SERIOUS INCIDENT

Aircraft Type and Registration:	Bombardier BD-700-1A11 (Global 5000), VP-CKM	
No & Type of Engines:	2 Rolls-Royce BR700-710A2-20 turbofan engines	
Year of Manufacture:	2012	
Date & Time (UTC):	15 November 2016 at 0138 hrs	
Location:	On approach to Hong Kong International Airport	
Type of Flight:	Private	
Persons on Board:	Crew - 3	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	None	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	56 years	
Commander's Flying Experience:	6,820 hours (of which 623 were on type) Last 90 days - 58 hours Last 28 days - 22 hours	
Information Source:	AAIB Field Investigation	

Synopsis

The aircraft was on an approach to Runway 07L at Hong Kong International Airport and descended to 390 ft amsl at a point on the procedure where its cleared altitude was 1,700 ft amsl. Acute fatigue and ineffective crew communication meant that the pilots did not have an accurate mental picture of their situation and did not appreciate they had descended below their cleared altitude. The evidence suggested that the operator did not monitor the professional standards of the crew, or ensure its Standard Operating Procedures (SOPs) were effective and being used consistently, and that this contributed to this serious incident.

History of the flight

Departure, cruise and descent

VP-CKM departed Beijing Capital Airport, China, at 2245 hrs UTC (0645 hrs local) for a private flight to Hong Kong International Airport in China with the commander as Pilot Flying (PF).

During the cruise, the commander commented to the co-pilot on several occasions that he was tired, stating at one point "I NEED TO STRETCH; I AM LOSING IT" before leaving the flightdeck for approximately nine minutes. The co-pilot did not refer to being tired.

While the commander was briefing the co-pilot for the ILS approach to Runway 07L at Hong Kong International Airport, ATC instructed the aircraft to descend to FL 8,400 m[1]. The co-pilot read back 8,300 m, which was corrected by the Air Traffic Control Officer (ATCO), and the correct level was set on the Flight Control Panel (FCP)[2]. The commander then completed his approach briefing.

After approximately 15 minutes, the commander left the flightdeck to fetch a hat because the sun was impairing his visibility. While he was away, ATC instructed the aircraft to descend to FL240 which was the first level to be given in 'feet'. The co-pilot read back the clearance correctly but set 2,400 m on the FCP. He advised the commander in the cabin that they were "HEADING ON DOWN TO TWO FOUR ZERO" but the commander questioned the cleared level on his return to the flightdeck. The co-pilot said "YES … TWENTY FOUR HUNDRED METRES" as the aircraft descended through FL260. Before reaching FL240 the aircraft was cleared to descend to FL230 which was set correctly on the FCP.

The commander questioned the co-pilot again about the previous level of 2,400 m. The co-pilot replied "IT WAS TWO THOUSAND FOUR HUNDRED, NOW IT'S TWO THOUSAND THREE HUNDRED". The commander responded "TWO THOUSAND THREE HUNDRED FEET, RIGHT … YOU HAD METRES". The co-pilot checked with ATC saying "JUST WANT TO VERIFY THAT STILL FLIGHT LEVEL TWO THOUSAND THREE HUNDRED FEET". The ATCO did not answer but instructed the crew to contact Hong Kong Radar. The commander then said "YOU'RE IN FEET … OKAY".

On contacting Hong Kong Radar, the co-pilot reported the aircraft level as "TWO THOUSAND THREE HUNDRED FEET", although it was actually at FL230, and this was corrected by the commander. The ATCO cleared the aircraft for the SIERRA 7A Standard Instrument Arrival and, at 0128 hrs (0928 hrs local), transferred the flight to Hong Kong Approach Control.

Standard Instrument Arrival

The weather at the airport was reported as: wind from 310° at 7 kt, 3,800 m visibility, no cloud, a temperature of 15°C and a QNH of 1017 hPa. The commander recalled that the weather was "very bright and very hazy". The aircraft was cleared to descend to 4,000 ft amsl, using a QNH of 1017 hPa, and to proceed direct to LIMES, the first waypoint on the ILS[3] approach to Runway 07L at the airport (Figure 1). The co-pilot read back the altitude correctly but told the commander that the QNH was 1011 hPa. The commander advised the co-pilot he was incorrect but the co-pilot disagreed, reading from the ATIS[4] that the airport QNH had been reported as 1016 hPa. The commander did not respond. Twenty seconds later, the aircraft was cleared to route direct to waypoint LIMES and the co-pilot asked the ATCO to confirm the QNH. On hearing that it was 1017 hPa, he commented to the commander that he (the commander) had been correct. The commander did not respond.

Footnote

1 Flight levels were being given in metres in the Guangzhou Flight Information Region (ZGZU).
2 The pilot can control the aircraft through the FCP by selecting navigation guidance modes and target values for parameters such as heading, airspeed, altitude and rate of climb or descent. The selected altitude on the FCP may be entered in either feet or metres. See later section *Automatic Flight Control System (AFCS)*.
3 Instrument Landing System: a precision approach using electronic localiser and glideslope signals to guide the aircraft to the runway laterally and vertically respectively.
4 ATIS: Automatic Terminal Information Service.

At 0132 hrs, the ATCO cleared the aircraft to descend to 3,000 ft amsl and proceed from LIMES to TONIC. Shortly thereafter, he gave the clearance: "FROM TONIC, CLEAR ILS 07L". This was not acknowledged by the co-pilot but, 20 seconds later, the ATCO cleared the aircraft for the ILS approach, which was acknowledged. Having been cleared for the ILS approach, the aircraft was expected to proceed to TONIC, turn right onto a track of 040°M and intercept the localiser signal, which would provide lateral guidance towards the runway (shown in Figure 1 by the black line marked with the localiser course of 073°).

