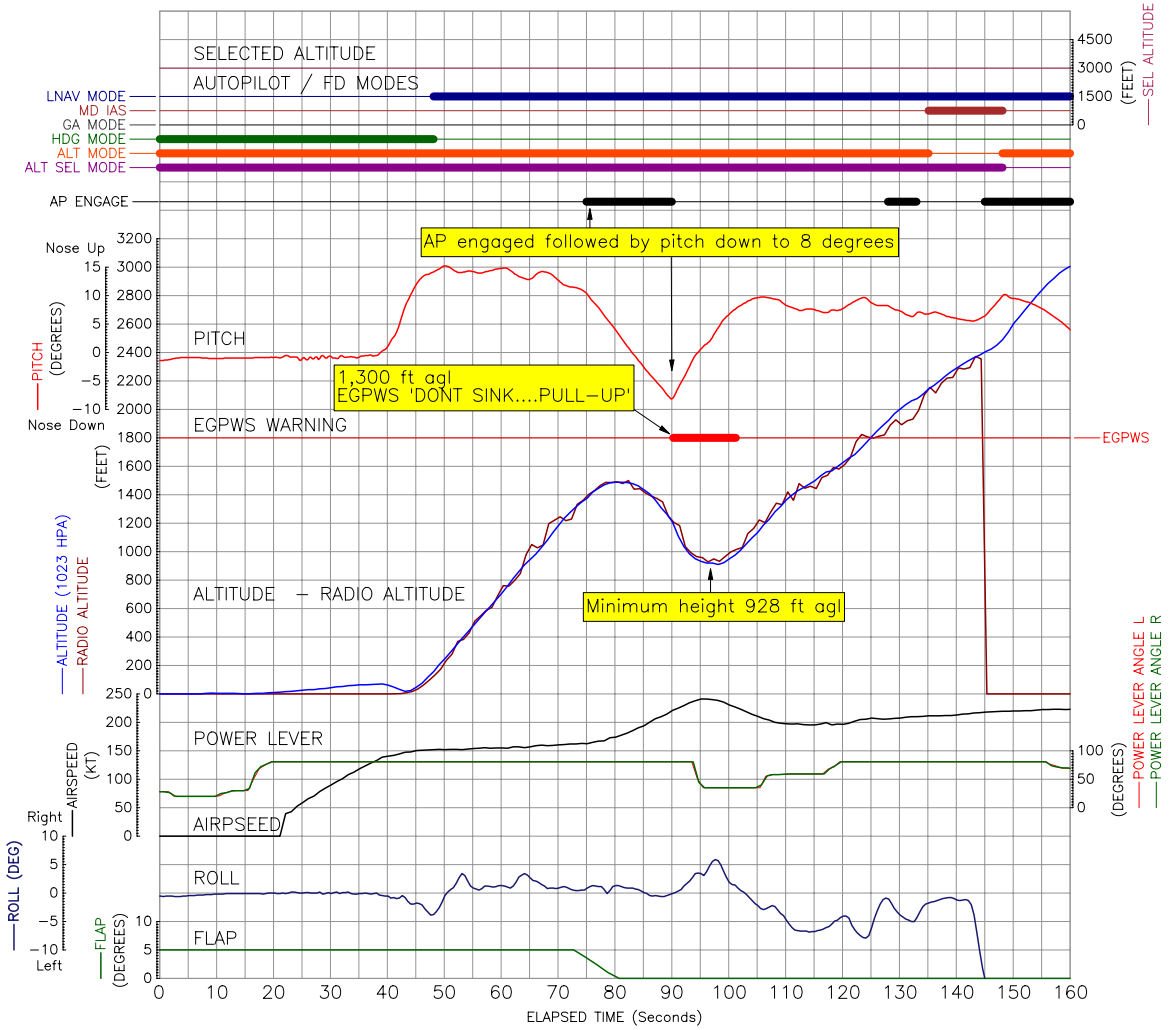

Figure 3

Descent following autopilot engagement

Previous occurrences of incorrect setting of the FD modes prior to takeoff

The operator of G-ECOE provided records of three previously reported occurrences of incorrect setting of the FD modes at takeoff on its DHC-8-402 fleet of aircraft. The details of these were:

- G-JECK operating from Glasgow to Belfast City on 3 January 2017. The FD modes were set to HDG and ALT SEL. When the autopilot was engaged, the aircraft pitched nose-down and descended by 150 ft to a height of 1,400 ft agl.

