CONTENTS

SPECIAL BULLETINS

None

COMMERCIAL AIR TRANSPORT

GENERAL AVIATION

SPORT AVIATION / BALLOONS

ADDENDA and CORRECTIONS

(ALL TIMES IN THIS BULLETIN ARE UTC)

INCIDENT

Aircraft Type and Registration:	Airbus A320-232, G-EUUR
No & Type of Engines:	2 International Aero Engine V2527-A5 turbofan engines
Year of Manufacture:	2003
Date & Time (UTC):	26 November 2008 at 0820 hrs
Location:	Approx 10 miles north-east of Glasgow Airport
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 4 Passengers - Not known
Injuries:	Crew - None Passengers - None
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	49 years
Commander's Flying Experience:	14,750 hours (of which 5,400 were on type) Last 90 days - 150 hours Last 28 days - 82 hours
Controller's Experience	The controller had qualified in 1973, had been an approach radar controller since 1980 and employed at Glasgow since 1994
Information Source:	AAIB Field Investigation

Synopsis

During a day IMC approach to Runway 23 at Glasgow the aircraft was given, and the flight crew accepted and actioned, a 'terrain unsafe' clearance. The flight crew then climbed the aircraft upon receipt of a GPWS warning. The minimum terrain clearance was 959 feet. During vectors for a second approach the aircraft was again descended below the permitted altitude, although in a location where there was no risk of terrain collision.

History of the flight

The CVR and DFDR were overwritten before this event was reported to the AAIB, so information to construct the history of the flight was obtained from the operator's flight data monitoring system, radar and ATC voice tapes, and interviews with the people involved.

The aircraft was operating a London Heathrow to Glasgow passenger schedule as the 'Shuttle 6C' (SHT6C). The flight was the first sector of the day for the flight crew and took off at 0724 hrs with the commander as the handling pilot. The flight was uneventful until the approach at Glasgow which commenced at around 0811 hrs with the aircraft level at FL050. In accordance with the operator's standard procedures, before the top of descent the commander handed control to the first officer, who was to conduct the approach with the commander taking carry out to conduct the landing.[1] This meantthat the first officer was 'pilot flying' (PF) throughout the events of this report.

The air traffic control officer (ATCO) was on his first shift since being on leave. At 0800 hrs he was 'single-staffed' on radar[2] with a light traffic load and had been in position for 20 minutes since his last break. He gave the incident aircraft, G-EUUR, a heading from the LANAK reporting point and a descent to 3,000 ft. After passing the base leg heading of 325°, and because of a strong westerly wind of around 40 kts, the controller considered the closing heading that he would pass to the aircraft. He then wrote this closing heading, of 275°, on the ATC strip but without transmitting it to the aircraft.

Believing he had given a closing heading to the aircraft, the controller cleared it to descend to 2,000 ft. The flight crew acknowledged the clearance and, with the aircraft still heading 325° (and, due to the wind, tracking more than 90° from the ILS centreline), initiated a descent. The PF used 'Open' (idle thrust) descent for this altitude change. He was initially concerned that the aircraft would have too much energy if he were given a short route towards the final approach: this resulted in a descent rate of 1,500 fpm.

The ATCO saw the aircraft on radar at around 10 miles from the airfield, descending on the base leg and thought it was doing a slow turn to the heading he believed he had passed. Approximately 35 seconds after the aircraft initiated the descent the ATCO realised that it was not turning and transmitted the heading of 275°.

Actions by the flight crew

The PF commenced the left turn to 275° using the autopilot, which commanded 25° of left bank. Realising that the energy management situation had reversed, the PF selected 'vertical speed' mode and was reducing the rate of descent as the aircraft descended through 2,500 ft amsl. The flight data monitoring system recorded a change in descent rate from 1,500 fpm to 1,300 fpm shortly before a GPWS mode 2 "TERRAIN TERRAIN PULL UP[3]" warning was initiated. The rate of terrain closure exceeded 6,000 fpm, due to a combination of steeply rising ground and aircraft descent rate.

On hearing the GPWS warning the PF disconnected the autopilot, selected full thrust and pitched the aircraft to approximately 17° nose-up, initially levelling the wings. He then followed flight director commands for a right turn and banked the aircraft right, the bank angle peaking at nearly 30°. The aircraft rate of climb reached over 5,000 fpm and, very shortly after initiating the climb, the flight conditions became VMC above the cloud layer.

An altitude loss of 130 ft was recorded from the start of the warning to the minimum recorded altitude. During the recovery manoeuvre the minimum recorded radio height was 959 ft, associated with an altitude of approximately 2,170 ft amsl and the turn towards 275° resulted in the track of the aircraft being to the left of the ridge of terrain that caused the alert. This ridge had terrain that was approximately 300 ft higher than that

Footnote

[1] A procedure known as a 'monitored approach'.

[2] This is normal practice in periods of low traffic; an additional controller was available to assist if required

[3] Although there was no CVR the flight crew confirm this audio occurred as per the data.

sensed by the radio altimeter so the minimum terrain clearance would have been reduced further by any lateral displacement to the right.

Actions by the controller

The controller had become involved in an exchange with an air ambulance flight and when he next looked at the radar G-EUUR was crossing the ILS centreline, but north of the 'Campsie Line' (Figure 1) and below the minimum altitude for that area. The controller had decided that, if he turned the aircraft further towards the ILS, it might still successfully intercept the localiser.

He had then given a further radar heading of 200° as the aircraft passed slightly through the localiser; at this point the flight crew informed him of the GPWS go-around and that they were climbing to 5,000 ft on heading 320°. The controller had acknowledged this and once the aircraft was level he vectored it for a right base to a final approach at 12 miles.

The second approach

On receiving the GPWS warning the PF had climbed the aircraft to 5,000 ft, which was above the Minimum Safe Altitude (MSA) on the approach chart (Figure 2) of 4,900 ft. The crew levelled at 5,000 ft before being vectored for a second approach.

The controller then instructed a descent from 5,000 ft to 4,000 ft. At the point the clearance was issued this altitude was permitted on the controller's terrain chart (Figure 3). However as the aircraft turned to the north north-east the track was influenced by the 40 kt south-westerly wind. The resulting ground track took the aircraft into an area where the ATC terrain chart had an MSA of 4,500 ft. The controller did not recognise this second breach of ATC MSA. The flight crew were unaware that this descent had taken them

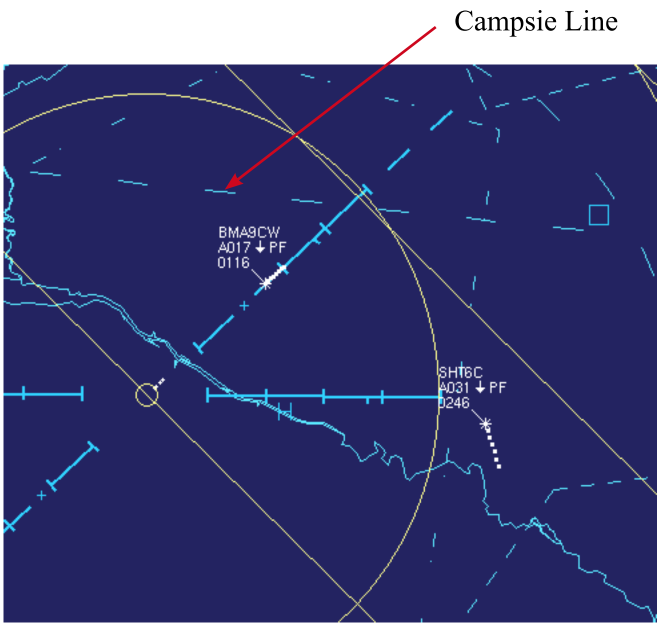

Figure 1

Radar 'screen grab' - Campsie Line & G-EUUR (SHT6C)

below radar MSA and were at this point outside the area covered by their approach charts.

Although below the MSA on the terrain chart, the aircraft remained 'terrain safe' throughout this second descent.

Both the ATCO and the flight crew reported the incident using their separate safety reporting systems. However, both continued to operate their remaining duty that day and neither considered that the event had affected their subsequent performance.

ATC information

Glasgow ATC use the procedure of '*write while you talk, read while you listen*'. An instruction should be written on the ATC strip at the same time as it is transmitted to the aircraft; the controller then reads the ATC strip as the flight crew reads back the instruction. This confirms the instruction is correctly understood and then provides the controller with a quick reference as to the expected actions of the aircraft.

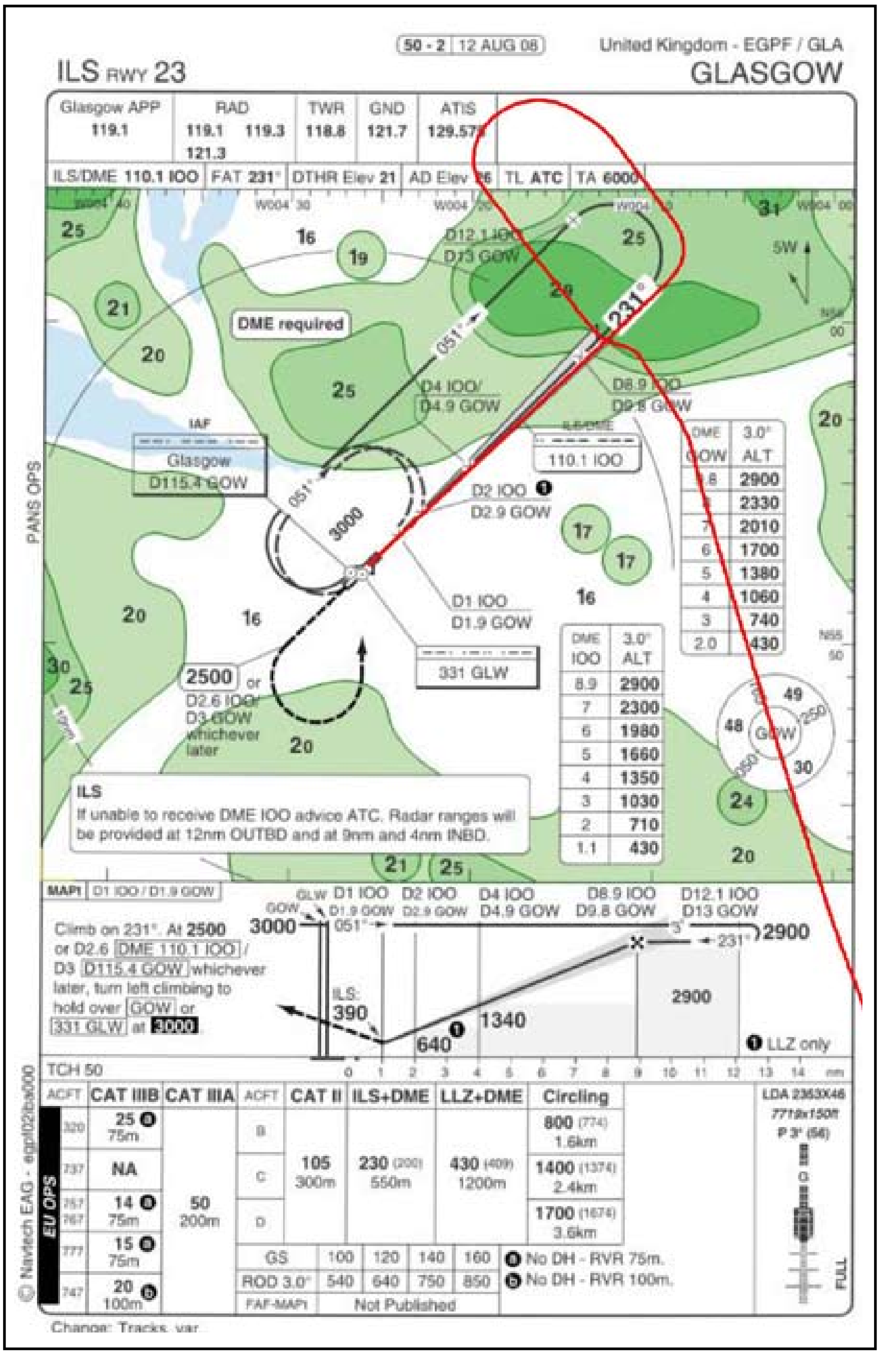

Figure 2

Approach chart - ILS RWY 23

The ATCO was unable to explain why he had written the heading on the strip without having transmitted it and this was the first time he was aware of making this mistake. He could see no reason why he would have done so.

During interview the controller commented that once he realised the aircraft was north of the Campsie Line he should have sent it around rather than attempt to recover the approach.

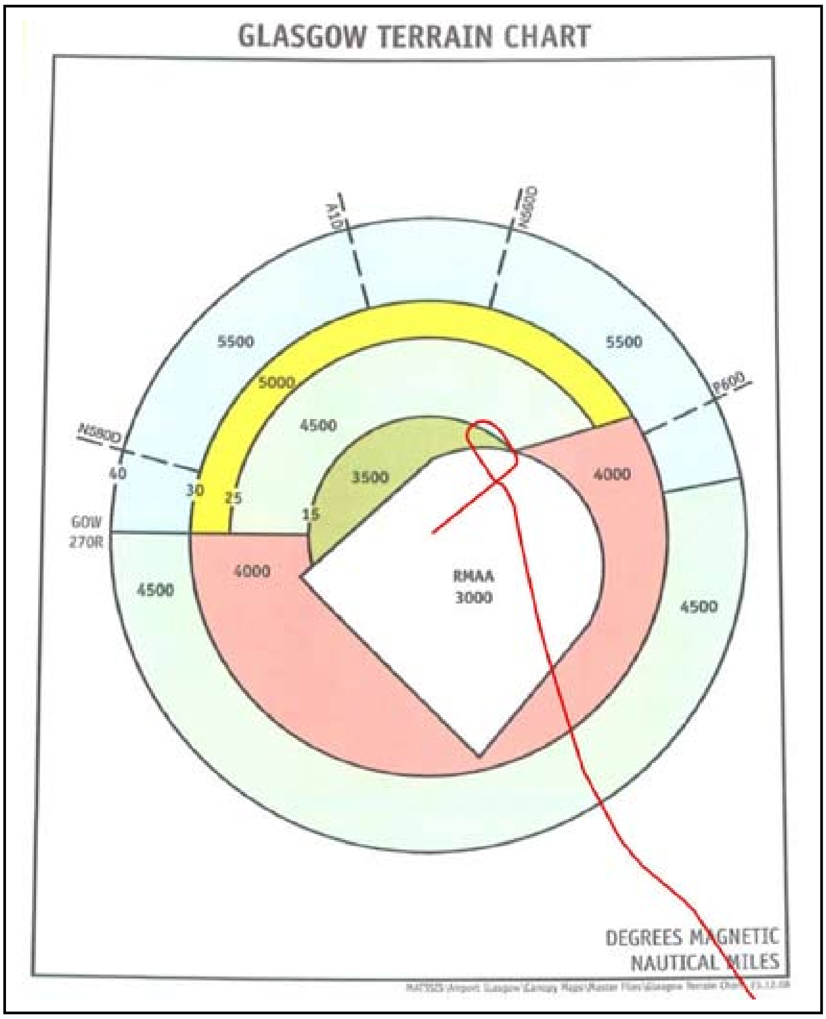

Figure 3

Glasgow Terrain chart

Airport and terrain information

Glasgow airport is located six miles west of the city of Glasgow. The airport is in the River Clyde valley with a field elevation of 26 ft. The terrain along the approach to Runway 23 is generally low-lying (150-300 ft elevation) out to a distance of 9.5 nm. There the ground rises sharply due to the Campsie Fells, an east-west line of hills with a peak height in the vicinity of the final approach track of 1,840 ft. Glasgow's ATC procedures are designed to allow for this ridge feature. The relevant part of the Manual of Air Traffic Services (MATS) describes a line 105°/285°, the 'Campsie Line' (Figure 1), at 9.5 nm on the approach for Runway 23.