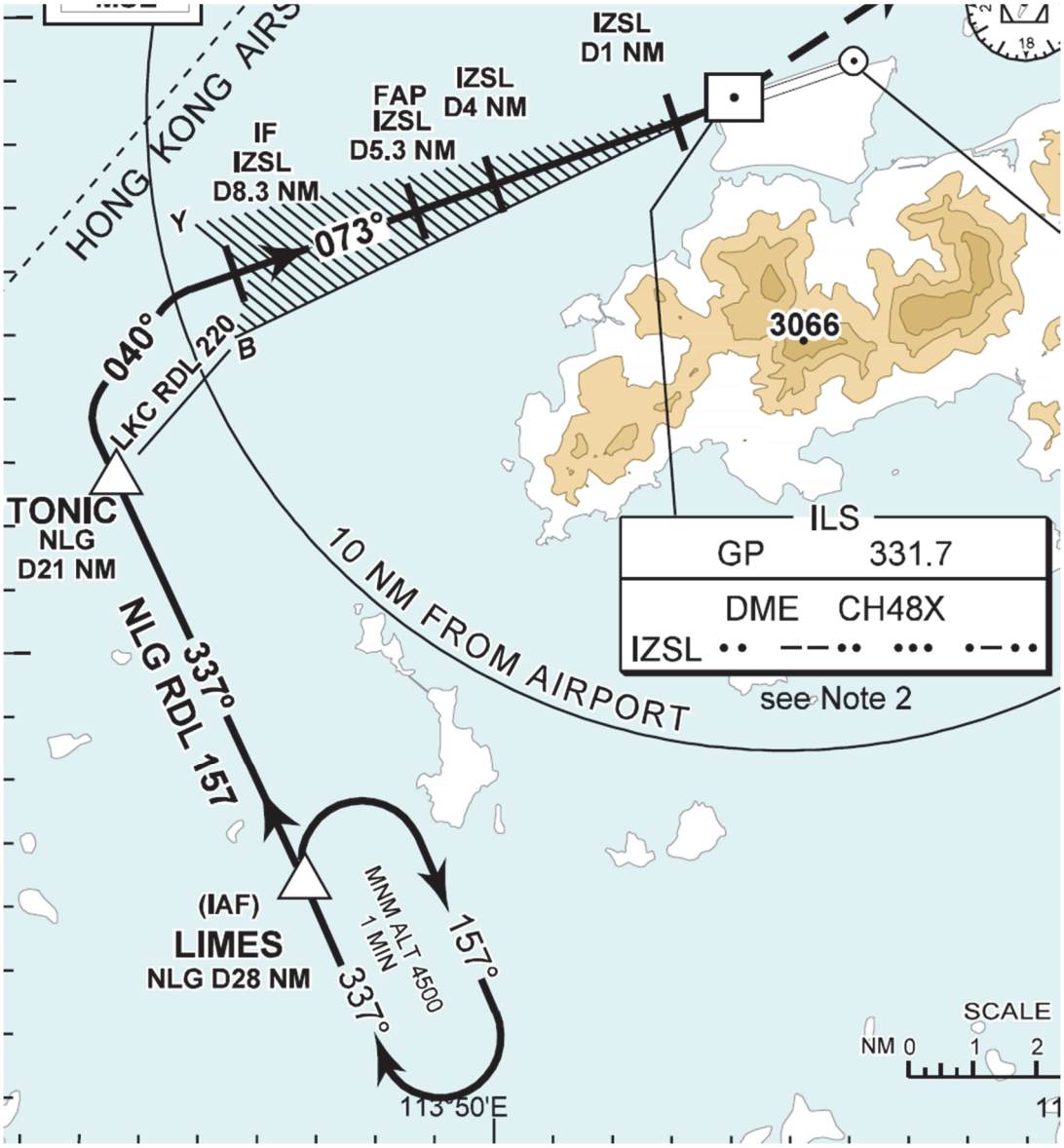

Figure 1

Plan view of the ILS for Runway 07L from the Hong Kong AIP
(valid at the time of the incident)

Figure 2, showing the vertical profile of the ILS 07L approach, indicates that, once cleared for the ILS approach and past LIMES, VP-CKM was permitted to descend to not below 1,700 ft amsl (shown in yellow). The aircraft was then expected to fly not below 1,700 ft amsl until intercepting the glideslope, which would provide vertical guidance towards the runway (shown in Figure 2 by the black line marked '*GP 3.0°*').

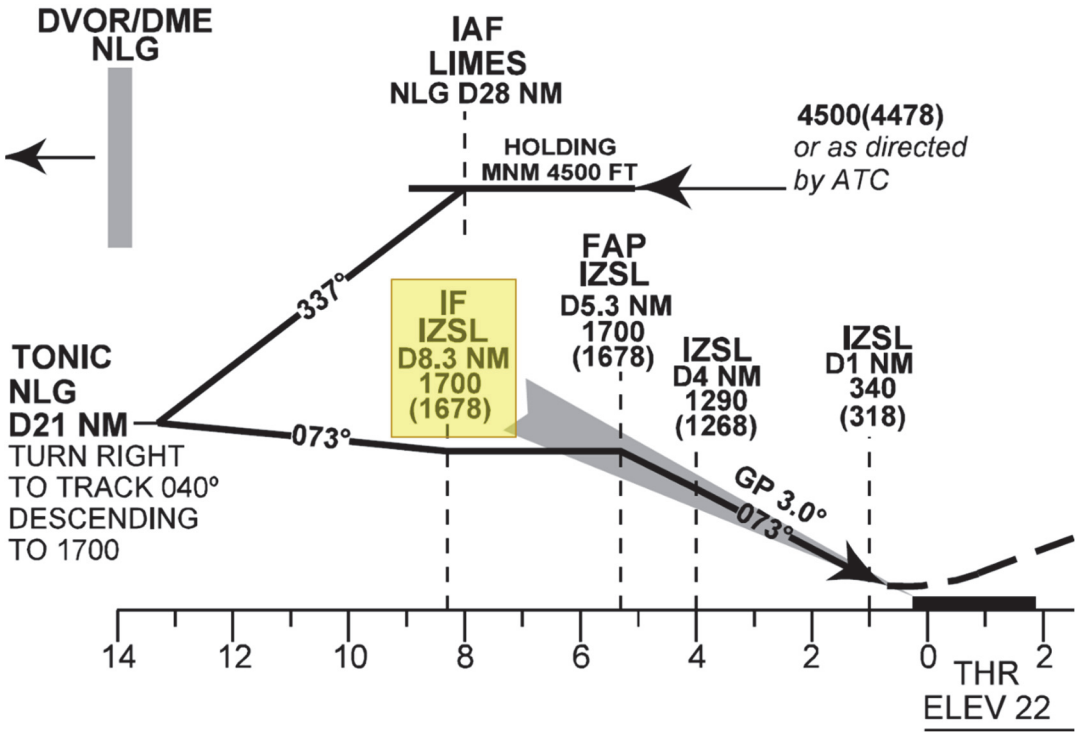

Figure 2

Vertical profile of the ILS for Runway 07L from the Hong Kong AIP

As the aircraft approached TONIC, it was at 3,000 ft amsl with the autopilot engaged in navigation (NAV) and altitude hold (ALT) modes[5] and, after passing the waypoint, the co-pilot displayed the approach chart on his electronic flight display (Figure 3). The approach chart contained information related to both the ILS 07L and LOC[6] 07L approaches (in the lower part of Figure 3, the vertical profile of the ILS approach is shown by a solid line and, for the LOC approach, by a broken line). The co-pilot confirmed that they had been cleared to fly the approach and this was acknowledged by the commander. Approach (APPR) mode was selected on the FCP, thereby arming the localiser and glideslope modes[7]. Shortly thereafter, an altitude of 1,000 ft was selected on the FCP, followed by vertical speed (V/S) mode with a descent rate of 1,100 fpm, and the aircraft began to descend.