- G-FLBC operating from Edinburgh to Southampton on 12 May 2017. The FD modes were set to HDG, ALT SEL and ALT. When the autopilot was engaged, the aircraft descended by 130 ft to a height of 1,350 ft agl.

- G-JECM operating from Exeter to Manchester on 19 July 2017. The FD modes were set to HDG, ALT SEL and ALT. The crew noticed the mis-setting after takeoff and selected GA mode, which deselected ALT mode, before engaging the autopilot.

The Air Safety Reports for two of these previous incidents stated that contributory factors to mis-setting the FD included *'rushed line up checks due to an expeditious departure"* and *"possibly caused by rushing to mitigate a delay'*.

Altitude and mode selection on G-ECOE

Testing of autopilot mode selection on G-ECOE was carried out as part of the investigation, and the sequence of selecting the FD modes and departure clearance altitude on the FGCP was established as being important. If the FD modes are selected to GA, HDG and ALT SEL before setting the selected altitude to an altitude greater than that of the aircraft, the ALT SEL mode will transition to the ALT mode and the GA mode was automatically deselected, leaving HDG and ALT as the selected modes.

During the tests it was established that if GA and HDG were selected, and then ALT was selected instead of ALT SEL, then the GA mode transitioned from GA to ALT, leaving HDG and ALT modes selected.

The operator included details in its LPC training on the importance of setting the departure clearance altitude on the FGCP before the FD modes, with information that the *'aerodrome elevation may be captured as the cleared altitude'.* However, this information provided to crews did not include specific details as to the change of the FD mode from ALT SEL to ALT.

Flight Data Monitoring (FDM)

The operator of G-ECOE monitored the operation of its fleet of DHC-8-402 aircraft using an FDM programme. At the time of the incident, the system was not programmed with an event[4] to detect if FD modes were set correctly prior to takeoff.

The operator has since introduced an FDM event to monitor for incorrect selection of FD modes at takeoff.

Crew duty periods

The commander had 10 days leave before commencing his duty period, which was scheduled to be block standby, but he was rostered to fly.

On Sunday 7 January 2018, he flew four sectors from his home base of Aberdeen starting at 1145 hrs and finishing at 2133 hrs. The following day he positioned as a passenger to Southampton via Belfast starting at 1055 hrs and finishing at 1613 hrs, staying overnight at a hotel some 30 minutes taxi ride from the airport. On Tuesday 9 January 2018, he flew four sectors starting at 0550 hrs and finishing at 1415 hrs, which included a short taxi ride to the hotel in Cardiff. The next day he flew two sectors starting at 0555 hrs before positioning as a passenger by taxi from Southampton to Birmingham and as a passenger to Aberdeen, finishing at 1710 hrs. On the day of the incident, he was called prior to the start of his Standby Duty and was scheduled to fly four sectors from Glasgow which required a taxi ride from Aberdeen to Glasgow starting at 1040 hrs and arriving at 1355 hrs for a 1510 hrs departure. The second two sectors were cancelled due to having been involved in the incident and he returned to Aberdeen by taxi.

The co-pilot was based in Glasgow and was not required to position for flights during the days preceding the event.

The crew duty hours for both the crew were within the EASA permitted Flight Time Limitations (FTL).

Analysis

The flight crew had an uneventful flight from Glasgow to Belfast City Airport, and after landing, the co-pilot set the selected altitude to zero as part of the after-landing checks. The aircraft was ahead of schedule when it parked on the stand and a normal turn around followed until changes with the payload required a new load sheet. This caused a delay during which the crew prepared the aircraft for the next sector to minimise delay.