According to MATS Part 2, aircraft being vectored for approach should not be descended below 3,000 ft unless south of this line and:

'• on final, or a closing heading for an instrument approach, and

• within 1nm of final approach.'

Charting and terrain representations

The flight crew had access to three sources of terrain information. Two of these were paper charts (the radar minimum altitude chart (Figure 4) and the ILS Runway 23 approach chart (Figure 2)). These were included in the company approach plate booklets, The aircraft's ground track has been overlaid on these figures. The radar minimum altitude chart provides an area overview and minimum vectoring heights for flight crew to use.

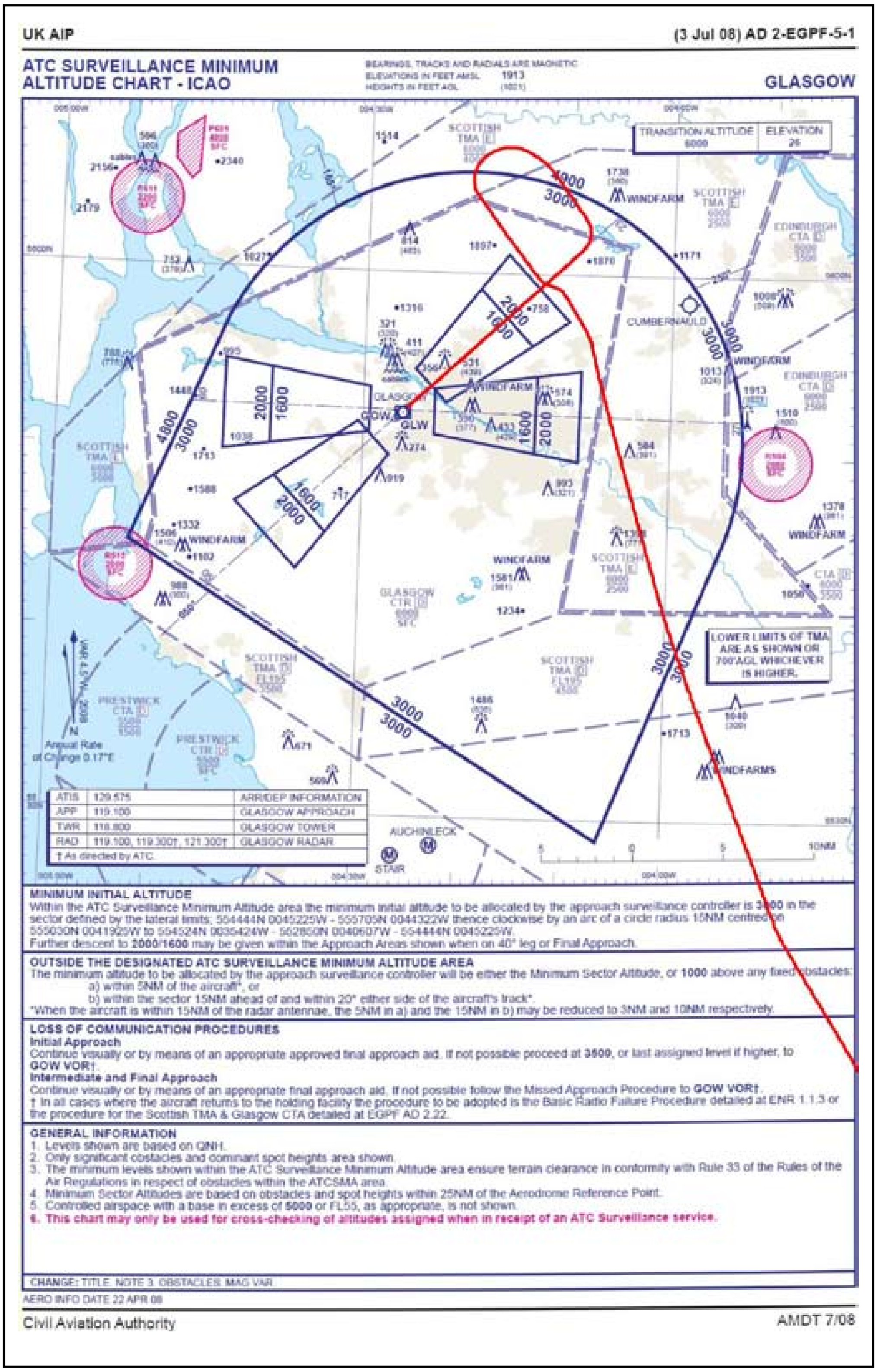

Figure 4

Minimum Altitude chart

The ILS RWY 23 chart shows the approach in detail and includes diagrammatic representations of the higher terrain in progressively darkening green. The side profile box provides greyed-out minimum altitudes for the approach. Both these charts also include a 25 nm MSA, based on the GOW VOR, for emergency use. For the sector used this shows an MSA of 4,900 ft within 25 nm.

The flight crew's third source of terrain information was the aircraft EFIS navigation display, which incorporates the EGPWS relative terrain display.

The ATCO had available two sources of terrain information however the radar overlays of certain features, including the Campsie Line (Figure 1), were his primary source of information. A laminated colour copy of the Glasgow Terrain Chart (Figure 3) was also available at his station. This chart is also contained in Glasgow's MATS Part 2 document. The track overlay in Figures 2 to 5 was generated using data overlays not available to the controller. Figure 5 is a summary, in side view, of data in Figures 2 to 4 (all in plan view).

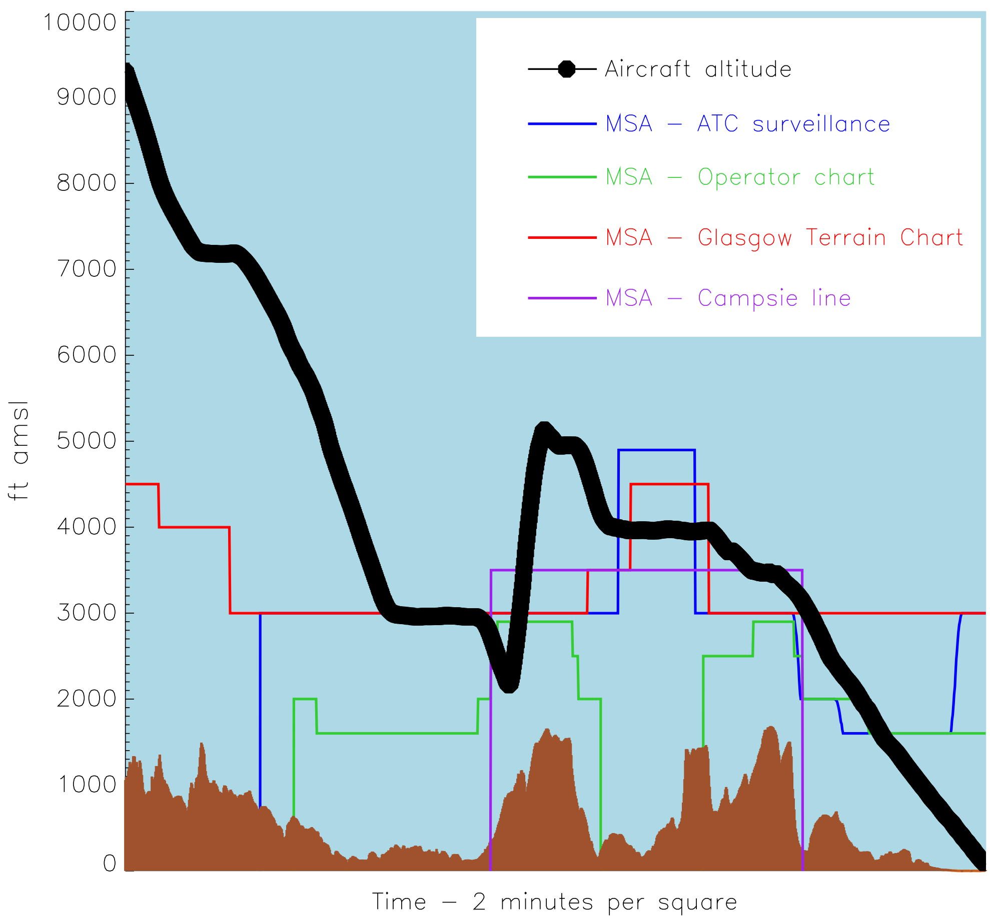

Fig 5

Summary of altitude data - G-EUUR

Use of ATC Glasgow terrain chart

During the investigation an attempt was made, by a CAA Air Traffic Services Investigator (ATSI), the AAIB Inspector and a NATS ATC Manager, to locate accurately the incident aircraft on the ATC Glasgow terrain chart, using an 'as live' radar replay. The team found this chart difficult to use and were unable to perform the task satisfactorily.

Previous events

The CAA provided details of all the Mandatory Occurrence Reports (MORs) from all operators regarding ground proximity warnings at Glasgow Airport between 1 Jan 2000 and 29 December 2008. Of these events two, in 2005 and 2007, appear to have very similar characteristics to this incident. The remaining 26 reports appear to consist of 'terrain safe' aircraft GPWS warnings, triggered by rapid change of radio height. In the years 2003, 2004 and 2005 there were six, five and six reports respectively; this reduced to two events in each of 2006, 2007 and 2008.

Minimum Safe Altitude Warning (MSAW)

MSAW is a ground-based 'safety net' system for the prevention of controlled flight into terrain (CFIT), by generating alerts of infringement of minimum safe altitude to ATC to enable the controller to alert and redirect the aircraft. The system relies on transponder altitude reporting and, depending on the MSAW system, either 'polygonal' MSAs, a digital terrain map or a combination of both. MSAW requires considerable location-specific configuration and is not, at the time of writing, widely used in Europe.

The radar system installed at Glasgow was fitted with the required hardware and software for MSAW functionality. However, at the time of the incident the system had not had the required location-specific work conducted, nor had it been approved for use. Initial work conducted by the service provider had shown a high number of false warnings generated by military and VFR traffic outside the control of Glasgow ATC, sufficient to render the system unsuitable for immediate deployment.

The current UK CAA position on MSAW was set out in a 2002 policy statement, that MSAW should be:

> *'... encouraged where a reduction in risk of CFIT can be demonstrated and the presentation of warning information to air traffic controllers does not result in any detrimental impact to the routine provision of air traffic control services.'*

The CAA has informed the AAIB that it intends to amend CAP 670 (Air Traffic Services Safety Requirements). This amendment is expected to alter the CAA's position on MSAW significantly.

Analysis

ATC actions

The air traffic controller was experienced both in role and at Glasgow. Immediately following the incident the controller identified the initiating action of the incident: writing down the closing heading on the ATC slip without having transmitted it to ATC. This broke the concept of '*write while you talk, read while you listen*'. He then issued a descent clearance to the aircraft, without checking that the aircraft was in compliance with unit procedures: it was not south of the Campsie Line, on a closing heading and within one mile of the final approach track. The controller acknowledged that as he observed G-EUUR passing through the ILS centreline he should have sent the aircraft around and then vectored it for a further approach. As he attempted to provide vectors to recover the approach, the aircraft responded to the GPWS alert and was above the MSA very quickly.

With the initial situation resolved and the aircraft above the MSA, tracking north-west, the controller then instructed a descent from 5,000 ft to 4,000 ft. At the point the clearance was issued this altitude was permitted on the controller's terrain chart. However as the aircraft turned to the north north-east its track was influenced by the 40 kt south-westerly wind. The resulting ground track took the aircraft into an area where the ATC terrain chart had an MSA of 4,500 ft and the controller did not recognise this second breach of ATC MSA.

Flight crew actions

The flight crew believed they were being conservative in the speeds they were flying on the approach and felt the aircraft was "in the groove", with no traffic or other stresses. The flight crew's mental model was similar to that planned by the ATCO. They were unconcerned when given the descent clearance to 2,000 ft as they were anticipating that the controller would shortly issue them with a turn to intercept the ILS.

During a post-incident interview the commander expressed surprise that he had accepted the ATC clearance. He also commented that the normal competence and confidence displayed by the local ATCOs could engender a sense of security which, in this instance, was false.

The clearance to descend to 2,000 ft was issued at a time when the aircraft was at 90° to the ILS and tracking towards high ground with an MSA of 2,900 ft. Both flight crew were aware of the approximate position of the high ground but their mental models differed subtly. The PF was anticipating a tighter turn onto the ILS. His decision to use 'open' descent, with its higher rate of altitude loss, reflected his concern that the aircraft had too much energy and might not remain below the glideslope. Had the descent clearance been followed immediately by a left turn towards the final approach track then this might have been a valid concern and the use of 'open' descent would have been prudent. However, as the aircraft remained on a heading of 325° ,the energy management situation reversed, so that a mode with a lower rate of descent would have been more appropriate. As such the PF was altering the vertical speed selector at the point where the GPWS alert started.

However, the flight crew did respond to the GPWS warning promptly and minimised further height loss. The extended turn to the right commanded by the flight directors had no effect on the terrain avoidance.

Conclusion

The terrain at Glasgow causes difficulties in descent and approach planning for both ATC and pilots. The ATC procedures in place will keep aircraft 'terrain safe' if followed accurately but records show that at least three arrivals in nine years have breached the Campsie Line below MSA.

In each case the actual ATC clearance, of 2,000 ft amsl, remained above the highest terrain, though safety margins were eroded. Thus, had the GPWS not operated in G-EUUR, or the crew not reacted to the warning, then this aircraft's cleared flightpath would not have resulted in a ground collision. There would, however, have been less margin for any other error, such as a mis-set QNH or a 'level bust' in descent. In all the reported cases, and for the vast majority of public transport aircraft, GPWS/TAWS provides a high level of protection. MSAW offers additional protection from human error and extends this protection to any transponding aircraft, though its technical complexity and high numbers of inappropriate warnings mean that it is not available for immediate deployment at Glasgow. The air traffic service provider continues to work on a technical solution for MSAW and no Safety Recommendation is made.

Safety actions

Actions by the air traffic service provider (ATSP)

The ATSP is planning to conduct further work, including trials, to overcome the issues with MSAW at Glasgow. The ATSP has also initiated changes to the presentation of the Glasgow terrain chart to improve readability and accuracy.

The unit is due to convert to electronic flight strips and new procedures relating to these will be utilised when the conversion goes ahead.

Actions by the aircraft operator

The aircraft operator produced a training package for its flight crews, relating to this incident. The package was deployed in May 2009, including a video debrief and simulator training.