Footnote

[5] See later section: Automatic Flight Control System (AFCS).
[6] A LOC approach is a non-precision approach using the ILS localiser signal but not the glideslope signal.
[7] The localiser and glideslope modes change automatically from armed to active when the respective guidance signal is intercepted.

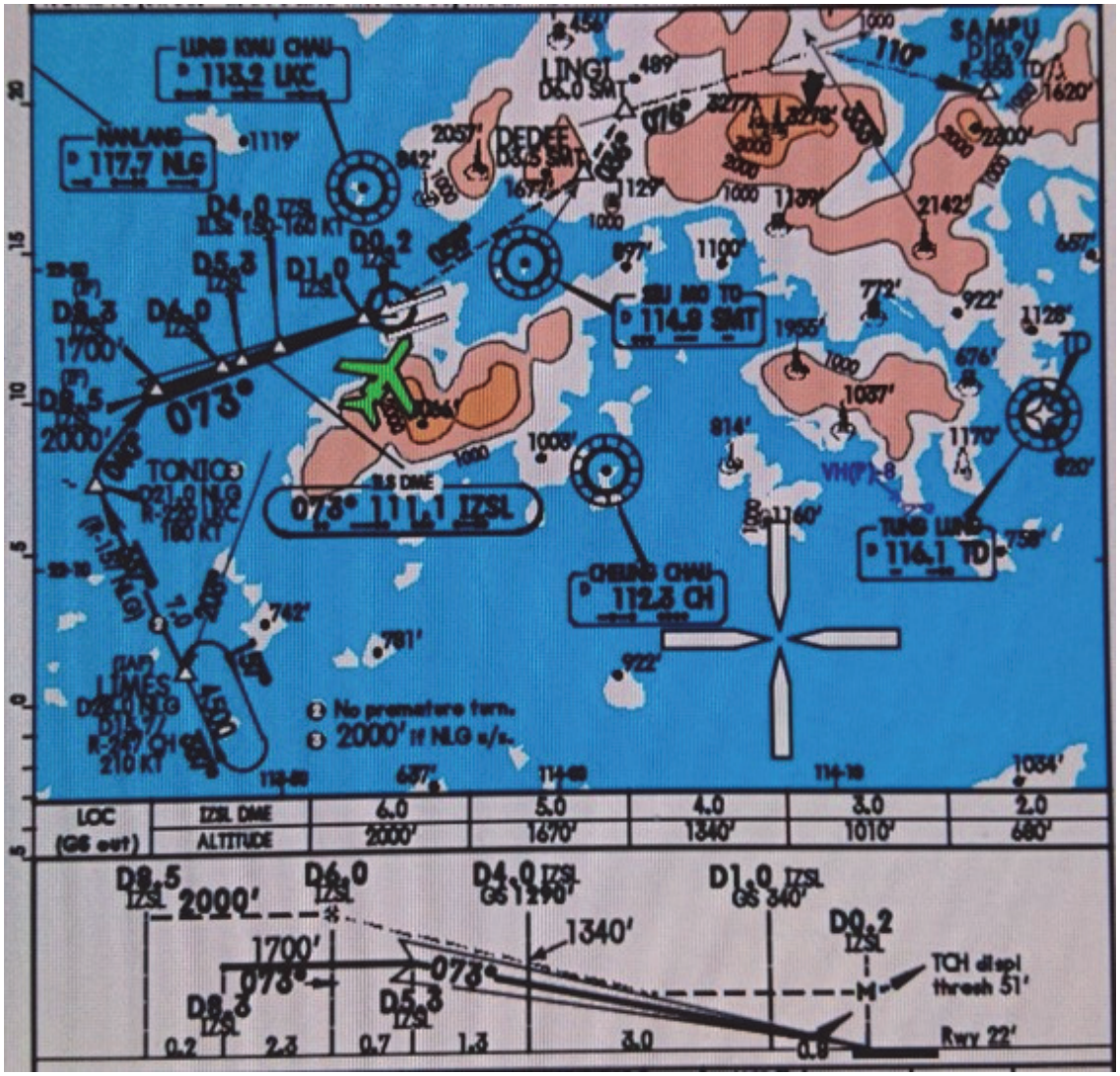

Figure 3

A section of the *ILS or LOC 07L* approach chart shown on the electronic flight display

Final approach

At 0135 hrs, as the aircraft descended through 2,000 ft amsl, a tone was generated in the cockpit indicating that there was 1,000 ft to go before it would reach the altitude selected on the FCP. The navigation system commanded the autopilot to begin a turn to the right in accordance with the procedure and, with the aircraft descending through the minimum cleared altitude of 1,700 ft amsl (Figure 2), the commander asked to what altitude the aircraft could descend. The co-pilot replied that, after TONIC they could descend to 2,000 ft amsl "OR LOWER". The commander queried the altitude and the co-pilot replied: "YOU'RE CLEAR FOR THE APPROACH … IT'S SHOOTING FOR 1,340 WHICH IS 4 DME". During this exchange, as the aircraft descended through 1,550 ft amsl, the commander disconnected the autopilot and selected a heading of 016°M on the FCP, and the co-pilot selected an altitude of 2,000 ft amsl on the FCP.