The crew's lack of familiarity with operating from Belfast City, combined with the delay due to the revised loadsheet, caused the PF to carry out as many tasks as he could before the

Footnote

[4] The core analysis function used within FDM systems is known as 'event' detection. Each event is typically developed to monitor a specific aspect of an aircraft's operation or its systems by using algorithms to identify if the data exceeds pre-defined trigger thresholds. The basis for many events and their trigger thresholds is the flight manual, operator's SOPs and principles of good airmanship.

pushback to save time. This included setting the autopilot FD modes, which the PF stated that he had selected GA, HDG and ALT SEL, before entering the cleared altitude of 3,000 ft amsl. Subsequent testing showed that this sequence will result in the ALT SEL mode changing to the ALT mode and the GA mode being deselected. At the time, this functionality was not known to the crew and neither noticed that the FD modes were set to HDG and ALT as the aircraft was pushed back.

During the DES taxi, the second engine should have been started before the aircraft entered the runway, but it was not started until during the backtrack of Runway 22. This created an increased level of activity on the flight deck and a sense of urgency, as the crew believed that there may have been another aircraft on the approach. Checks were completed but interrupted by an ATC transmission clearing takeoff and cabin crew confirming the cabin was secure. Despite this high level of activity, the 'Line Up' checks did cause the PF to identify that ALT SEL was not selected but he did not see that ALT was active instead of GA. The PF was also expecting to pitch the aircraft to about 15º nose-up instead of the 10º nose-up that the FD bar would have indicated with GA mode selected. It is possible that this was a reason why he did not notice that the FD bars were showing about 0º pitch on the PFD.

If the HDG, ALT SEL and ALT modes are selected on the ground, subsequently as the aircraft climbs after takeoff above the target altitude, the FD vertical guidance bar will progressively move to a nose-down pitch attitude. Upon engagement of the autopilot, the aircraft will pitch down to follow the FD vertical guidance bar to descend to the target altitude. For this incident this target altitude would have been set to about 0 ft amsl.

When the aircraft pitched down as the autopilot was engaged, neither pilot initially noticed the change in pitch attitude but the **"**DON'T SINK" and **"**PULL UP**"** EGPWS warnings alerted the crew to the situation. The PF reacted promptly in accordance with the trained sequence of actions and returned the aircraft to a safe flight path. During the event the aircraft lost about 500 ft in 18 seconds, with a maximum rate of descent of 4,300 ft/min and having reached a minimum height of 928 ft agl.

When the autopilot was re-engaged, the aircraft again pitched nose-down but this was identified by the crew. They engaged IAS mode which replaced the ALT mode and with ALT SEL also selected the aircraft climbed and levelled at the cleared altitude of 3,000 ft.

Conclusion

Prior to pushback, the crew had selected the FD modes without entering a target altitude. This caused one mode to default to ALT instead of ALT SEL, which was not detected by the crew.

Due to the DES being carried out whilst backtracking the runway, there was reduced time available in which to complete all required checks which, when combined with a sense of urgency, led to the crew not seeing the incorrect FD modes displayed on the FMA.

During the line-up checks, the PF noticed that ALT SEL was not displayed on the FMA. When ALT SEL was selected, the crew did not confirm that GA, HDG, and ALT SEL were displayed on the

PFD. Instead ALT mode was active and displayed which led to a target altitude of 0 ft amsl being set, resulting in a descent when the autopilot was engaged. Timely warnings of the hazardous flight path were provided by the EGPWS, and prompt corrective action by the PF returned the aircraft to safe flight.

Safety actions

As a result of this incident the operator has taken several safety actions as follows:

1) Issued an Operational Notice to flight crews in which it describes the incident and sets out the policy for the flight deck actions once ATC clearance has been obtained.

2) Amended the Taxi Checklist to include:

   'PF to review clearance including:

   Confirming FMA selections (the heading bug should be adjusted for the expected drift).'

3) Updated the operator's simulator training within the operator's recurrent training and testing programme.