Actions by the CAA

Before this incident occurred the CAA was already reviewing their policy regarding MSAW.

SERIOUS INCIDENT

Aircraft Type and Registration:	DHC-8-402 Dash 8, G-JECI
No & Type of Engines:	2 Pratt & Whitney Canada PW150A turboprop engines
Year of Manufacture:	2005
Date & Time (UTC):	23 December 2008 at 1600 hrs
Location:	On approach to Edinburgh Airport
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 4 Passengers - 59
Injuries:	Crew - None Passengers - None
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	54 years
Commander's Flying Experience:	6,926 hours (of which 150 were on type) Last 90 days - 109 hours Last 28 days - 45 hours
Information Source:	AAIB Field Investigation

Synopsis

The aircraft descended below a cleared altitude and then below the ILS glideslope because the appropriate mode of the flight director was not selected. The deviation from the correct flight path was noticed by an ATC controller when the aircraft had descended to within 800 ft of local terrain approximately 5 nm from the runway threshold. The crew were advised accordingly and although the aircraft's descent rate was adjusted, it did not regain the correct vertical flight path, however, the aircraft landed without further incident. A subsequent event involving the same operator and aircraft type is also considered in this report.

Two Safety Recommendations are made and the operator and ATC unit have taken safety action aimed at preventing a recurrence.

History of the flight, G-JECI

The aircraft was being operated on a scheduled passenger service from Southampton to Edinburgh as BEE247S ("JERSEY TWO FOUR SEVEN SIERRA"). As it commenced its final approach to Runway 24 at Edinburgh the approach controller (APC) instructed the aircraft to turn onto a heading of 280° to intercept the ILS localiser, descend from 3,000 ft to 2,100 ft and maintain a speed of at least 160 kt until 4 nm from touchdown. During the descent the aircraft accelerated to approximately 200 kt with flap and landing gear up.

The aircraft did not level off as intended at 2,100 ft but continued to descend at a constant vertical speed such that it remained at all times below the ILS glideslope. At an altitude of approximately 1,800 ft, apparently without having noticed that the aircraft had descended below the cleared altitude before intercepting the ILS, the APC instructed the pilots to contact the aerodrome controller (ADC). At about this time Flap 5 was selected and the aircraft decelerated to approximately 180 kt.

The ground movement controller (GMC), who sat beside the ADC in the visual control room (VCR), saw the aircraft when it was approximately 5 nm from touchdown and noticed that it looked "substantially below the glidepath". He mentioned this to the ADC. When shortly afterwards the co-pilot called, "TOWER JERSEY TWO FOUR SEVEN SIERRA IS FIVE AND A HALF MILES TWO FOUR", the ADC responded "JERSEY TWO FOUR SEVEN SIERRA ROGER AND WE'VE GOT YOU FIVE MILES OUT SHOWING NINE HUNDRED FEET IS EVERYTHING OK".

The co-pilot replied "ERR AFFIRM JERSEY TWO FOUR SEVEN SIERRA". Not content with the response the ADC replied "JERSEY TWO FOUR SEVEN SIERRA HOW LOW ARE YOU PLANNING ON DESCENDING AT THE MOMENT". The co-pilot responded "ERR WE'RE GONNA LEVEL NOW ACTUALLY OUR GLIDESLOPE CAPTURE OBVIOUSLY FAILED JERSEY TWO FOUR SEVEN SIERRA". The controllers in the VCR saw the aircraft climb slightly and continue an apparently normal approach.

Attempting to regain the correct flight path manually, the commander initially experienced some difficulty disconnecting the autopilot and found that the aircraft tended to adopt a pitch attitude 8° below the horizon. When able to resume full control, at approximately 700 ft agl, he called for Flap 15 and landing gear down. The landing was completed without further incident.

After landing the commander and co-pilot discussed the event and decided that the most likely cause of the deviation from the intended flight path was failure of the ILS. They communicated this to the ADC.

Meteorological information

A report of meteorological conditions valid at the time of the event indicated a surface wind as 240°/1kt, visibility in excess of 10 km, temperature 10°C and dew point 7°C. Sunset was at 1542 hrs and the commander described the light conditions as "night".

Flight director control

The flight director (FD) on the Dash-8-402 provides lateral and vertical guidance displayed in the form of a vertical and horizontal bar on each pilot's Primary Flight Display (PFD). It can also be coupled to the autopilot (AP) for automatic control of the aircraft.

Pilots manage the flight director and autopilot engagement using a Flight Guidance Control Panel, (FGCP) mounted in the centre of the glare shield above the main instrument panel, and two buttons on each pilot's control wheel; a Tactile Control Steering (TCS) pushbutton[1] and an AP disengage switch.

The status of the FD is displayed on the Flight Mode Annunciator (FMA) at the top of each PFD. The FMA has three fields. Vertical guidance modes are indicated in the right field in white if armed and in green if active. A mode is considered to be engaged only when it is indicated on the FMA, not just when the associated pushbutton has been pressed. It is therefore vital for pilots to monitor the FMA in response to each selection on the FGCP or control wheel.

Altitude Select mode

In the ALTITUDE SELECT mode the FD provides commands to acquire and hold a selected altitude target.

Footnote

1 When pressed the TCS pushbutton overrides the autopilot momentarily without disconnecting it. When the pushbutton is released the flight director modes update their targets to the roll, pitch, altitude, airspeed and vertical speed values at the moment of release.

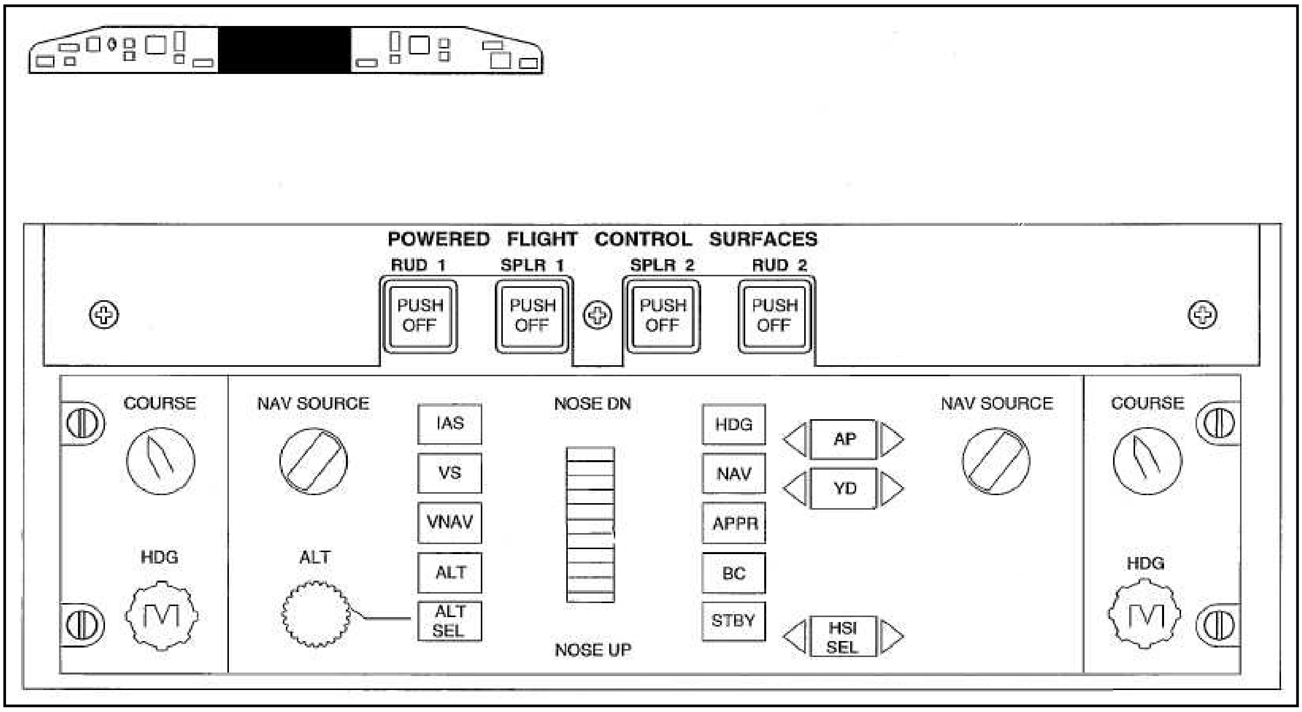

Figure 1

Flight guidance and control panel, location and functions

It has ARM and CAPTURE sub-modes. To operate the ALTITUDE SELECT mode, pilots must preselect an altitude target using the ALT knob, press the ALT SEL pushbutton to arm the mode and manoeuvre the aircraft towards the preselected altitude target using a FD vertical mode.

When armed, the symbol 'ALT SEL' appears in white on the FMA. If the ALTITUDE SELECT mode is not armed, the aircraft will continue through the selected altitude in the active vertical mode unless either pilot intervenes to change the flight path.

Vertical modes

The aircraft can be manoeuvred vertically in several modes using the FD and AP. The pilots of G-JECI used the VERTICAL SPEED mode to descend the aircraft below 3,000 ft. This mode is activated by pressing the VS pushbutton on the FGCP and indicated by the symbol 'VS' in green in the right field of the FMA when active. The desired vertical speed is selected using the pitch thumbwheel in the centre of the FGCP, labelled 'NOSE UP' and 'NOSE DN', and indicated beside the 'VS' symbol in the same FMA field.

With the AP engaged, and in the absence of further pilot inputs or system failures, as the aircraft approaches the selected altitude, the FD will change automatically to the ALTITUDE CAPTURE mode and the symbol 'ALT*' (referred to by this operator as "altitude live") will appear in green on the FMA. As the aircraft levels at the selected altitude, the FD will change automatically to the ALTITUDE HOLD mode and the symbol 'ALT' will appear in green on the FMA. If, before the FD enters a capture mode, the altitude selection is changed to one above the current aircraft altitude, the aircraft will continue to descend in the active vertical mode and in an 'open descent' until the pilots intervene to change the flight path.

ILS Approach mode

The ILS APPROACH mode is a combined lateral and vertical mode in which the FD captures and tracks the ILS localiser (lateral) and glideslope (vertical) beams. When an appropriate ILS frequency is tuned and selected as the navigation source, the GLIDESLOPE sub-mode (and, simultaneously, the LOCALIZER sub-mode) is armed by pressing the APPR pushbutton on the FGCP and indicated by the symbol 'GS' in white on the FMA.

As the aircraft approaches the ILS glidepath, the FD will change automatically to the GLIDESLOPE CAPTURE mode and the symbol 'GS*' (referred to by this operator as "glideslope star") will appear in green on the FMA. Having intercepted the glideslope beam, the FD will change automatically to the GLIDESLOPE TRACK mode and the symbol 'GS' will appear in green on the FMA. If the vertical path of the aircraft remains below the ILS glideslope the FD will not be able to capture the glideslope and the aircraft will continue to descend in the active vertical mode unless the pilots intervene to change the flight path.

The GLIDESLOPE mode is deactivated if the localiser modes are deactivated, the pitch thumbwheel is operated or any other vertical mode is activated.

Flight director standby mode

The STBY pushbutton on the FCGP clears all active and armed FD modes and removes the flight director bars from the PFD if the autopilot is disengaged.

Proposed modification by manufacturer

The operator stated that prior to these events the aircraft manufacturer proposed to modify the FD software so that selection of the ALTITUDE SELECT mode would be automatic upon selection of a new altitude and vertical mode. Recent correspondence between the two parties indicated that the manufacturer had delayed implementation of the modification.

Ground proximity warning system

The ground proximity warning system monitors the flight path of the aircraft when its height is between 50 ft and 2,450 ft. The system compares aircraft position, attitude, airspeed and glideslope inputs with internal terrain, obstacle and airport databases to determine if the present flight path would result in impact with terrain and, if so, will provide visual and aural indications to alert the pilots.

It has five modes of operation. Mode 5 – *'deviation below glideslope'* operates when the following conditions are met:

- An ILS frequency is set
- The landing gear is down
- The aircraft is less than 925 ft agl
- The aircraft is below the glidepath
- The BELOW G/S pushbutton is not pushed

When activated the system provides the aural warning "GLIDESLOPE" accompanied by illumination of an amber BELOW G/S pushbutton on the glare shield in front of each pilot. An alert will occur if the aircraft descends 1.3 dots or more below the ILS glideslope. Further alerts will occur for each subsequent 20% increase in deviation. Below 300 ft agl, if glideslope deviation is 2 dots or more, the aural alert "glideslope, glideslope" is given at twice the volume of the single alert and every three seconds until the aircraft exits the warning envelope. The BELOW G/S pushbuttons remain illuminated until glideslope deviation reduces to less than 1.3 dots.

Recorded information

Salient parameters obtained from analysis of the data from G-JECI's Quick Acces Recorder (QAR) for the incident are presented in Figure 2. The data starts just under four minutes before touchdown on Runway 24 at Edinburgh airport. At this point, the aircraft was flying straight and level at 3,000 ft amsl, with the landing gear and flaps retracted; the airspeed was 190 kt and decelerating. The autopilot was engaged with ALTITUDE HOLD mode and HEADING mode selected.

A heading of 280º was then selected, and as the aircraft turned, the autopilot was switched from ALTITUDE HOLD mode to VERTICAL SPEED with a descent rate of 1,100 ft/min.

Flap 5 was selected as the aircraft passed through 1,800 ft amsl. The aircraft was four dots right of the localizer and two dots below the glideslope. The autopilot was then switched from HEADING mode to LOCALIZER. The aircraft was now two dots to the right of the localizer so a turn to the left was initiated. The aircraft captured the localizer 20 seconds later at 1,250 ft amsl, 3.5 dots below the glidepath. The crew selected the Edinburgh Tower frequency and as the aircraft passed through 1,000 ft amsl they transmitted:

16:06:26 G-JECI	"TOWER JERSEY TWO FOUR SEVEN SIERRA IS FIVE AND A HALF MILES TWO FOUR"
16:06:30 Tower	"JERSEY TWO FOUR SEVEN SIERRA ROGER AND WE'VE GOT YOU FIVE MILES OUT SHOWING NINE HUNDRED FEET IS EVERYTHING OK"
16:06:38 G-JECI	"ERR AFFIRM JERSEY TWO FOUR SEVEN SIERRA"

With the aircraft at 800 ft amsl and four dots below the glidepath, the autopilot was disengaged and the descent rate was reduced to about 225 ft/min. Communications continued as the aircraft descended at the reduced rate and as the airspeed slowed from 185 kt to 150 kt:

16:06:48 Tower	"JERSEY TWO FOUR SEVEN SIERRA HOW LOW ARE YOU PLANNING ON DESCENDING AT THE MOMENT"
16:06:51 G-JECI	"ERR WE'RE GONNA LEVEL NOW ACTUALLY OUR GLIDESLOPE CAPTURE OBVIOUSLY FAILED JERSEY TWO FOUR SEVEN SIERRA"
16:06:57 Tower	"JERSEY TWO FOUR SEVEN SIERRA THANKS NOW SHOWING FOUR MILES OUT AT SIX HUNDRED FEET"
16:07:01 G-JECI	"THAT'S COPIED JERSEY TWO FOUR SEVEN SIERRA"

During the descent the landing gear was selected down, and by 630 ft amsl (still four dots below) and 3.5 nm DME[2], the gear was down and locked.