As the aircraft approached the runway centreline the commander began a right turn to intercept the localiser signal using an angle of bank which reached a maximum of 44°. As the bank angle increased, the pitch attitude decreased to a maximum of 4° nose-down and the rate of descent increased rapidly to 3,600 fpm. At 1,000 ft amsl, the Terrain Awareness Warning System (TAWS) generated a "SINK RATE[8]" aural caution and, shortly afterwards, the aircraft rate of descent reduced to 1,900 fpm. Immediately after this caution, the commander said "OK GIVE ME ... UH ... FLAPS 16". The co-pilot acknowledged the command (although he selected FLAP 6) before saying JUST HOLD YOUR ALTITUDE RIGHT THERE. DON'T DESCEND ANY MORE". Two seconds after the "SINK RATE" caution, a configuration "GEAR[9]" aural alert was triggered seven times. Following the seventh alert, the commander asked for the landing gear to be selected DOWN, which the co-pilot did as the aircraft descended through 760 ft amsl.

The co-pilot asked the commander why they were still descending and, although there was no response, the aircraft's pitch attitude was adjusted and the rate of descent reduced. As the aircraft descended past 540 ft amsl, the co-pilot reported to ATC that the aircraft had intercepted the localiser. The ATCO asked the crew to confirm the aircraft's altitude and, at the same moment, with the aircraft at 520 ft amsl, the TAWS "GLIDESLOPE[10]" aural alert was triggered. Fourteen seconds later, the TAWS "TERRAIN; TERRAIN[11]" aural warning was followed by a "PULL UP[12]" aural warning as the aircraft reached a minimum altitude of 390 ft amsl. Six seconds later, the co-pilot said to the commander "GET IT UP TO A THOUSAND ... GET UP TO A THOUSAND FEET" and, although the commander did not reply, the aircraft had already begun to climb.

As the aircraft climbed through 1,000 ft amsl, a tone was generated in the cockpit indicating that there was 1,000 ft to go to before it would reach the altitude selected in the FCP (2,000 ft). At 0137 hrs, the co-pilot said: "YOU'RE 5.5 MILES OUT; HOLD YOUR ALTITUDE RIGHT HERE; THIRTEEN HUNDRED". The aircraft continued to climb to 1,640 ft amsl before intercepting the glideslope signal and landing without further incident. During the final approach, and again after landing, the commander said "I'M SO TIRED I CAN'T SEE STRAIGHT".

Information from the pilots

Commander

The commander recalled that the crew arrived at the hotel at approximately 2200 hrs local time the night before the flight. He went to bed at about midnight but did not sleep well and received his crew wake-up call at 0300 hrs.

Footnote

[8] A TAWS Mode 1 Caution indicating an excessive descent rate (based on a comparison of radio altitude and descent rate).

[9] An aircraft configuration warning indicating that the gear is not down. It is triggered by a comparison of radio altitude, rate of descent, throttle angle and slat/flap control lever position.

[10] A TAWS Mode 5 alert triggered when the flightpath is below the glideslope by more than a set margin during an ILS approach. In this case, it was a 'soft alert' indicating glideslope deviation of more than 1.3 dots on the ILS display.

[11] A TAWS Mode 2A Caution enabled when a high terrain closure rate is sensed while the flaps are not in position for landing. Initial penetration into the Mode 2A envelope leads to a GND PROX message on the Attitude and Direction Indicator (ADI) and an aural message "TERRAIN TERRAIN".

[12] A TAWS Mode 2A Warning indicating continued penetration into the Mode 2A envelope. It generates a PULL UP message on the ADI and a voice warning "PULL UP".

The commander recalled that, after passing TONIC, the aircraft did not appear to be capturing the localiser signal, so he disconnected the autopilot to fly the aircraft manually. Because he was confused by the co-pilot's answer to his question about the cleared descent altitude, he tried to confirm the information from his own chart. He believed that this, combined with fatigue and "hazy" flight conditions meant he did not realise the aircraft was descending below the approach profile. He recalled that he initiated a climb when he heard multiple GPWS[13] warnings including "PULL UP".

The commander stated that he was tired and was distracted by the co-pilot who had missed or misunderstood some radio transmissions during the flight. He was confused about what the co-pilot was doing and this increased his workload. He stated that the arrival was rushed and required multiple changes to the Flight Management System (FMS) "with my pilot monitoring becoming more of a distraction than an assisting crew member, contributing to the deterioration of crew resource management and situational awareness".

Co-pilot

The co-pilot reported that the commander had indicated that he was tired before leaving the hotel but had rejected the co-pilot's suggestion that he (the co-pilot) should operate the flight as PF. The commander did not recall this conversation.

The co-pilot expected the autopilot to remain engaged until just before the landing because the FMS had been programmed to fly the arrival and approach. He was surprised when the autopilot was disconnected and commented that this, along with the commander's "non-standard SOPs", increased his workload. He believed that he was distracted from his monitoring role by ATC and checklist requirements, leading him to miss the fact that the aircraft was descending below the approach profile.

While he was instructing the commander to climb the aircraft, he was also holding the flight controls and considering taking control. However, he felt some resistance from the PF through the controls and did not want to compound the situation by forcibly taking control at such a critical time, especially since he considered the commander to have "a very aggressive attitude". He stated that he found the commander difficult to fly with and "it causes problems if [I] do not do things [his] way".

Information from Hong Kong Airport ATC

To comply with the published ILS RWY 07L Approach procedure, an aircraft that has been cleared for the approach is not permitted to descend below an altitude of 1,700 ft until established on the glideslope. In this case, clearance for the approach was given by ATC when the aircraft was maintaining 3,000 ft and the controller expected the aircraft to descend as per the procedure. When the co-pilot reported that the aircraft was established on the localiser, the controller noticed that the aircraft was low and requested the crew to confirm the aircraft's altitude. The crew responded that they were "visual" and "correcting". Because the aircraft was significantly below the published altitude, the controller asked

Footnote

[13] GPWS: Ground Proximity Warning System, which is a TAWS.

the crew to state the aircraft's altitude in order to verify that the altitude displayed on the surveillance system was within tolerance. After receiving the crew's response that the aircraft was at 400 ft, the controller gave position information to the crew immediately in order to assist them in building their situational awareness. The aircraft was subsequently observed climbing and the crew reported that they were established on the glideslope.

Pilot information

Commander

The commander had an FAA-issued Air Transport Pilot's Licence, with a type rating on the Global 5000 aircraft valid until 30 September 2017, and a First Class medical certificate, valid until 20 November 2017. He reported that he had a total of 6,820 hours of flying, including 623 hours on the Global 5000 of which 590 hours were in command.

Co-pilot

The co-pilot had an FAA-issued Air Transport Pilot's Licence, with a type rating on the Global 5000 valid until 3 October 2017, and a First Class medical certificate valid until 12 July 2017. He reported that he had a total of 6,500 hours of flying, including 580 hours on the Global 5000 of which 500 hours were in command.

Recorded information

A complete record of the accident flight was available from the aircraft's FDR including the status of the Automatic Flight Control System (AFCS), and cautions and warnings generated by the TAWS. The 120-minute duration CVR recording started when the aircraft was in the cruise, 520 nm to the north of Hong Kong, and ended when the aircraft was shut down after landing.

Selected data from the FDR are presented in Figure 4.

Note: the aircraft's altitude was derived by correcting the recorded pressure altitude for a QNH of 1017 hPa[14], and the aircraft's height above the surface of the sea was derived from radio altimeter data.

Information obtained from the recorded data and CVR was included in the earlier section *History of the flight*.

Recorded data showed that, during the approach, the commander's Head-up Display (HUD) was deployed and the Enhanced Vision System (EVS) was enabled. The Synthetic Vision System (SVS) was not enabled on the HUD or on either of the PFDs[15].

Footnote

[14] The recorded altitude values were based on the standard pressure datum of 1013 hPa.
[15] See later section for an explanation of EVS and SVS.

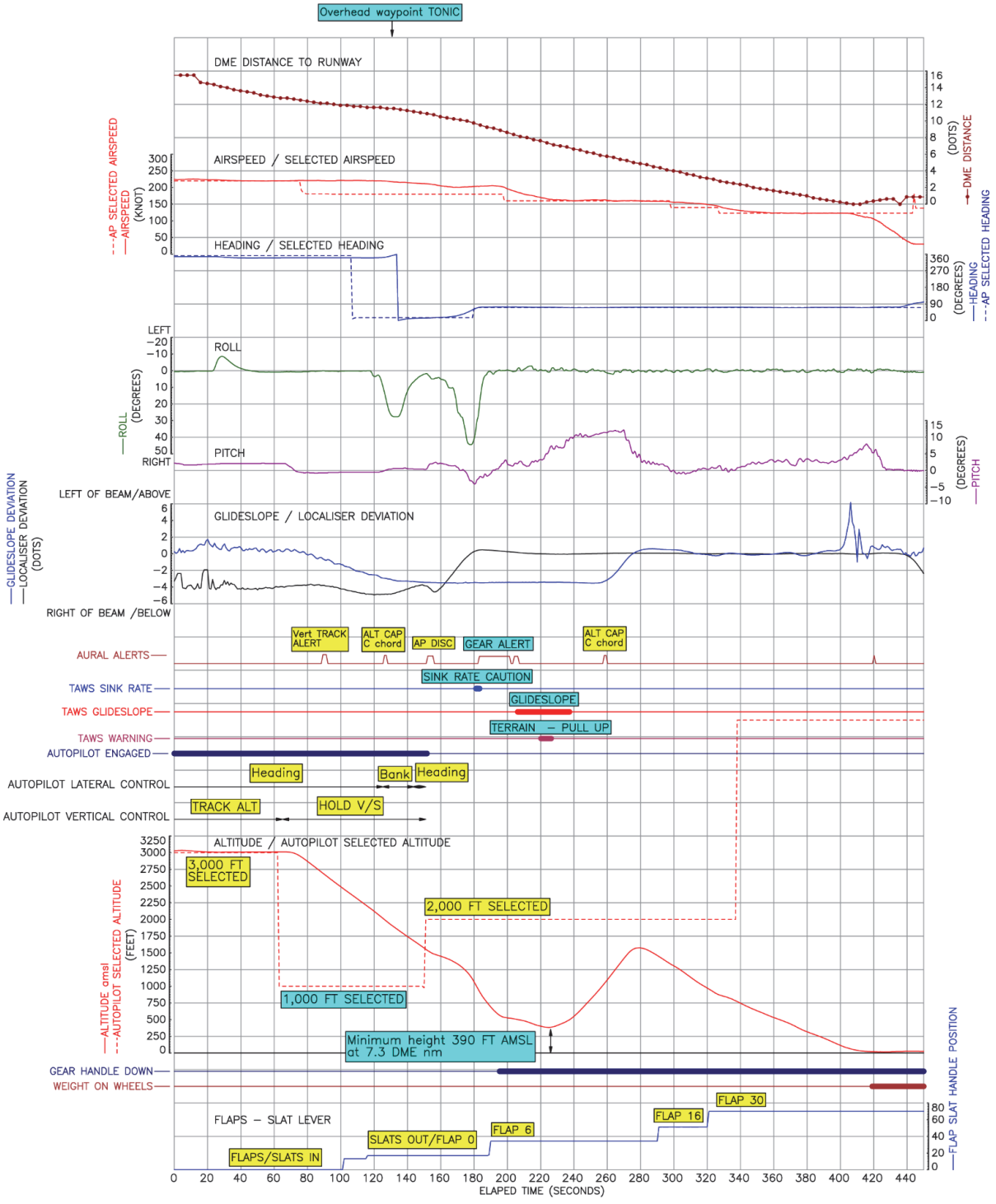

Figure 4

FDR data during the approach to Hong Kong Airport – Runway 07L

Automatic Flight Control System (AFCS)

The Bombardier Global 5000 is fitted with a dual-channel AFCS, which is integrated with the Flight Director (FD), dual-axis autopilot, automatic pitch trim and yaw damper. Flight guidance is computed by the AFCS and can be displayed on one or both Primary Flight Displays (PFDs). Guidance functions are grouped into either 'selected' or 'managed' modes. 'Selected' guidance is based on pilot-selected references, or targets, on the FCP, and 'managed' guidance is associated with lateral and vertical flight commands provided by the FMS. The FCP is located at the top of the instrument panel and is the pilots' primary interface with the AFCS (Figure 5).