At 570 ft amsl and 3 nm DME, Flap 15 was selected and clearance to land was given. The aircraft commenced a short climb, reaching 750 ft amsl (0.5 dots below) about 20 seconds later, before completing an uneventful descent and landing.

Standard operating procedures

Part B4 of the company's operating manual, relevant to operation of the Dash 8-402 and referred to colloquially as "the B4", is intended to provide operating crew members with information on the technical, procedural and performance characteristics of the aircraft. Section 2.2 of this document, entitled *'Flight deck management'* states, in part:

Footnote

2 Distance measuring equipment.

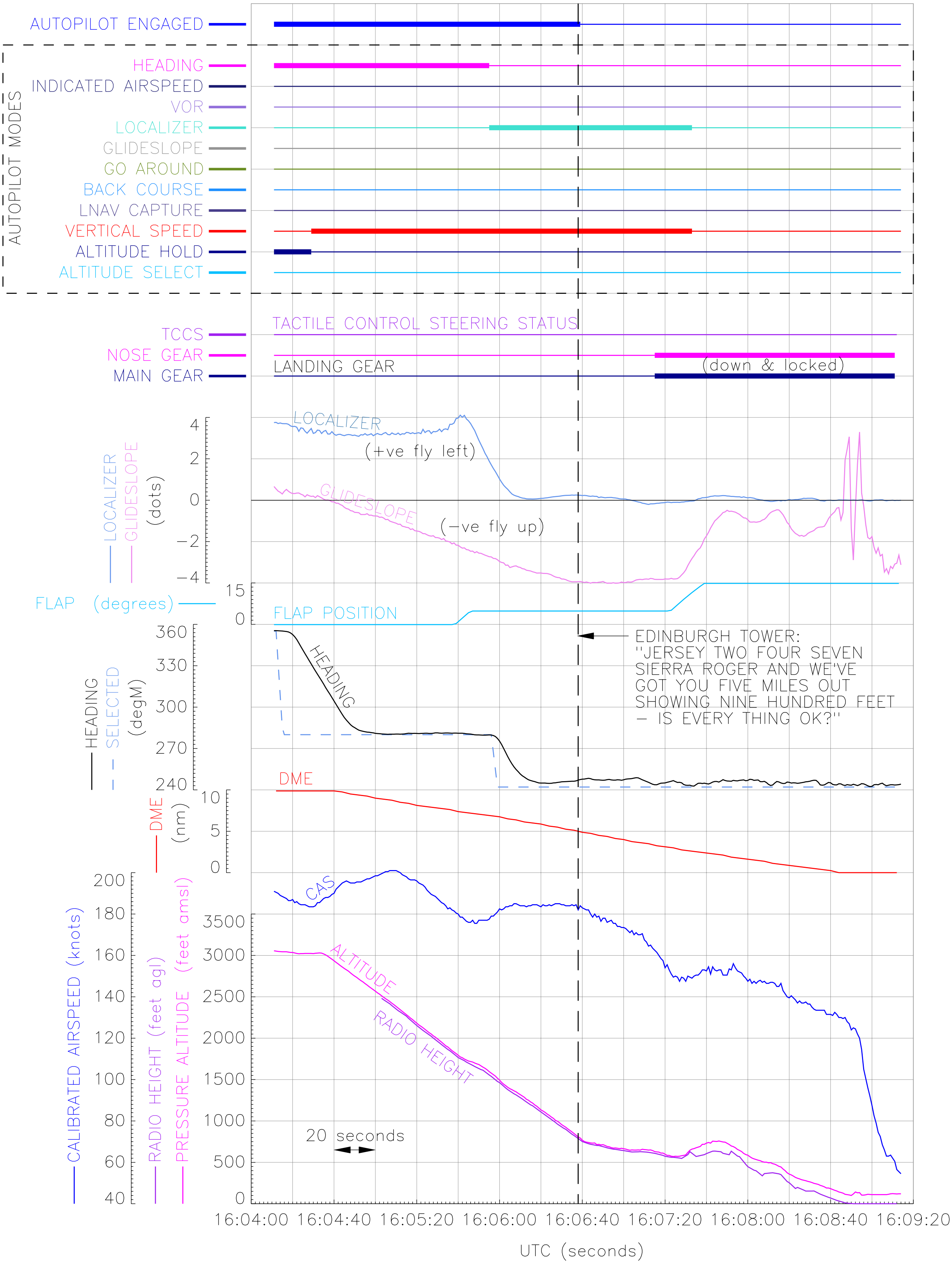

Figure 2

Salient FDR Parameters, G-JECI

> *'Pilots must adhere to the company standard operating procedures (SOPs). It is important that each pilot knows what to expect of the other and that each pilot can perform his tasks without continual reference to the other for agreement.*
>
> *'Occasionally, there is a need to depart from some aspect of the SOPs. In this case, the aspect should be clearly briefed and announced as* **"non standard"**. *Non-standard calls should be the exception rather than the norm. If difficulty is found in following these SOPs, it must be reported.'*

This section makes several references to the importance of monitoring the flight path of the aircraft, including the statement:

> *'PFs[3] main task is to fly the aircraft and monitor its flight path. PNF[4] must also monitor the aircraft flight path whenever possible whilst carrying out his other tasks.'*

Section 2.13 – *'Approach'* describes the manner in which the approach phase of a flight is to be conducted. Under the heading *'stabilised approach criteria'* it states that when the aircraft is 4 nm from touchdown the following criteria *should* be met: landing gear down, flap at least 5° and speed not above 160 kt. At 500 ft agl (referred to as the "must gate") the following criteria *must* be met: landing gear down, landing flap set, speed V_{REF} +15 kt maximum, landing checks complete. It states that a go-around is mandatory if these criteria are not met.

The operator's procedure for conducting an ILS approach requires pilots to monitor the vertical profile by comparing the actual altitude of the aircraft to the altitude shown on published charts at a specific location on the approach such as over a marker beacon, a locator beacon or at a fixed distance from a DME transmitter. This is sometimes referred to as the "final fix". According to the B4 current at the time of the incident:

> *'Provided PF has called* **"visual"**, *no further reference to altitude is required and if the visual profile is normal, no reference to speed and sink.'*

Commander's perspective

The commander recalled that in making selections on the FGCP to descend from 3,000 ft to 2,100 ft he pressed the ALT SEL pushbutton and announced that he had done so. He observed LOC* on the FMA when the aircraft intercepted the localiser and then set the go-around heading. He recalled that when he announced "visual" (in sight of the runway) the PAPI[5] was showing 4 red lights. He commented that when he attempted to disconnect the autopilot to regain the required vertical flight path he may have pressed the TCS button. When he released whichever button he had pressed, the aircraft pitched nose down and continued to descend with the FD bar indicating an attitude 8° below the artificial horizon indicated on his PFD.

He recalled that approaching 4 nm the altitude check was incorrect and ATC queried the aircraft altitude. He then pressed the autopilot disconnect button to remove all automatic flight inputs and flew the aircraft manually to

Footnote

3 Pilot flying.
4 Pilot not flying.

Footnote

5 Precision Approach Path Indicator. Four red lights indicate that the observer is more than 2.5° below the glidepath for which the system is calibrated.

regain the required flight path. At 700 ft amsl he called for Flap 15 and landing gear down. He did not recall if there had been any GPWS "glideslope" warnings prior to the event. Although the speed of the aircraft as it approached 500 ft was higher than he intended, his earlier difficulties taking manual control of the aircraft persuaded the commander to continue the approach rather than execute a go-around and missed approach.

The commander assessed the causes of the event as excessive airspeed, a rushed approach and not complying with the standard operating procedures. He noted that the co-pilot's capacity to monitor the flight may have been reduced during the time he was changing frequency to call the ADC.

Co-pilot's perspective

The co-pilot recalled that the commander selected an altitude of 2,100 ft and pressed the ALT SEL button on the FGCP. He then received an ATC instruction to change to the Edinburgh Tower frequency.

The co-pilot stated that from this point in the approach he had been able to see the runway and was able to keep it in sight throughout the subsequent approach. He stated, however, that he "could not make out" the PAPI, although it did become visible when the aircraft was approximately 4 nm from touchdown. A mandatory check by pilots of aircraft altitude at the "final fix", regardless of weather conditions, would, in his opinion, improve monitoring and help to prevent a recurrence.

The co-pilot recalled seeing the magenta "cross hairs" of the FD centred over the aircraft attitude symbol on his PFD, indicating that the autopilot was correctly following the selected flight director parameters. He therefore assumed that the aircraft had captured the ILS glideslope.

Commenting on the difficulty that the commander experienced in raising the nose to regain the correct flight path, the co-pilot noted that, when engaged, the autopilot would have trimmed the aircraft to maintain the selected vertical speed and that the effort to overcome this trim may have caused the commander to believe he was encountering "control problems". Accordingly, at the "must gate" height of 500 ft the co-pilot was content with the commander's decision to continue the approach instead of executing a go-around.

The co-pilot stated that during the flight he was experiencing physical discomfort from a "back problem". For pain relief he had taken "one or two" tablets or capsules of an ibuprofen type analgesic approximately 5 hours before the incident. He concluded that although his performance was degraded by the affects of his back problem he did not believe he was suffering from fatigue.

His greatest concern during the approach had been what he considered to be the excessive speed of the aircraft, not its altitude.

Airport information

The Edinburgh control tower is situated towards the centre of the airport approximately 1 km from the Runway 24 threshold. Consequently an aircraft 5 nm (9.25 km) from touchdown on approach to this runway will be over 10 km from the tower.

The ATC watch manager stated that the PAPI would normally be on throughout the operating hours of the airport. The Airside Safety and Environment Coordinator for the airport stated that system function was checked visually and automatically throughout the day and that there had been no problems reported.

Medical information

The "Medical" section of the United Kingdom Civil Aviation Authority (CAA) website provides general guidance on the use of "over the counter" medications by pilots which states, in part:

> *'If you need medication to 'make you feel better' you should not be flying unless your authorised medical examiner or medical adviser (who knows you are a pilot) has approved its use. Professional pilots should take advice from a doctor experienced in aviation medicine.*
>
> *If you have been taking a medication that can affect judgement, especially those with drowsiness or dizziness listed as potential side effects, a suitable period should elapse after the last dose to enable any effects to dissipate. If the dosage regime is 'every 4-6 hours' do not fly until 12 hours has elapsed after the last dose. If dosage is 'every 10-12 hours' do not fly for 24 hours'*

Subsequent event

History of the flight

On 8 May 2009 a Dash-8-402, G-JECK, departed Southampton on a scheduled passenger service to Glasgow with 60 passengers and four crew members on board. The commander was the pilot flying the aircraft. Before the flight the pilots were informed by the previous crew that earlier that day the aircraft had failed to follow an ILS glidepath in gusty conditions and that the yellow CAT 2 FAIL[6] amber caution had flashed in the FMA field of the PFD.

During the initial approach to Runway 23 at Glasgow Airport the pilots requested several heading changes to avoid adverse weather conditions. The approach controller cleared the aircraft to descend from 3,000 ft to 2,000 ft, turn onto a heading of 270° to intercept the ILS localiser and when established, descend further with the ILS glideslope. The commander selected a target altitude of 2,000 ft, armed the ALT SEL mode, activated the VERTICAL SPEED mode and set a vertical speed of -1,000 fpm (down). When the aircraft was established on the localiser, the commander also armed the GLIDESLOPE mode.

The aircraft encountered turbulence throughout the approach and its indicated airspeed fluctuated but with the AP engaged it appeared to follow the flight director guidance on what the commander considered to be a "normal descent profile". Both pilots reported that they could see the ground. The commander stated that at an altitude of approximately 1,100 ft the GPWS "glideslope" warning sounded, in response to which he disconnected the AP and deactivated the flight director by pressing the STBY pushbutton. Simultaneously, the ADC queried the aircraft's height. The commander then manoeuvred the aircraft to intercept the correct glidepath and landed without further incident.

Meteorological information

A report of meteorological conditions valid at the time of the event indicated a surface wind from 240° at 6 kt, gusting to 18 kt, visibility greater than 15 km with light showers of rain and hail, broken cumulonimbus cloud with a base at 2,000 ft, temperature 7°C and dew point 4°C. Sunset was at 2149 hrs and the commander described the light conditions as "twilight".

Footnote

6 This indicates that the dual FD mode necessary for a CAT 2 ILS approach is cancelled. The operator stated that in its experience this can occur in gusty conditions if the aircraft is unable to follow FD commands in ILS mode.

Recorded information

Salient parameters from the QAR for this flight are presented in Figure 3 which start about six minutes before touchdown on Runway 23 at Glasgow Airport. At this point, the aircraft had levelled at 3,000 ft amsl, the landing gear was up, the flaps retracted and the airspeed was 190 kt. The autopilot was also engaged with ALTITUDE HOLD mode and HEADING mode selected.

A heading of 300º was selected and as the aircraft turned, the flaps were extended to the Flap 5 position. The selected heading was then changed to 300º and the autopilot was switched from ALTITUDE HOLD mode to VERTICAL SPEED with a descent rate of 1,000 ft/min.

As the aircraft passed through 2,600 ft amsl, the autopilot was switched from HEADING mode to LOCALIZER. The aircraft was 3.5 dots right of the localizer and one dot below the glideslope at 9 nm DME.

The aircraft continued descending at 1,000 ft/min, turning to the left, and intercepted the localizer at 7.5 nm DME and at 2,150 ft amsl (1.5 dots below the glideslope). By 1,600 feet amsl the landing gear was down and locked. The flaps were then moved to Flap 10 then Flap 15. The first GPWS "glideslope" warning was recorded at 5.4 nm DME as the aircraft descended through 975 ft agl, 3 dots below the glideslope.

Initially the aircraft continued to descend with the same vertical speed but after the second GPWS "glideslope" warning was recorded at 920 ft agl and 5.3 nm DME, the autopilot was disconnected and the rate of descent reduced. The third GPWS "glideslope" warning was recorded at approximately 730 ft agl and the aircraft continued in level flight over slightly rising ground. At 630 ft agl, 4.1nm DME the fourth GPWS glideslope warning was recorded. The aircraft remained in level flight with a full "fly up" indication on the glideslope indicator and the final GPWS "glideslope" warning was recorded at 4.0 nm DME. The aircraft intercepted the ILS glideslope at 3.6 nm DME, and continued to an uneventful landing.

Safety investigation by the operator

The aircraft QAR data was downloaded by the operator's flight safety department on 26 May 2009, almost 3 weeks after the event. The proprietary flight data monitoring (FDM) tool, used by the operator, did not automatically register an event requiring investigation by the flight safety department. Operational issues relating to the incident involving G-JECK were first identified on 31 July when, having found no fault with the ILS system, the operator's maintenance department requested that the Flight Safety Manager (FSM) examine flight data relevant to the flight.