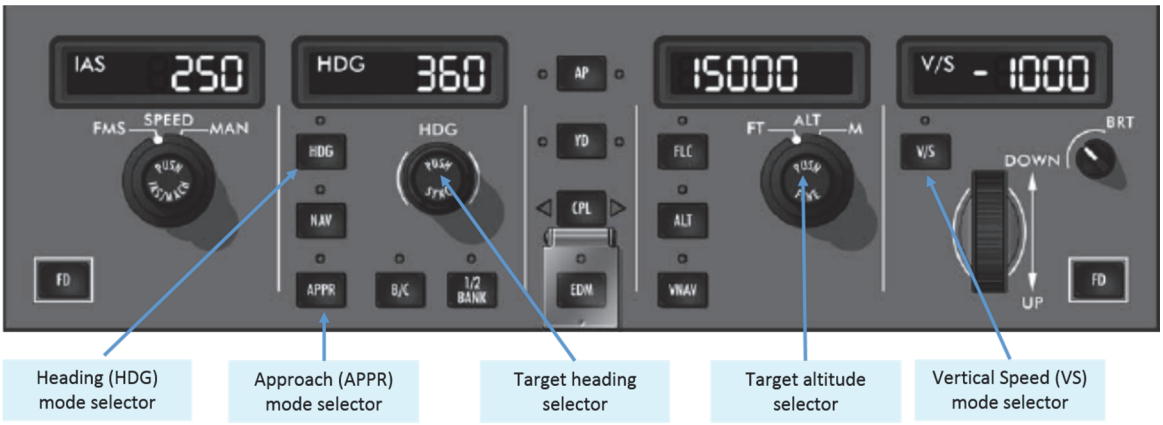

Figure 5

Flight Control Panel
(taken from the Flight Crew Operating Manual)

AFCS indications are provided on each PFD and include the FD cue, flight path vector symbol and flight mode annunciations (FMA) (Figure 6). The FMA display, located at the top of the PFD, is divided into columns of text, separated by vertical lines. The display indicates the status of the autothrottle, the lateral and vertical modes, FD coupling and autopilot status. Active modes are shown in green at the top of their respective column, while armed modes are shown directly below them in white.

The FD function computes roll and pitch commands based on data from several systems and sensors, including attitude, heading, air data, radio altimeter, navigation and pilot reference inputs. A green flight path vector (FPV) provides vertical and lateral indications of the aircraft flightpath and a FD cue, which is magenta in colour, provides vertical and lateral steering commands.

Aircraft heading may be controlled manually by selecting heading select mode (HDG) on the FCP and setting the desired heading manually using the HDG knob. HDG is also a transition mode which, once engaged, remains active should either NAV or APPR mode be selected with the aircraft outside the respective mode's capture parameters. In such circumstances, the FD remains in HDG mode, providing heading guidance as selected by the pilot, until the aircraft arrives at a point where mode capture can occur.

The Approach mode provides for the automatic intercept, capture and tracking of the localiser and glideslope signals. The ILS is automatically tuned by the FMS when the aircraft is within 30 nm of the airfield. To prevent premature descent, the GS mode is not permitted to become active until the LOC mode is active.

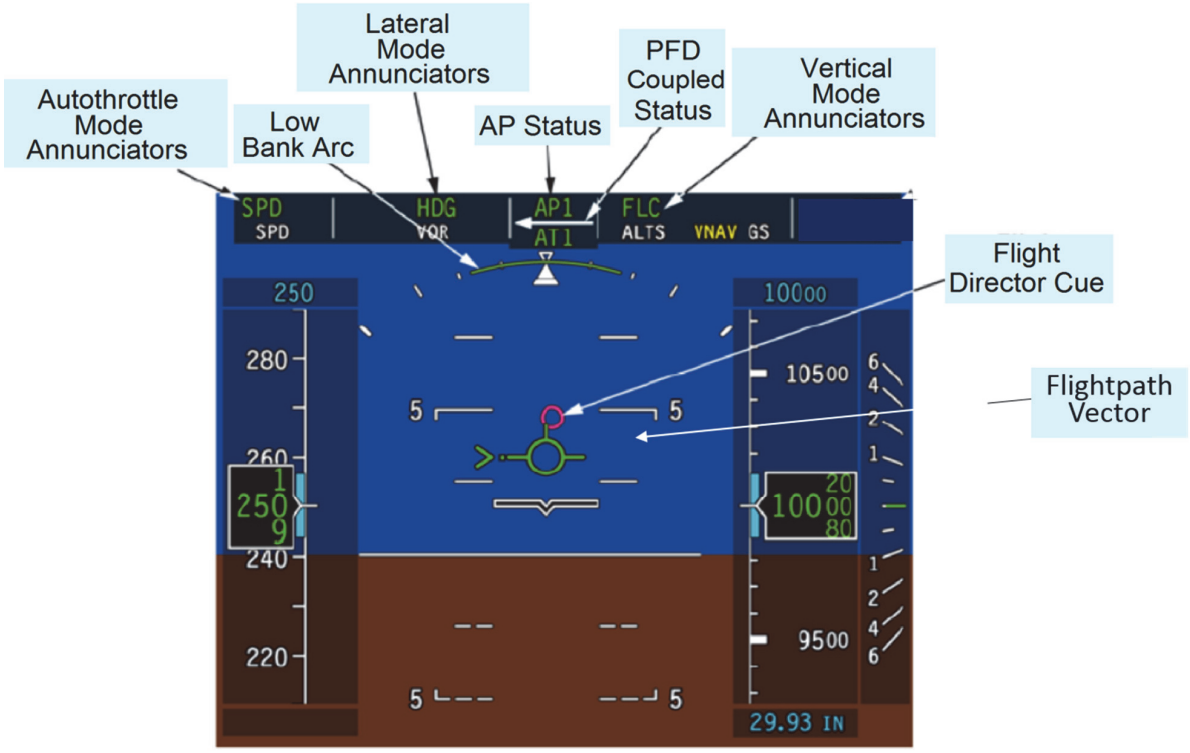

Figure 6

Primary Flight Display
(taken from the Flight Crew Operating Manual)

Enhanced Vision System (EVS) and Synthetic Vision System (SVS)

The EVS uses an infrared sensor to provide a thermal image of the external world ahead of the aircraft within a 30° field of view and is intended to aid situational awareness in conditions of poor visibility. It was displayed on the HUD during this event.

The SVS provides a computer-generated representation of the external environment, including terrain, obstacles, airports and runways. It can be displayed on the HUD and PFDs, although it was not in this event. The manufacturer commented that, had the SVS been selected on the PFDs, the crew might have noticed the flightpath vector symbol intercepting the surface before the runway symbology, indicating that the aircraft would hit the surface before reaching the runway.