When interviewed by the operator, both pilots recalled seeing a green GS* symbol on the FMA, although there was no record of this annunciation and other data indicated that the aircraft did not get close enough to the glidepath for this annunciation to appear. The FSM suggested to the pilots that they may have misidentified LOC* as GS*, because selection of the go-around altitude occurred almost coincidentally with localiser capture, whereas the go-around heading was not selected until approx 2 seconds later. The FSM concluded, however, that selection of the go-around heading followed correct identification of LOC* and that something else triggered selection of the go-around altitude.

The pilots may have had reduced confidence in the accuracy of the glideslope presentation on the PFDs with the knowledge that the aircraft had failed to follow the glideslope on an earlier approach. However, having examined data for that flight the FSM concluded that

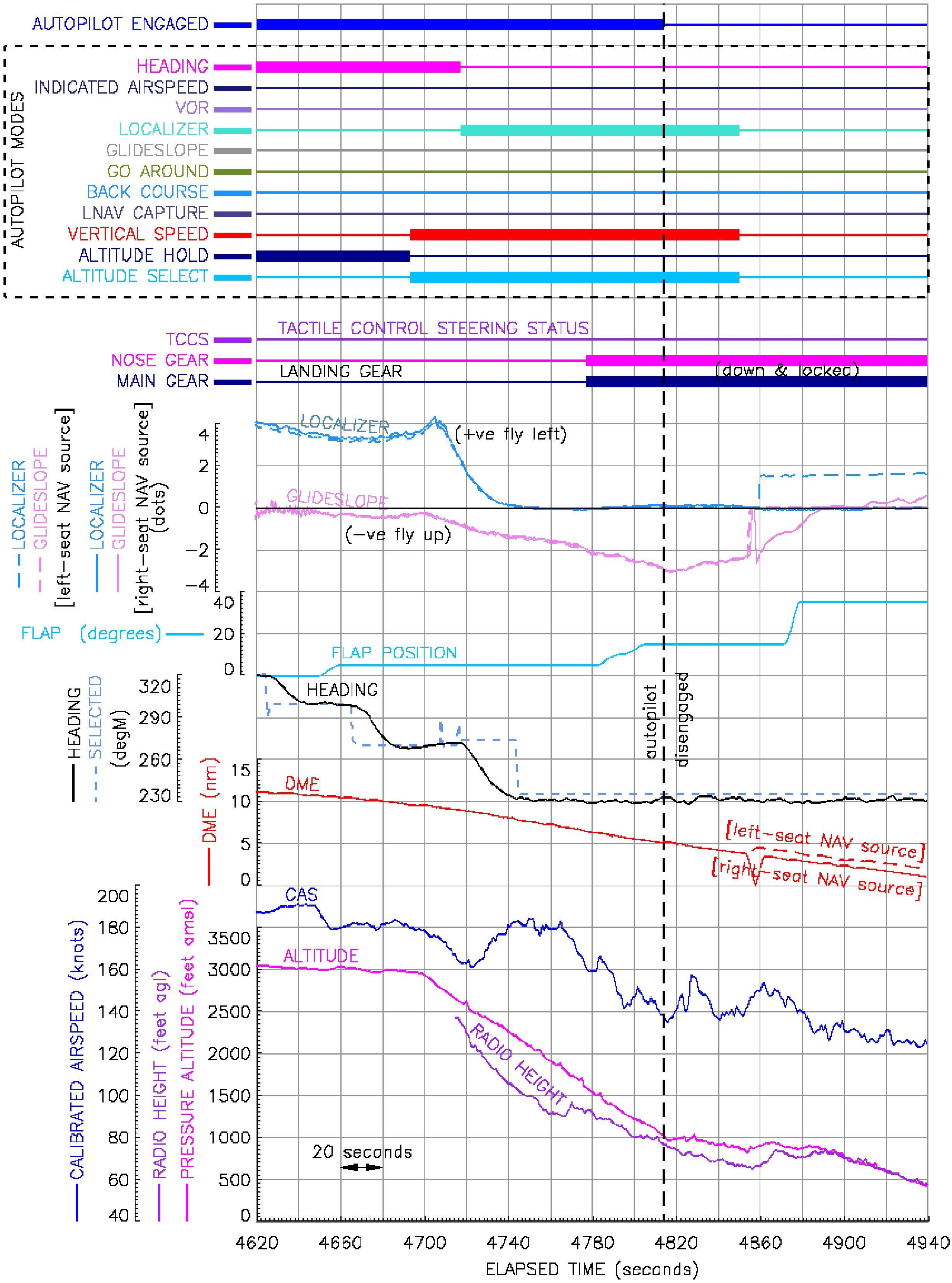

Figure 3

Salient FDR Parameters, G-JECK

on that previous approach, the aircraft had followed the glideslope adequately in what he described as "moderate turbulence" with winds in excess of 40 kt.

The commander stated that his main reference was the FD display. Assuming that the pilots would have altered the vertical profile had they been aware that the aircraft was lower than intended, it is probable that no checks were made of the approach profile until either the GPWS "glideslope" warning activated or ATC queried the height of the aircraft. The operator's standard procedures did not require such a check if the pilot flying had called visual, which he could have done in these conditions. Neither pilot could recall if the commander had made the visual call.

The Emergency Checklist (ECL) states that on receipt of a GPWS "glideslope" warning the response is to stop descent and regain the glideslope. The pilots of G-JECK did so by flying level to regain the glidepath.

The human factors element of the operator's investigation found that neither pilot felt fatigued or unwell. Both pilots were certain that they had seen a 'GS*' annunciation on the FMA before setting the go-around altitude, although neither could recall seeing 'ALT' or 'ALT*' indications prior to this.

Both pilots stated that although they were able to see the runway as the aircraft descended below 2,000 ft, it was not immediately obvious that the aircraft was below the correct glidepath.

Nevertheless the commander stated that during the final approach something "felt wrong" and he became preoccupied with trying to identify the cause of his unease. He stated that although the FD "looked correct", both he and the co-pilot became aware visually that the aircraft was descending below the correct vertical path. The commander stated that he continued to follow the FD commands because that is what he had been trained to do.

The co-pilot could not remember checking the aircraft height at 4 DME. Doing so would have provided an opportunity to determine that the aircraft was 649 ft below the ILS indicated glideslope. The pilots were inclined to suspect a problem with the ILS installation, either on the ground or in the aircraft, because of information from the previous pilots. The co-pilot stated that he moved his hand behind the power levers in anticipation of a missed approach but did not initiate one because the rate of descent had been reduced and the aircraft was stable, albeit very low.

The operator made the following observations:

- The pilots set the go-around altitude before the flight director entered a capture mode (GS* or ALT*), causing the aircraft to continue to descend at the selected vertical speed.
- The pilots did not monitor aircraft behaviour adequately during the approach and aircraft profile.
- Knowing that a previous crew had reported a problem with the aircraft ILS system the pilots may have suspected failure, rather than mis-selection, of the associated FD modes.
- Weather avoidance may have been a distraction.
- The commander followed FD guidance with little or no reference to other available data.

The operator also noted that the ECL did not give clear guidance on what action to take in the event of a GPWS "glideslope" warning.

Minimum safe altitude warning (MSAW) equipment

MSAW utilises secondary surveillance radar[7] and trajectory tracking to determine if an aircraft is at risk of controlled flight into terrain (CFIT). In a policy paper of 22 April 2002 entitled *'Implementation of Minimum Safe Altitude Warning (MSAW) equipment in the UK'*, the CAA determined that:

> *'The system is technically complex (due to the need to compensate for radar processing delays) and requires careful installation, commissioning and operation to ensure that false alert occurrences do not present a hazard to operations.'*

The paper concluded:

> *'Mandating the installation of MSAW facilities in all radar display systems is not justified because:-*
>
> - *Improved Aircraft Equipment (e.g. GPWS, TAWS[8]) is available*
> - *Low level SSR coverage is limited*
> - *Cost benefit analysis does not conclusively support mandatory action'*

Two of the operational radars at Edinburgh are equipped with MSAW for trial purposes but the system was not active at the operational positions used by Air Traffic Control Officers (ATCOs) controlling G-JECI.

Footnote

[7] A radar system in which a suitably equipped aircraft can respond to transmissions from a ground installation to provide information other than range and bearing, such as altitude and aircraft identification.

[8] Terrain Awareness Warning System.

Occurrence reporting

Civil Aviation Publication (CAP) 382 – *'The Mandatory Occurrence Reporting Scheme'* published by the CAA states, in part, that:

> *'The objective of the MOR Scheme is to contribute to the improvement of air safety by ensuring that the relevant information on safety is reported, collected, stored, protected and disseminated.'*

Under the heading *'Items to be reported'* it states:

> *'A reportable occurrence in relation to an aircraft means any incident which endangers or which, if not corrected, would endanger an aircraft, its occupants or any other person.'*

And:

> *'A report should be submitted on any occurrence which involves, for example, a defective condition or unsatisfactory behaviour or procedure which did not immediately endanger the aircraft but which, if allowed to continue uncorrected, or if repeated in different, but likely, circumstances, would create a hazard.'*

Section 11 of Part A of the operator's manual, entitled *'handling of accidents and incidents'* details the procedures that the operator wishes pilots to follow in the event of an accident or incident. It contains a list of examples of serious incidents that should be reported, including *'controlled flight into terrain only marginally avoided'*. It also states that:

> *'Air Safety reports are to be used to report any incident which may or may not be reportable under the MOR scheme.'*

CAP 493 – *'Manual of Air Traffic Services – Part 1'* contains procedures, instructions and information intended to form the basis of air traffic services within the United Kingdom. It defines a serious incident as one involving circumstances which indicate that an accident nearly occurred. It states:

> *'The AAIB are the final arbiters in deciding whether the incident will be considered serious and so, if doubt exists, an incident should be reported rather than excluded.'*

It gives several examples of incidents likely to be considered serious, including:

> *'Controlled flight into terrain only marginally avoided.'*

Reporting by flight crew

The commander of G-JECI stated that he attempted to file an air safety report (ASR) shortly after the accident but was unable to do so until 6 days after the event, first because of problems with the operator's electronic ASR system and then due to administrative difficulties. The commander of G-JECK filed an ASR in accordance with the operator's procedures.

Reporting by Edinburgh Air Traffic Control Unit

The incident involving G-JECI was not reported at the time by the controllers on duty and no information was logged in the watch log. Managers of the unit conducted an investigation when they became aware of the event following a request from the operator for information.

The ATC investigation found that before passing control of the aircraft to the ADC the APC appeared "busy on the frequency" and did not notice that the aircraft had already descended below its cleared level. The ADC indicated that when first challenged, the pilots of G-JECI did not appear concerned. When, after a period of observation, the ADC again notified the pilots that the aircraft was significantly below the glide path the "tone of voice" of the responding pilot became "stressed".

The ATC investigation determined that collectively the controllers assisted in preventing the aircraft from descending into terrain. It noted that the GMC reported "fluctuations" in the ILS glideslope to the airport telecommunications engineers in accordance with the pilot's comments but that otherwise controllers did not file a report of any kind. It was apparent that not all Air Traffic Control Officers (ATCOs) at the unit were aware of when a report was required.

The ATC investigation concluded that although the ATCOs helped to resolve the situation, "more proactive measures could have been taken to significantly reduce the possible risk of controlled flight into terrain". It noted that the investigation was delayed due to the lack of reporting.

Analysis

Flight director operation

In the case of G-JECK the vertical modes were armed but the target altitude was reselected to a value above the current aircraft altitude before the FD captured the glideslope. In both cases, starting from a position below the ILS glideslope and with a vertical speed sufficient to remain below it, the aircraft could not intercept the glideslope even if the ILS APPROACH mode was armed. Both incidents demonstrate the importance of ensuring that the desired FD modes are indicated in the FMA field of the PFD. It is not sufficient simply to press the associated buttons.

Both incidents appear to have been initiated by FGCP selections which resulted in FD modes other than those intended by the pilots. In the case of G-JECI, recorded data indicates that the ALTITUDE SELECT mode was not armed after selection of a lower altitude. This problem would be alleviated if the ALTITUDE SELECT mode was automatic upon selection of a new altitude and vertical mode, as is the case on several other aircraft types and as envisaged by the aircraft manufacturer in its discussions with operators. Therefore, the following Safety Recommendation is made:

Safety Recommendation 2009-005

It is recommended that Bombardier Aerospace enable automatic arming of the altitude select mode of the flight director fitted to Dash-8-400 series aircraft upon selection of a new altitude and vertical mode.

Standard operating procedures

The conditions were such that a visual approach could be conducted and a "final fix" check was not required under existing operator procedures. However, as a procedure already exists for making such a check, its use on all instrument-based approaches, even those flown in visual meteorological conditions, would not introduce additional complication but may assist pilots' monitoring of the vertical flight path. Accordingly, the following Safety Recommendation is made:

Safety Recommendation 2009-006

It is recommended that Flybe consider amending its standard operating procedures to require an altitude check whilst on final approach even when the pilots are in visual contact with the runway.

In relation to this Safety Recommendation the operator is in the process of reviewing the approach procedure such that pilots must make a "final fix" check even if they are conducting the approach visually.

Having determined that the aircraft was substantially below the intended flight path the pilots took action to regain it. In the case of G-JECK the recovery flight path was essentially level, in accordance with the procedure described in the ECL for responding to the GPWS "glideslope" warning, namely to *'Stop descent, regain glideslope'*. The FSM indicated that the operator would prefer pilots to take positive action to climb the aircraft to regain the proper profile and has taken the safety action noted below.

In each case, failure of the aircraft to maintain the intended flight path indicates either that the pilots chose not to follow the ILS glideslope or that they were unaware that the aircraft was not following it. The latter would indicate that the pilots were not monitoring the FD against other data such as basic indications of ILS glideslope and localiser deviation, commonly referred to as "raw data".

In its Operating Manual, the operator refers several times to the importance of monitoring the flight path.

ATC issues

In the case of G-JECI, deviation from the cleared altitude was not identified by the APC and the subsequent descent of the aircraft below the normal glidepath was not identified by the ADC. The proximity of the aircraft to terrain was eventually identified by the GMC, who had no formal role in this phase of flight. At the point that he did so the aircraft was approximately 10 km away from the tower. Any reduction in visibility below 10 km would have delayed the moment at which the GMC was able to see the aircraft and determine that it was lower than usual. Had visibility degraded to 6 km the GMC might not have seen the aircraft until its original flight path intercepted local terrain. Correct operation of the GPWS would then have been the only warning of impending flight into terrain.

In its policy paper of 2002 the CAA concluded that mandatory installation of MSAW was not justified, but the Edinburgh ATC concluded in its own report that MSAW equipment already installed for trial purposes should be considered for operational use.

Safety action

Safety action by the operator

The General Manager responsible for DASH-8-402 operations indicated that the company is considering a change to the ECL to reflect the procedure that the operator expects its pilots to adopt in response to a GPWS "glideslope" warning. Because the wording of the ECL follows that of the aircraft manufacturer's original document the General Manager has undertaken to liaise with the manufacturer to achieve the appropriate change.

At the request of the FSM, the FDM tool provider has activated parameters within the system that will in future highlight events such as those involving G-JECI and G-JECK during routine FDM operations.

Safety action by Edinburgh ATC

Edinburgh ATC took the following safety action:

1. The issue of whether high controller workload contributed to the APC not identifying the initial altitude deviation will be highlighted in unit publications.

2. The example of the incident involving G-JECI will be used to reiterate the need for ATCOs to comply with the provisions of CAP382.

3. The unit has emphasised to its controllers the correct action to be taken in the event an aircraft becomes dangerously positioned on final approach.

The unit will also consider the operational use of MSAW.

SERIOUS INCIDENT

Aircraft Type and Registration:	DHC-8-402 Dash 8, G-JECR
No & Type of Engines:	2 Pratt & Whitney Canada PW150A turboprop engines
Year of Manufacture:	2006
Date & Time (UTC):	3 September 2009 at 0544 hrs
Location:	Isle of Man (Ronaldsway) Airport
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 4 Passengers - 27
Injuries:	Crew - None Passengers - None Others - 1 (Minor)
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	40 years
Commander's Flying Experience:	6,947 hours (of which 855 were on type) Last 90 days - 116 hours Last 28 days - 45 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The aircraft had been pushed back off stand and the commander had been cleared by ATC to start the engines. He initially delayed the start, due to an ATC slot delay but, at the same time as he was instructed by the ground crew to set the parking brake, ATC informed him that there would be no delay to his departure. He confirmed that the brakes were set, cleared the ground crew to remove the tow bar and received clearance from the ground crew supervisor to start the right engine. He instructed the co-pilot to start that engine, which caused the forward nosewheel undercarriage (landing gear) doors to close, trapping the ground crewman who was attempting to remove the tow bar.

The aircraft operator and ground handling agent promptly issued instructions to their respective staff to prevent a recurrence of this incident.

History of the flight

The aircraft was on its first flight of the day and was scheduled for a departure to London Gatwick Airport. The flight crew had completed their before-start preparations and had received clearance from ATC to push back off their parking stand and start the aircraft's engines. The ground crew comprised a tug driver who was wearing a cordless headset and was in communication with the aircraft commander, and a ground crewman who was wearing ear defenders and would disconnect the tow bar, when cleared to do so. The tug driver was the supervisor for the movement of the aircraft, which was coupled to the tug by a tow bar attached to the aircraft's nose landing gear (also referred to in this report as the nosewheel undercarriage).

The commander contacted the tug driver and, in accordance with the aircraft operator's and ground handling agent's standard operating procedures, confirmed that the brakes were released. The tug driver acknowledged that the brakes were released and then commenced the pushback, with the other ground crewman located on the right side of the aircraft. Normally the engines are started as the aircraft commences the pushback. However, because they had pushed back early, the commander planned to park the aircraft in a waiting area, with the APU running, and start the engines nearer the departure time.

As the aircraft approached the end of the pushback, ATC informed the commander that the aircraft would be able to depart without delay. The aircraft came to a stop and the commander was instructed by the tug driver that the pushback was complete and to select the parking brake ON. The commander confirmed that the brakes were set and gave clearance for the tow bar to be disconnected. Having obtained permission from the ground crew supervisor, the commander then instructed the co-pilot to start the right engine. The ground crewman, whose task it was to remove the tow bar, knelt down beneath the nose of the aircraft and, with some difficulty, attempted to remove the tow bar. At this point the right engine was started and pressurised the No 2 hydraulic system. This caused the forward nosewheel undercarriage doors to close and, as they did so, the ground crewman was caught by his right upper arm and chest. He was able to grasp the right door with his left hand and attempted to prevent it from closing.

On seeing his colleague's predicament, the tug driver went to his assistance and instructed the flight crew to stop the right engine. His call was not heard by the crew but the commander noticed that the nose landing gear door amber caption was still illuminated. He asked the tug driver to confirm if the doors were still open but, initially, could not understand his reply. When it became apparent that the other ground crewman had become trapped, the commander immediately shut down the right engine, pulled the landing gear door release handle and exercised the elevator to dissipate the hydraulic pressure.

The ground crewman was able to release himself with the assistance of his colleague and was taken to hospital with minor injuries.

First flight of the day

Before the first flight of the day, the operator's engineering department carries out an inspection on the aircraft, including the nose landing gear bay. In order to perform this inspection, the two forward nosewheel undercarriage doors are opened fully and left in that position until the right engine is started. The landing gear and associated doors are operated using the No 2 hydraulic system, the pump for which is driven by the right engine. When the right engine is started, the hydraulic system pressurises and the forward nosewheel undercarriage doors close. Subsequently, the doors close after the nose landing gear has been raised or lowered and remain closed until the landing gear is next cycled.

Safety action

Following an initial investigation, the ground handling agent issued a Memorandum to its airside staff on 3 September 2009. This stated:

> *'**Before disconnecting the tow bar on any Dash 8 Q400 aircraft you must ensure that the nose wheel undercarriage is in the fully closed position.***
>
> *If the nose wheel undercarriage is not in the fully closed position you must inform the captain and ask them to ensure it is closed **BEFORE** disconnecting the tow bar from the aircraft.'*

The aircraft operator issued a similar Ground Services Bulletin (GSB) No33 on 7 September 2009 which stated:

> ***'Before disconnecting the tow bar on any Dash 8 Q400 aircraft, ground operators must ensure that the 'forward' nose wheel undercarriage doors are in the fully closed position.***
>
> ***If the forward nose wheel undercarriage doors are not in the fully closed position, the Captain must be informed and the tow bar must not be disconnected from the aircraft.***
>
> ***When engine start clearance is given the nose wheel bay area must be clear. DO NOT ALLOW ANYONE TO APPROACH THE WHEEL BAY DURING ENGINE START.***
>
> ***During the engine start, hydraulic pressure will close the doors automatically. If the doors still do not close, inform the Captain again. Only once the doors have fully closed may the tow bar be disconnected.'***

The operator included two photographs in the GSB illustrating the forward doors closed and open, Figures 1 and 2.

Figure 1
Doors closed

Figure 2
Doors open

ACCIDENT

Aircraft Type and Registration:	BA Swallow 2, G-AFCL
No & Type of Engines:	1 Pobjoy Niagara III piston engine
Year of Manufacture:	1937
Date & Time (UTC):	27 August 2009 at 1845 hrs
Location:	Niden Manor, near Daventry, Northamptonshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to the propeller, both wings, forward fuselage and the right main landing gear assembly
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	37 years
Commander's Flying Experience:	9,000 hours (of which 100 were on type) Last 90 days - 150 hours Last 28 days - 42 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

After a normal landing on a grass airstrip, the aircraft veered to the right and departed the right side of the runway. It struck a fence at slow speed and sustained damage to its propeller, forward fuselage, both wings and the right main landing gear. The pilot, who had been unable to correct the aircraft's turn to the right, reported that the cross-strut on the right main landing gear had failed, probably during the landing, altering the landing gear's geometry. He was unable to explain the cause of the failure but did not consider that it was a result of the landing, which had been normal.

History of the flight

The aircraft, which had already been flown twice without incident, was returning to a private airstrip after a five-minute flight in good weather. The grass runway, which was orientated east/west, was reported to be 800 m in length and 20 m wide. The pilot, for whom this was the first flight of the evening, flew a curving approach to the westerly runway, to avoid obstacles under the final approach path, and completed a normal landing. He estimated that the surface wind was from the south-west at about 10 to 15 kt. Immediately it touched down the aircraft entered a slow turn to the right, which the pilot was unable to correct. The aircraft departed the right side of the runway, mounted an earth bank and struck a fence at slow speed. The pilot, who was uninjured, shut the aircraft down and vacated it normally. The aircraft was reported to have sustained damage to the propeller, the leading edges of both wings, the forward left fuselage and the right main landing gear assembly.

Following the accident, the pilot determined that the right main landing gear cross-strut had fractured, probably on touchdown, resulting in the right main gear folding outwards, causing the loss of control. He did not consider that the landing had been abnormal or firm and, as such, could not explain the failure of the cross-strut.

ACCIDENT

Aircraft Type and Registration:	Cessna 182K Skylane, G-AVGY
No & Type of Engines:	1 Continental Motors Corp O-470-R piston engine
Year of Manufacture:	1967
Date & Time (UTC):	27 November 2009 at 1624 hrs
Location:	Fenland Airfield, Lincolnshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Wings, nosewheel, propeller and fuselage
Commander's Licence:	Private Pilot's Licence
Commander's Age:	Not known
Commander's Flying Experience:	Total hours - not known (of which 2 were on type) Last 90 days - 2 hours Last 28 days - 1 hour
Information Source:	Aircraft Accident Report Form submitted by the pilot

On entering the grass runway at Fenland Airfield with the intention of taking off, the pilot reported applying power before the aircraft was fully aligned with the runway. Shortly after full power was selected, the aircraft entered the edge of the adjacent wheat field, which was very wet following recent rain. As the aircraft came to a rapid stop, it turned over.

ACCIDENT

Aircraft Type and Registration:	Cessna U206G Stationair, G-BSUE
No & Type of Engines:	1 Continental Motors Corp IO-520-F piston engine
Year of Manufacture:	1978
Date & Time (UTC):	28 July 2009 at 1650 hrs
Location:	Elstree Aerodrome, Hertfordshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 5
Injuries:	Crew - None Passengers - None
Nature of Damage:	Landing gear, both wings and propeller
Commander's Licence:	Private Pilot's Licence
Commander's Age:	39 years
Commander's Flying Experience:	97 hours (of which 9 were on type) Last 90 days - 35 hours Last 28 days - 11 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The aircraft took off for a local sightseeing flight. The weather conditions were good, although the strong westerly wind was described as "gusty at times". After takeoff, the pilot noticed that the aircraft "was not gaining speed as it normally did". Witnesses to the takeoff described the aircraft as having a higher nose-up attitude than normal. The pilot lowered the nose and the aircraft accelerated but he felt that more power than normal was required, so he decided to land back at Elstree. Close to the threshold on final approach, the aircraft suddenly dropped. The pilot applied power to minimize the impending bounce but, as he did so, the aircraft yawed violently to the left and struck the ground. The aircraft stopped quickly and the pilot and his five passengers exited the aircraft normally, uninjured. There was no fire.

The pilot considered that, being heavier than usual, the aircraft stalled at a higher speed than he was expecting, although he did not recall hearing the stall warning horn. He thought the sudden yaw to the left may have been because his front seat passenger, alarmed by the aircraft's sudden descent, inadvertently applied pressure on the left rudder pedal.

ACCIDENT

Aircraft Type and Registration:	Piper PA-23-160, G-APFV
No & Type of Engines:	2 Lycoming 0-320-B3B piston engines
Year of Manufacture:	1959
Date & Time (UTC):	21 October 2009 at 1630 hrs
Location:	Longside Airfield, near Peterhead, Aberdeenshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Propellers and engines damaged, flaps and fuselage underside abraded
Commander's Licence:	Private Pilot's Licence
Commander's Age:	53 years
Commander's Flying Experience:	2,591 hours (of which 320 were on type) Last 90 days - 31 hours Last 28 days - 14 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The aircraft landed with its landing gear retracted.

History of the flight

The aircraft had flown under instrument flight rules from Stavangar, Norway to Longside Airfield. The pilot stated that during its descent the aircraft entered cloud at 3,000 ft, becoming clear of cloud at 1,200 ft as it passed over Peterhead, from where the airfield was clearly visible. Local sunset was at 1647 hrs and the pilot described light conditions as "approaching dusk". He reported weather conditions "consistent with the reports at Aberdeen Airport". Weather reports for Aberdeen Airport at 1620 and 1650 hrs indicated wind from 130° at 20 gusting up to 31 kt, 4,000 m visibility, cloud scattered between 600 and 800 ft with a base broken at 900 ft and overcast at 1,000 ft.

The pilot delayed extending flap and landing gear until joining the circuit and recalled checking that the flaps were fully down before turning onto a right-hand base leg. He noted that the final approach to Runway 10 required "high power" to maintain the required approach angle. The landing gear warning horn sounded shortly before touchdown and the propeller tips struck the runway before the pilot was able to take corrective action.

The aircraft settled on its retracted landing gear, whose wheels protrude from their nacelles, and stopped approximately 230 m beyond the point of the first propeller contact. The pilot turned off the fuel and electrical systems and vacated the aircraft without injury. He then reported the incident to Aberdeen ATC, confirming that there were no injuries and that no assistance was required from the emergency services.

Aerodrome information

Longside Airfield has a single tarmac landing strip approximately 490 m long that forms part of a disused runway at the former RAF Peterhead. There are no ground facilities for instrument approaches at the airfield and all approaches must be made under visual flight rules.

Discussion

The pilot commented that because the speed at which he normally extended the landing gear was higher than for flap, having established that the flap was extended he assumed that the landing gear was too. He listed as contributory factors to the accident his "recollection" of having selected the landing gear down and failure to confirm the landing gear position indicators on short final. It is possible that the meteorological conditions provided an additional distraction.

This is an example of what is sometimes referred to as "environmental capture", in which an operator has not consciously checked their performance of a habitual or frequently exercised skill[1]. Failure to do so may be affected by raised workload or stress[2].

Footnote

1 R.D. Campbell, Michael Bagshaw, *Human performance and limitiations in aviation*, third edition, pp113-116

2 J.T. Reason, *Human error,* 2003, p107

ACCIDENT

Aircraft Type and Registration:	Piper PA-28-140 Cherokee, G-LFSC
No & Type of Engines:	1 Lycoming O-320-E2A piston engine
Year of Manufacture:	1973
Date & Time (UTC):	28 September 2009 at 1745 hrs (approx)
Location:	South Cave (Mount Airey) Airfield, East Yorkshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 (Minor) Passengers - N/A
Nature of Damage:	Nose landing gear collapsed, propeller strike and engine shock-loaded
Commander's Licence:	Private Pilot's Licence
Commander's Age:	52 years
Commander's Flying Experience:	94 hours (of which 94 were on type) Last 90 days - 7 hours Last 28 days - 3 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

After landing in an uphill direction on a grass surface, but with a strong tailwind, the aircraft departed the runway to the left into a cultivated field. This caused the nose landing gear to collapse and the propeller to strike the ground.

History of the flight

On arrival at Mount Airey (South Cave) Airfield, the pilot overflew the runway to ascertain the runway in use. The windsock at the 'downhill' end of Runway 07/25 was missing, having been detached by the strong wind during the day, and the pilot reported that he did not see another windsock at the 'uphill' end of the runway. He made a decision to land 'uphill' on Runway 07 and, after being too high on his first three attempts, managed to touch down close to the threshold of the 732 m long grass runway. The local wind was reported as 300°/30 kt.

After touching down, the pilot reported losing rudder control, possibly due to a gust associated with the tailwind, and the aircraft departed to the left of the runway. As it entered the adjacent cultivated field, the nose landing gear collapsed, allowing the rotating propeller to strike the ground.

The pilot later commented that he had remained on the Humberside radio frequency, rather than changing to the airfield frequency. Had he done so, he said he would have been advised by pilots on the ground to land in the opposite direction.