Operational oversight of the operator

VP-CKM is registered in the Cayman Islands and oversight responsibility rests with the Civil Aviation Authority of the Cayman Islands (CAACI). The CAACI may issue a Private Flight Operations Approval (PFOA) to the operator of a private turbojet aircraft, such

as VP-CKM, under Part 134 of the Air Navigation (Overseas Territories) Order. The requirements to operate such aircraft registered in the Overseas Territories are specified in the Overseas Territories Aviation Requirements (OTARs[16]). The Part 134 Approval may be obtained by an OTAR Compliance Assessment by the CAACI or, alternatively, through the completion of an International Standard for Business Aircraft Operations (IS-BAO)[17] Registration assessment conducted by the International Business Aviation Council (IBAC).

At the time of the incident the operator of VP-CKM had a PFOA valid until 31 January 2017. The operator submitted to an IS-BAO audit between 25 and 27 January 2017 which recommended a further one year IS-BAO registration, after which the PFOA was also renewed for a further year.

Operating Procedures - general

International Standard for Business Aircraft Operations

The IS-BAO encourages the use of best operating practices for business aircraft using Standards and Recommended Practices (SARPS) derived from ICAO[18] SARPS. Operators may implement requirements relevant to their operation and set aside those not relevant. Section 6.1 of IS-BAO discusses SOPs and states:

> *'SOPs are the foundation of effective crew coordination and a key component of crew resource management and threat and error management. Accordingly, operators of aircraft with two or more crew shall establish and maintain an SOP … that enables the crew members to operate the aircraft effectively. An operator that has established SOPs … shall ensure that …they are used by the crew.'*

IS-BAO Section 10, *Company Operations Manual* states:

> *'For non-commercial operations, the operations manual shall contain the SOPs and a fatigue management system.'*

National Business Aviation Association (NBAA)

The NBAA, which manages the IS-BAO registration process on behalf of the International Business Aviation Council (IBAC), publishes a Best Practices Manual which contains a section on SOPs. It states:

> *'Crew coordination is the effective delegation of responsibility and division of workload [and] is essential for the safe operation of aircraft. SOPs … create a standardised system whereby pilots become immediately aware of any departure from the normal sequence of events. The PF and PNF shall coordinate with each other prior to initiating the following:*

Footnote

[16] OTARs can be found here: http://www.airsafety.aero/Requirements-and-Policy/OTARs.aspx
[17] See next section for more information on IS-BAO.
[18] ICAO: International Civil Aviation Organisation.

- *A change in aircraft configuration*
- *A transferring of aircraft control*
- *Selection or change of navigation equipment settings or frequencies*
- *Checklist initiation and completion*
- *A change in altitude.'*

Operator's Flight Operations Manual

Standard Operating Procedures

Shortly after this incident, on 21 November 2016, the operator issued a non-type specific *SOP Quick Reference Sheet* stating that, among other things:

a. Mode changes on the FCP were to be called out.
b. Changes in altitude were to be cross-checked.
c. A call was to be made when the aircraft was 1,000 ft from the assigned altitude.

Chief Pilot

The Operator's Flight Operations Manual (FOM) detailed the responsibilities of a Chief Pilot which included monitoring the professional standards of flight crew, the development of SOPs and ensuring crew scheduling complied with flight time limitations (FTL). The FOM required crews to follow type specific SOPs from the Airplane Flight Manual (AFM) and stated that:

'Standardisation/observation flights, and an internal audit program ensure that all personnel adhere to [the] *SOPs.'*

The operator did not have a Chief Pilot at the time of the incident. On 5 December 2016, the operator appointed a Chief Pilot with responsibilities which included: "*Comply* [with] *the applicable relevant responsibilities for Chief Pilot listed in* [the operator's] *Flight Operations Manual".*

Fatigue management

According to the aircraft flight log, during the 17-day period from 28 October 2016 until the day before the incident, the crew flew the aircraft on four separate days. The maximum duty time was seven hours and the rest periods between flights were between two and four days.

The crew declared that, on the day before the incident, they were on duty from approximately 1510 hrs to 2010 hrs local time. They arrived at the hotel at approximately 2200 hrs local time and departed at 0400 hrs the following morning. Following the incident flight, the crew were off duty at approximately 1010 hrs.

The FOM stated that pilots were to observe the FTLs and not work when fatigued. The FOM defined a 'local night' as '*a period of eight consecutive hours falling between the period of 2200 and 0800 local time'.* The FTL table within the FOM required the crew to have 10 continuous hours off duty in any 24 hours.

Investigating fatigue

A paper by Clockwork Research[19] gives a methodology, adopted in this report, for analysing the effect of fatigue on an occurrence. The methodology considers whether an individual was suffering from fatigue, whether fatigue had an impact on performance, and whether fatigue may have been a contributory or causal factor to the occurrence.

For fatigue to have contributed to the occurrence, two conditions must be met:

a. At the time of the incident the individual was fatigued.

b. A change in performance consistent with fatigue contributed to the incident.

In determining whether an individual might have been suffering from fatigue, the methodology considers the opportunity for sleep, the sleep quality and quantity, other reasons for fatigue and/or sleep loss, and physical signs of fatigue.

In determining whether there was a change in performance consistent with fatigue, the methodology considers whether the following behaviours or characteristics were observed:

a. Reduced alertness, increased response times and impaired situational awareness.

b. Inefficient or ineffective communication.

c. Failure to react appropriately (or at all) to external stimuli.

In determining whether fatigue might have been a contributory or causal factor, the methodology considers whether the changes in performance had an impact on the sequence of events.

Analysis

Flightpath

The aircraft was cleared for the ILS approach to Runway 07L while approaching TONIC and was expected to follow the lateral path shown in Figure 1, and descend not below 1,700 ft amsl until intercepting the glideslope as shown in Figure 2. The autopilot was engaged and the flightpath was being controlled laterally by the FMS, which was in navigation (NAV) mode. The aircraft was flying level at 3,000 ft amsl in altitude hold (ALT) mode. In this configuration, the aircraft would have automatically followed the lateral path of the procedure and remained at 3,000 ft amsl.

Footnote

[19] Available from: http://www.clockworkresearch.com/publications/

When the commander selected APPR mode it armed the localiser and glideslope modes (LOC and GS). In this configuration, the aircraft would have turned onto 040°M after passing TONIC until it captured the localiser signal, when it would have turned onto the final approach course. It would subsequently have descended when it captured the glideslope signal. Instead, an altitude of 1,000 ft was selected on the FCP, vertical speed (V/S) mode was engaged and the aircraft began to descend. There was no announcement that the selected altitude had been changed to 1,000 ft.