ACCIDENT

Aircraft Type and Registration:	Piper PA-34-200T Seneca II, G-BEAG
No & Type of Engines:	2 Continental Motors Corp TSIO-360-EB piston engines
Year of Manufacture:	1976
Date & Time (UTC):	14 September 2009 at 1306 hrs
Location:	Runway 04, Gloucestershire Airport
Type of Flight:	Training
Persons on Board:	Crew - 2 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Damage to aircraft underside and propellers, engines shock-loaded
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	55 years
Commander's Flying Experience:	3,645 hours (of which 1,370 were on type) Last 90 days - 50 hours Last 28 days - 29 hours
Information Source:	Aircraft Accident Report Form submitted by the commander

Synopsis

A student undergoing Instrument Rating Training was attempting a simulated engine-out touch-and-go. The landing gear was not lowered and the aircraft landed gear-up.

History of the flight

The purpose of the flight was Instrument Rating Training. Part of the training detail involved the student performing a low approach and go-around, followed by a circuit with a touch-and-go. The whole exercise was to be flown with one engine throttled back to simulate an engine failure. During the go-around the gear unsafe warning sounded and the instructor attempted to silence it by adjusting the throttle lever position on the throttled-back engine.

The student recalled making the downwind checks. During the turn onto the base leg the instructor checked that the mixtures were rich, the propeller levers were fully forward and 'three greens' were showing. There were patches of sunlight in the cockpit and the instructor later considered that the landing gear indication lights might have appeared to have been illuminated when they were not. The aircraft was cleared to perform a touch-and-go and no final call was made. The student flared the aircraft and shortly thereafter the propellers struck the runway. The aircraft settled onto its belly and came to a stop on the runway centreline. None of the occupants recalled hearing the gear unsafe warning during the approach or landing.

The instructor concluded that the pre-landing checks had not been performed adequately and consequently the landing gear was not selected down.

ACCIDENT

Aircraft Type and Registration:	Reims Cessna F152, G-BLWV
No & Type of Engines:	1 Lycoming O-235-L2C piston engine
Year of Manufacture:	1981
Date & Time (UTC):	10 October 2009 at 1000 hrs
Location:	Hawley Lakes, Hampshire
Type of Flight:	Training
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 (Minor) Passengers - N/A
Nature of Damage:	Aircraft damaged beyond economic repair
Commander's Licence:	Student pilot
Commander's Age:	38 years
Commander's Flying Experience:	29 hours (of which 29 were on type) Last 90 days - 13 hours Last 28 days - 4 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

Whilst on the downwind leg of a solo circuit, the engine rapidly lost power. The student pilot was unable to restore power and conducted a forced landing on an area of heathland. The aircraft struck trees during the landing and was severely damaged, but the pilot escaped with minor injuries and was able to vacate the aircraft unaided.

History of the flight

The student pilot, with one hour of solo time, had just completed five dual circuits with an instructor and had been briefed to fly up to a further five circuits, solo. On the downwind leg of the second circuit, shortly after completing the downwind checks, the engine rapidly lost power. The pilot reported that he checked the mixture, carburettor heat, throttle, magnetos and master switch controls, all of which were correctly positioned. He closed and then fully opened the throttle, which produced a slight resurgence in power, but it was only short-lived.

The pilot declared a MAYDAY with ATC and attempted to achieve the best-glide speed before selecting a suitable landing area. He contemplated returning to the airfield but believed he was too far away and was concerned that the approach would have required two descending turns, with an increased risk of stalling and entering a spin. He chose instead an open area of heathland ahead. He overshot the chosen landing site because the aircraft was too fast and too high and continued towards a second area of open ground that he had identified. The two areas were separated by a narrow gap between trees. As he attempted to fly through the gap, the aircraft collided with the trees, which brought it rapidly to a stop.

Although the aircraft was severely damaged, the cockpit area remained intact and the pilot was able to release his seatbelt. He selected the master switch, magnetos and fuel switch to OFF before vacating the aircraft through his door.

Comments

At the time of writing the aircraft's operator had not been able to determine positively the cause of the loss of engine power. If any information subsequently becomes available it will be published in an addendum to this bulletin.

The student pilot was faced with a highly demanding situation at a very early stage of his training. He considered that the successful outcome was, in part, due to the advice he had received from his instructors regarding the hazards of attempting turns at low level after an engine failure and the importance of always flying the aircraft.

ACCIDENT

Aircraft Type and Registration:	Spitfire Mk 26, G-CEPL (80% scale kit-built)
No & Type of Engines:	1 Jabiru 5100A eight cylinder piston engine
Year of Manufacture:	2007
Date & Time (UTC):	19 July 2009 at 1107 hrs
Location:	Knoke Hall Farm, Bulphan, Essex
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 (Minor) Passengers - N/A
Nature of Damage:	Left wing main and rear spars skin rippled; right landing gear leg failed, propeller blades broken; engine seized
Commander's Licence:	Private Pilot's Licence
Commander's Age:	56 years
Commander's Flying Experience:	2,941 hours (of which 0 were on type) Last 90 days - 3 hours Last 28 days - 0 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot, information supplied by the LAA based on its investigation of the accident, including an engine strip report and AAIB follow-up inqurries to the engineers concerned.

Synopsis

During the kit-built aircraft's first test flight, following a two-year period of construction, the engine seriously overheated and failed, and the right landing gear failed to deploy for the landing. The engine failure resulted from an incorrect setting of the carburettors, resulting in a too lean fuel/air mixture. The landing gear failure to deploy occurred because the uplock pin could not be withdrawn, most probably due to it being a tight fit in the receptacle in the leg. This accident was investigated fully by the LAA, with particular emphasis on overall project management, during both the build stages and during the lead-up to the first flight, as well as the conduct of the flight itself. The outcome of their investigations, and lessons drawn from it, form the basis of a case study published in an article in the November 2009 issue of the LAA's "Safety Spot" magazine which can be found on the LAA's website.

Introduction

The accident occurred during the aircraft's first flight, and was being flown by a pilot who had no previous experience on type, but who had been authorised by the Light Aircraft Association (LAA) carry out the post-build test flights of the aircraft in question. This was subject to conditions and advice contained in a letter from the LAA Chief Engineer, who is experienced on the aircraft type. In particular, the pilot was instructed to familiarise himself with the operation of the landing gear system by, first, sitting in the cockpit with the aircraft on jacks and cycling the gear. Although the pilot reports that he had not had sight of this letter, he prepared for the flight over a period of some four months, drawing both on information supplied by the aircraft's designer/kit manufacturer in Australia, and on published reports and pilot's notes from two owners of the type. Particular attention was paid at this stage to the electrically-controlled constant-speed propeller, which was limited to a maximum of operating speed of 2,800 RPM (200 RPM below the engine's RPM limit), and to the operation of the retractable landing gear system.

Landing gear description

The landing gear design is both technically complex and possessed of an unusually complicated operating logic. Each main leg is operated by its own independent retraction and extension system, incorporating an electric motor, to provide the necessary power, together with its own entirely separate set of controls in the cockpit, indicators, and mechanical uplocks and downlocks. The LEFT and RIGHT landing gear controls in the cockpit were arranged side by side and, with appropriate dexterity, may be operated simultaneously to effect a synchronised retraction or extension of the landing gear legs:

The controls themselves comprise, for each leg:

- A toggle switch, used to set the direction of rotation of the actuating motor, to cycle the gear up or down as required. This switch does not, by itself, direct power to the motor.

- A selector lever which, when moved into the fully forward position, operates a mechanical linkage that moves a lock pin into engagement with the leg, to lock it into either the UP or the DOWN position, depending on the leg's physical position when the selector lever is pushed forward. When pulled progressively back, this lever firstly disengages the mechanical lock, allowing the gear to move, and when it reaches the fully aft position, it activates a microswitch. This directs electrical power to the actuating motor via the UP/DOWN selector switch described above, to drive the leg to the selected position. Once this has been achieved, the selector lever is returned to the fully forward position, de-activating the motor and re-engaging the mechanical lock to maintain the leg safely in the selected position.

- An orange light illuminates when the leg is in transit, and a green indicator illuminates when the leg is locked down.

- A mechanical indicator on each wing, visible from the cockpit, provides visual indication of the landing gear's state when retracted.

- A mechanical emergency disconnect mechanism, operated from the cockpit, physically disconnects the landing gear leg from its retraction motor, allowing it to free-fall, provided the selector lever is pulled back sufficiently to withdraw the mechanical lock-pin.

The pilot was given a functional demonstration of the retraction cycle with the aircraft on jacks during a visit to the aircraft's home base airfield some two months before the accident flight. However, he did not actually sit in the aircraft and cycle the gear himself at this time, nor did he do so at any other time prior to the test flight. During this demonstration, the left landing gear would not extend. It is understood that remedial work, involving re-reaming of the lock pin receptacle, was subsequently carried out. During the course of this visit, the pilot was able to familiarise himself with the aircraft's ground handling by taxiing it and carrying out high-speed runs on the runway. During these tests, he noted that the aircraft accelerated well (without takeoff flap selected), but that the wheel brakes were rather ineffective. Work was subsequently carried out by the owner to remedy this. The pilot also reports that, following these ground tests, it was found that the propeller had not been achieving a fully-fine pitch setting, and it was adjusted accordingly.

History of the flight

On the day before the first flight, the pilot met the owner to review the aircraft's documentation and to discuss the weight and balance schedule. The outcome of this was that he decided to carry 20 kg of ballast immediately aft of the pilot's seat; the aircraft is designed to accommodate a passenger. The flight reference cards were also amended at this time, to take account of a recently promulgated reduction in flap limiting speed from 99 kt to 80 kt.

Prior to the initial test flight, the pilot went through a period of more intensive cockpit familiarisation with the assistance of the owner, with particular attention being paid to the flap controls and indicator positions, the engine controls and associated instruments, radio fit and operation, the propeller speed control, and the landing gear operating switches, levers, lights and the emergency disconnect system. The stall warning system was only partially installed at this stage, and its wiring was taped up and securely out of the way on the left side of the cockpit floor.

Following an uneventful engine start and warm-up, full-power engine checks were conducted (with two people holding down the tail), during which manual carburettor heat and magneto checks were carried out at various power settings (with minimal 'RPM drops' being noted in each case) and the aircraft was taxied onto the airfield. A high-speed run was then carried out along Runway 25, with 10° of flap selected, during which the aircraft accelerated well and a tendency to swing was easily contained with use of rudder. Afterwards, the pilot taxied back for a review of some minor issues that had become apparent, including the positioning of the propeller fully-fine pitch indicator light, which was outside the pilot's normal line of sight. None of these items were judged to be of sufficient importance to require postponement of the test flight and, after restarting the engine, the aircraft was taxied to the holding point for Runway 25, where a further power check at 1,500 RPM was carried out; nothing abnormal was noted. As part of the pre-takeoff checks, the engine cowl flap was set to OPEN, the electrical carburettor heat was set to 2, 10° of flap were selected, the landing gear switches were pre-selected to UP, and the pilot states that he set the propeller speed to 2,800 RPM in 'auto' mode[1]. After an uneventful

Footnote

[1] In the LAA Safety Spot article covering this event, it is stated that the pilot set the propeller control to MANUAL.

takeoff, the engine temperatures and pressures were checked, and found to be within limits, and the aircraft climbed at 75 kt to 300ft, when the flaps were retracted, the carburettor heat setting was reduced to 1, and the climb speed increased to 90 kt.

Full power was not used to takeoff, but the rate of climb was still well below that expected and, as the aircraft passed 500 ft, power was increased with the propeller control still set to 2,800 RPM. A climbing turn was then initiated towards the north and, with the aircraft still climbing at 90 kt, and mindful of the gear limiting speed of 110 kt, the landing gear was selected up by pulling both landing gear selector levers fully back. The orange 'gear in transit' light for each leg illuminated as the legs retracted, and the right leg mechanical indicator showed UP, followed shortly afterwards by the left. Both landing gear selector levers were returned to the forward position, both transit lights went out, and the levers were then pushed gently home to engage the uplocks.

After climbing downwind to an altitude of 2,000 ft over a distance of some 5 km, the aircraft was turned back towards the airfield overhead and power was reduced. This power reduction resulted in an immediate reduction in propeller speed to 2,400 RPM. The propeller control was then set to maintain 2,400 RPM, with 20 inches manifold pressure but, with the aircraft in a level attitude at an airspeed of 110 kt, the pilot found that the altitude could not be maintained. Manifold pressure was therefore increased to 24 inches, but this caused the propeller speed to exceed 3,000 RPM. The power was reduced immediately to limit the propeller speed to 2,800 RPM. A series of medium bank turns was then flown over the airfield with the aircraft in this condition, during which its handling was assessed.

At about this stage, fumes began to enter the cockpit via the fresh air vents, and light smoke was seen emanating from the left bank of exhausts stubs. The vents were immediately repositioned in an effort to limit further entry of fumes, engine power was reduced, and the aircraft turned away from the overhead in preparation for a let-down to the north of the airfield. Manual carburettor heat was applied at this time, and the pilot considered shutting down the engine. He rejected this course of action in light of the unknown flight characteristics of the aircraft during the approachand instead, adopted a low power setting.

The landing gear was released by selecting the two switches to DOWN and pulling back on both selector levers. The right gear deployed correctly into the down position and a green light obtained, but the left selector lever was reluctant to move fully aft and the left gear 'in transit' orange light remained illuminated. By this stage, a considerable amount of smoke was entering the cockpit from the exhaust stubs, so the pilot closed the throttle fully and opened the canopy. Thirty degrees of flap was selected and confirmed, the propeller speed was reset to 2,800 RPM in auto mode, and the pilot's shoulder straps were tightened. A further attempt to lower the left gear was made by pulling its selector fully back, recycling its selector switch and, finally, by pulling the its emergency-disconnect toggle but the gear remained up.

The pilot briefly considered retracting the right leg to allow for a 'belly' landing, but he immediately rejected this option because he found flying the aircraft under increasingly difficult circumstances, with smoke continuing to enter the cockpit, quite demanding. A turn on to base leg was initiated at a height of 1,000 ft, approximately 1 km from Runway 25 threshold, but it quickly became apparent that the rate of descent was too great to enable the aircraft to reach the airfield. A judicious increase of throttle produced a temporary power increase but the engine then failed completely; the pilot turned both magnetos off.

Two potentially viable landing fields were identified to the east of the airfield: one, adjacent to the airfield and separated from it by a main road, had a crop of mature standing corn in rows running across the line of flight; the other was closer, and appeared to be mix of soft earth and stubble. The aircraft had descended to a height of about 500 ft at this time, which appeared initially to be too high to permit landing in the nearer field. However, after making a positioning turn to the right and lowering the nose to maintain a 60 kt minimum airspeed, followed by a turn back to the left, the aircraft arrived over the landing spot, into wind, just as the landing flare was initiated. A gentle touchdown was made on the extended right landing gear, and the aircraft tracked gently to the right as the left wing descended and made contact with the ground. At this point, it yawed rapidly left and then slid sideways to the right about 20 metres before coming to rest with the right gear collapsed. The electrical system and fuel cock were turned off, and the pilot vacated the aircraft unaided, having suffered a blow to his left elbow from the cockpit wall and strained neck and shoulder muscles on his right side. The flight lasted just seven minutes.