As the aircraft descended through 1,700 ft amsl, the commander asked the co-pilot to confirm the cleared altitude. The co-pilot replied that they could descend to 2,000 ft amsl but then said "OR LOWER", which confused the commander. The co-pilot added that "IT'S SHOOTING FOR 1,340 WHICH IS 4 DME". The altitudes to which he was referring (2,000 ft and 1,340 ft) are shown on the lower portion of Figure 3 and relate to the localiser approach (LOC 07L), not the approach for which they were cleared (ILS 07L). Altitudes relating to both approaches were shown on the co-pilot's electronic approach chart. At approximately the same time as this verbal exchange, the co-pilot set 2,000 ft on the FCP and the commander disconnected the autopilot. The co-pilot did not announce that he had changed the selected altitude or why he had chosen 2,000 ft (although it corresponded with the minimum cleared altitude on the LOC 07L approach before descending with the procedure). However, because 2,000 ft was above the aircraft's altitude at the time, it meant the aircraft was descending in vertical speed mode without a target altitude below it. In this configuration, with the aircraft already below the glideslope, the FD cue, if followed, would have continued to command a descent until the aircraft struck the surface of the sea.

Operating procedures

The NBAA Best Practices Manual states that crews are to coordinate changes in aircraft configuration, altitude and navigation equipment settings. In this occurrence, the use of such coordination was sporadic and did not appear to follow a consistent, verbal format. Flight Level, altitude and other clearances were misheard or misunderstood and, although there was an approach briefing, the co-pilot appeared to have been referring to altitudes on his chart which related to the wrong approach. The commander felt that the co-pilot was becoming a distraction, the co-pilot found the commander difficult to fly with and, in the latter stages of the incident, warnings from the co-pilot and aircraft systems that the aircraft was too low and descending too quickly were not acknowledged verbally by the commander. It was concluded that the crew did not exchange sufficient information on altitude selections and aircraft control modes for them to share an accurate mental model of their situation. Consequently, they were not aware that they had descended below their cleared altitude with the aircraft navigation equipment set to command a descent into the sea.

The autopilot was disconnected despite the FMS having been set correctly to fly the approach automatically, and the hand-flown turn onto the localiser used a maximum angle of bank of 44° which led directly to the high rate of descent. It is likely that disconnecting the autopilot increased the workload for both pilots making it less likely that they would exchange sufficient information to keep the situation under control.

Fatigue

The following analysis follows the methodology discussed in the section, *Investigating fatigue.*

The crew arrived at the hotel at 2200 hrs local time and the wake-up call was at 0300 hrs but the commander stated he did not get to sleep until close to midnight and did not sleep well. The FOM classified a local night as eight hours between 2200 hrs and 0800 hrs. It was concluded that the crew did not have adequate opportunity to obtain a local night's sleep, and the sleep actually obtained was inadequate.

The co-pilot reported that, before the flight, he offered to operate the flight as PF in response to the commander indicating that he was tired (although the commander did not recall this conversation). During the cruise, the commander left the flight deck to stretch because, as he said, "I AM LOSING IT". Later in the flight, the commander said twice that "I'M SO TIRED I CAN'T SEE STRAIGHT", and during interview he stated that he had been tired. Despite the different recollections of the conversation before the flight, it was considered likely that the commander was suffering from acute fatigue. However, based on the amount of time the crew had free of duty between 28 October 2017 and this incident, it was unlikely they were suffering from cumulative fatigue.

The earlier discussion on operating procedures supports a conclusion that communication between the pilots could be classified as inefficient or ineffective. The section *History of the flight* shows that the commander did not respond to the co-pilot on a number of occasions as the aircraft descended, although it is possible that this was partly because he was finding the co-pilot to be a distraction. It was concluded earlier that the pilots were not aware that they had descended below their cleared altitude, and it was likely that their understanding of that cleared altitude was, itself, incorrect ie the co-pilot appeared to be using altitudes relating to the incorrect approach. Finally, the commander did not acknowledge or react decisively to system alerts or co-pilot warnings about the low altitude and high rate of descent. It was likely, therefore, that the commander's performance was impaired due to fatigue. It was also considered likely that the impaired performance contributed to the sequence of events.

Operational oversight

IS-BAO considers that SOPs enhance crew coordination and error management and expects operators to ensure they are used. The operator's FOM stated that standardisation flights and an internal audit program would ensure crews adhered to SOPs, and the Chief Pilot would monitor professional standards, develop SOPs and ensure crew scheduling complied with FTL. In this incident, ineffective use of SOPs contributed to the sequence of events, and scheduling did not comply with FTL because the crew did not have the opportunity for a local night's rest. It was not clear whether the operator carried out standardisation flights and/or audits, because it did not respond to requests for relevant information. However, there was no Chief Pilot and it was likely that professional standards and the proper use of SOPs were not being monitored effectively. After this event, the company appointed a Chief Pilot and, subsequently, renewed its registration with IS-BAO.

Conclusion

The aircraft's FMS was set correctly to fly the approach and the autopilot was engaged when a descent was initiated towards 1,000 ft amsl in vertical speed mode. At 1,550 ft amsl, the commander disconnected the autopilot at approximately the same time that the co-pilot selected the target altitude to 2,000 ft amsl. The aircraft was then being flown manually with the FMS set such that, if the FD was followed without further intervention, it would have commanded a descent until the aircraft struck the surface of the sea.

It was concluded that the crew did not exchange sufficient information to share an accurate mental model of their situation and, consequently, were not aware that they had descended below their cleared altitude. Disconnecting the autopilot increased their workload, making it less likely they would regain an awareness of the situation, and made it necessary to fly the turn onto the localiser manually, which led directly to a high rate of descent and to TAWS cautions and warnings. Shortly after the first TAWS warning, the co-pilot told the commander not to descend any further. However, the commander did not respond decisively to the co-pilot's warnings or system alerts until the aircraft was below 500 ft above the surface. Acute fatigue and a breakdown of SOPs within the flight deck led to the ineffective communication between the pilots. It was likely that the operator was not effectively monitoring the professional standards of its crews, or their use of SOPs, because it had no Chief Pilot and this made the ineffective communication more likely.

BULLETIN CORRECTION

When originally published the report stated incorrectly that the aircraft involved in the serious incident was a Bombardier Global Express BD700. The aircraft was a **Bombardier BD-700-1A11 (Global 5000)**.

The online version of the report was amended on 22 December 2017.