The pilot was of the opinion that his lack of serious injury was attributable to the combination of low ground speed at touchdown, due to a 15 kt headwind, use of 30° flap, the fine pitch setting of the propeller and the softness of the ground; this had been ploughed the previous day. He commented that the four-point harness had been very effective in restraining him during the landing. Afterwards, he observed that each of the propeller blades had fractured, confirming his recollection that the propeller had continued to rotate until touchdown, and he also noted a great deal of oil on the lower fuselage and around the tailwheel, and signs of burning in the left exhaust stubs.

Observations

The pilot offered the following observations about the flight:

- The propeller pitch appeared never to have moved out of the fully-fine position, but the indicator light which would have shown this condition could be seen only by "ducking" one's head down in the cockpit to obtain line-of-sight. He felt that it would have been more helpful to him had this light been within his normal field view in the cockpit. He also commented that, with hindsight, it might have been possible to restore correct propeller function and reduce its speed by pulling the circuit breaker, setting the propeller control to manual, re-setting the breaker, and readjusting the propeller speed setting.

- Operation of the landing gear actuating motor required the associated selector lever to be pulled fully aft, otherwise it would not engage the microswitch that activates the retraction/extension system.

- The positioning of the fuel cock on the cockpit floor immediately in front of the control column, and its design which incorporated a central knob that had to be pulled whilst the cock was twisted through 90°, was such as to make it practically impossible to operate in an emergency situation such as that which he encountered.

- Because the aircraft's systems were dependant on an electrical supply, and the flaps had a further two stages available if required (40° and 59°), the battery master was not switched off until after the landing.

- With regard to the engine failure, the pilot stated, "at no point in the flight was the engine speed allowed to approach 3,300 RPM, this being the maximum rated speed for a fixed propeller installation."[2]

Technical investigation

The engine was strip examined at the behest of the aircraft's insurer, and the accident was also the subject of wider investigation by the LAA with a view to promulgating lessons learned through the medium of its 'Safety Spot' publication.

A preliminary inspection of the engine in situ revealed that, whilst it had been installed to a high standard overall, each of the cylinder head temperature (CHT) probes had been fitted under the top cylinder head bolt, instead of beneath the spark plugs as recommended by the manufacturer. It was also noted that no exhaust gas temperature (EGT) or Lambda (fuel-air ratio) sensor had been installed.

After removal of the engine, 4.75 pints of oil were drained from the sump. A preparatory external examination revealed that both front crankcase clamping nuts, and a No 6 cylinder head nut, had split. The No 4 cylinder was missing a nut which was also presumed to have split and fallen off. Removal of the rocker covers released a strong smell of burnt oil, suggesting that the engine had been running very hot.

Footnote

[2] The maximum rated speed for the engine is quoted as 3,000 RPM

Bulk dismantling of the engine revealed the following:

- The No 8 cylinder head, piston, and cylinder were undamaged and functional.

- The Nos 4 and 6 cylinder exhaust valve seats had migrated clear of their seats in the cylinder heads, the pistons were burned, and aluminium deposits from the pistons were evident on the cylinder walls.

- The No 2 cylinder head was apparently undamaged, but there was a large hole in the piston crown and evidence of heat-seizure on the cylinder wall.

- The No 7 cylinder head was apparently undamaged, but evidence of heat-seizure of the piston was apparent on the cylinder wall, and the little end was abnormally tight.

- The No 5 cylinder inlet valve pushrod was dislocated from its rocker arm, but the cylinder head and valves were apparently undamaged. Evidence of heat-seizure was present on the cylinder wall.

- The No 3 cylinder head was burned virtually clean of carbon deposits and the piston showed signs of detonation and heat seizure, with corresponding indications on the cylinder wall.

- The No 1 cylinder head was similarly burned clean of carbon deposits and the piston crown was burned through over a part of its circumference, with corresponding overheat damage and aluminium deposits evident on the cylinder wall.

It was evident the engine failure had been caused by detonation of the mixture and consequential overheating of the engine, resulting in a progressive loss of power due to a combination of piston burn-through and to burning/dislocation of valves seats. This had been exacerbated by power absorption and further generation of heat associated caused by the partial seizure of pistons in their cylinders.

It was concluded that a number of factors potentially caused and/or contributed to the detonation and overheating, including:

- A lean mixture jet and needle set-up in the carburettors, which appeared to be the 'as delivered' setting from the factory, suitable for a fixed pitch propeller sized to give an operating speed range of 2,500 to 3,000 RPM, with a normal cruise speed in the range 2,700 to 2,800 RPM
- The installation of a variable pitch propeller. Had this operated at a more coarse than optimal pitch setting during the flight, an attendant loading of the engine at relatively low speed may have occurred
- The installation of a free-flow extractor exhaust system, which requires a richer mixture setting for correct combustion than a normal exhaust system

Effective monitoring of engine temperatures during both the accident flight and the preceding engine runs and taxi tests was undoubtedly compromised by incorrect installation of the CHT sensors beneath cylinder head bolts, instead of beneath the spark plugs as recommended by the engine manufacturer. Comparative flight tests were carried out subsequently by the engineer who conducted the strip examination, using an aircraft fitted with a six-cylinder Jabiru engine. One of its CHT sensors was relocated to beneath a cylinder head nut, to permit direct comparison with the output from a correctly installed sensor. The incorrectly sited sensor exhibited significant thermal lag and reduced temperature indications compared with the correctly installed sensor. Specifically, the temperature reading from the incorrectly located sensor was only 20% of the reference value following engine start, rising to 50% once warm-up was complete. During takeoff, as a cooling flow through the engine cowl became established, this reading reduced to 16%, and remained at about 16% of the reference value thereafter during the climb and in cruising flight. Based on this data, there is little doubt that the CHT gauge on G-CEPL was so grossly under-reading as to render it useless, a problem that was compounded by the absence of any alternative (EGT) temperature instrumentation.

As regards the indications of an excessively lean mixture, the baseline fuel-air ratio delivered by the Bing "constant depression" type carburettors installed on this engine, will be determined by a combination of:

- the jets sizes installed
- the profile of the metering needle (ie the type of needle)
- the setting of the metering needle in its carrier, ie, which notch it is set to, and the position of its adjustment screw
- the level of fuel in the float chamber, determined by the shut-off setting of the float valve

In addition to these setting-up variations, any induction air leaks and leaks at the cylinder head-to-barrel seals will tend to lean the mixture. Also, different exhaust systems will demand different mixtures, the more free-flowing extractor systems, in particular, requiring a richer mixture than systems producing more back-pressure.

The constant depression-type carburettor is designed to maintain an optimal mixture throughout the engine's operating range by varying the throat geometry to match the engine's operating condition, and is achieved by means of a choke barrel that descends into the choke tube, progressively obstructing it. A tapered metering needle, attached to the base of the choke barrel, moves up and down within the main jet so as to adjust the effective jet size to match the throat area at any given instant. The top of the choke barrel is mounted on the underside of a diaphragm-sealed piston, which moves inside a sealed chamber against a light spring that biases the assembly downwards, towards the restricted throat position and reduced jet area setting. A reduction in pressure above the piston, caused by increasing depression downstream of the throat as the throttle is opened to demand more power, creates a differential pressure across the piston causing it to lift upwards against the bias spring, increasing the throat area and hence the mass flow rate of air through the carburettor. This lifting of the metering needle, increases the effective jet size to match the increased mass-flow of air, maintaining the correct fuel/air ratio. The lower half of the piston chamber is ported to atmospheric pressure which amongst other things, provides altitude compensation.

In practice, matching the carburettor's operating characteristics to actual engine demand requires knowledge and experience, and careful consideration of the loading environment which the engine will encounter in service, in particular, its propeller characteristics. If the jet sizes and the profile of the metering needle and/or its setting are not correctly matched to these characteristics, and especially if the engine is operated under high load at speeds below that for which the needle and jet set-up has been optimised, the engine will run lean with a corresponding risk of overheat damage. The operation and setting up of these carburettors is covered at length in a series of Service Bulletins from the engine manufacturer, issued initially in 2004 and more recently updated as Service Bulletin JSB 018-2 dated 7 May 2009, in which the importance of setting the carburettor's mixture characteristics to match propeller loading is stressed. The setting-up procedures are covered in some detail.

The reason for the left landing gear's failure to extend was not positively established, but the symptoms, including its failure to free-fall after disconnection of its drive motor, imply a failure of the uplock pin to withdraw.

Conclusion

This accident was investigated fully by the LAA, with particular emphasis on overall project management, during both the build stages and during the lead-up to the first flight, as well as the conduct of the flight itself. The outcome of their investigations, and lessons drawn from it, form the basis of a case study published in an article in the November 2009 issue of the LAA's "Safety Spot" magazine (www.lightaircraftassociation.co.uk/Magazine/Nov%2009/Safety_Spot_Nov09.pdf).

ACCIDENT

Aircraft Type and Registration:	Zenair CH 701 STOL, G-BRDB
No & Type of Engines:	1 Rotax 912-UL piston engine
Year of Manufacture:	2003
Date & Time (UTC):	25 October 2009 at 1500 hrs
Location:	Benington Airstrip, Stevenage, Hertfordshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Propeller, cowling, engine, fuselage and wing
Commander's Licence:	Private Pilot's Licence
Commander's Age:	75 years
Commander's Flying Experience:	452 hours (of which 209 were on type) Last 90 days - 2 hours Last 28 days - 1 hour
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The pilot made an approach to Runway 24 at Benington Airstrip but, due to the low angle of the sun and rain on the windscreen affecting his vision, he executed a go-around and made an approach to Runway 06. This approach was at the correct airspeed but was higher than normal and downwind. The aircraft touched down deep into the grass runway and overran the end of the runway coming to rest on its nose in a ditch. The pilot was uninjured and there was no fire.

History of the flight

The pilot had decided to carry out an engine oil change on his aircraft. In order to ensure that the oil was at the proper temperature, he carried out a short local flight. The aircraft was located at Benington Airstrip which has a grass runway orientated 06/24, 460 m in length and approximately 18 m wide. He departed from Runway 24 with a surface wind which he estimated as 240°/10 kt.

The pilot flew in the local area for some ten minutes before returning to Benington. Close to the airstrip and prior to the approach, he flew through a small rain shower before joining straight in for Runway 24. On the final approach, the combination of the rain on the windscreen and the low angle of the sun made it difficult to see the runway. The pilot carried out a go-around and positioned the aircraft for an approach to Runway 06, which had the same declared runway length as Runway 24. He stabilised the approach speed at 45 kt but was a little higher than normal on the approach and also aware that this time there was a tailwind.

The aircraft touched down deeper into the runway than usual and, despite the application of the brakes, the aircraft overran the end of the runway at low speed. The nosewheel dropped into a ditch and the aircraft pitched onto its nose. The pilot was able to exit the aircraft uninjured and, with the help of others at the airstrip, recovered the aircraft from the ditch.

The pilot considered that the cause of the accident was that he had touched down too far along the runway for the conditions and should have gone around and made another approach.

ACCIDENT

Aircraft Type and Registration:	Robinson R44 Raven, G-CDXB
No & Type of Engines:	1 Lycoming O-540-F1B5 piston engine
Year of Manufacture:	2006
Date & Time (UTC):	7 October 2009 at 1132 hrs
Location:	Culter Helipad, Aberdeenshire
Type of Flight:	Training
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 (Minor) Passengers - N/A
Nature of Damage:	Aircraft damaged beyond economic repair
Commander's Licence:	Private Pilot's Licence[1]
Commander's Age:	39 years
Commander's Flying Experience:	220 hours (of which 106 were on type) Last 90 days - 19 hours Last 28 days - 10 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

During the after-start checks the aircraft became unexpectedly airborne. This was probably a result of the collective lever being raised excessively, or the throttle being set too high, as part of completing the low rotor RPM check. The aircraft landed again on its right skid before rolling on its side.

History of the flight

The pilot was undertaking a refresher course to renew his type rating on the R44, his previous rating having expired the month before. He was due to undertake a training flight as part of this course and had been briefed by his instructor to start the aircraft on his own after which the instructor would join him. The aircraft was started and after allowing some time for the engine to warm up, the instructor was approaching the aircraft when it suddenly became airborne. The right skid then contacted the ground and the aircraft rolled onto its right side. The pilot isolated the fuel and was assisted out of the aircraft with minor injuries.

Parts of the main rotor were found up to 90 metres from the aircraft but there were no injuries to anyone on the ground.

Footnote

1 The 'commander' details in this section refer to the pilot on board at the time of the accident; not the instructor.

Post-accident inspection

The training organisation carried out a post-accident inspection of the aircraft and reported that the governor was off, collective friction was off but cyclic friction on and the hydraulic switch was on.

Analysis

If the switches were undisturbed as a result of the accident, it would appear, from the post-accident inspection, that the after-start checklist had not been completed. For the aircraft to have become airborne, it is most likely that the collective had been raised. If this was a deliberate action, the check which calls for this to be done only calls for a small movement of the lever, just sufficient to check the low rotor RPM warning horn and light. It is possible that either the lever was inadvertently raised excessively or that, with the governor switched off, the rotor RPM had been set excessively high at the point the lever was raised.

Once the aircraft became airborne, the pilot would have had additional difficulty in trying to control it, both as a result of surprise and the fact that the cyclic friction was still applied. This is likely to have contributed to the subsequent loss of control leading to the aircraft rolling over.

ACCIDENT

Aircraft Type and Registration:	Robinson R44 Raven II, G-TIMC
No & Type of Engines:	1 Lycoming IO-540-AE1A5 piston engine
Year of Manufacture:	2006
Date & Time (UTC):	27 September 2009 at 1410 hrs
Location:	Barnsdale Hotel, near Rutland Water, Rutland
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to tail boom and right side of fuselage
Commander's Licence:	Private Pilot's Licence
Commander's Age:	44 years
Commander's Flying Experience:	162 hours (of which 65 were on type) Last 90 days - 10 hours Last 28 days - 2 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

During takeoff the helicopter developed a nose-up and right-skid-low attitude. The pilot compensated with the cyclic control and lowered the collective lever. The helicopter touched down, bounced, and came to rest at 90° to its original starting position. The pilot checked the controls but no problems were evident. The landing site, which was unlicensed, was constructed of concrete 'waffle-type' paving stones. The pilot believed that the rear shoe of the right skid had become snagged in the grooves in the surface of the landing site.

ACCIDENT

Aircraft Type and Registration:	Rotorway Executive 162F, G-JONG
No & Type of Engines:	1 Rotorway RI 162F piston engine
Year of Manufacture:	2004
Date & Time (UTC):	14 June 2009 at 1845 hrs
Location:	1.5 miles east of Bullington Cross on A303, Hampshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 (Minor) Passengers - N/A
Nature of Damage:	Tail boom severed, damage to main rotors, landing gear and body panels
Commander's Licence:	Private Pilot's Licence (Helicopters)
Commander's Age:	52 years
Commander's Flying Experience:	1,471 hours (of which 43 were on type) Last 90 days - 19 hours Last 28 days - 5 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot, an AAIB strip examination of the engine and subsequent metallurgical examination of engine components

Synopsis

The helicopter was in flight when the engine stopped suddenly and without any warning. During the subsequent forced landing onto soft ground, the helicopter pitched forward, the main rotor blades struck the ground, and it rolled on to its right side.

It was established that the cast alumimium gear which drives the camshaft within the engine was of poor manufactured quality, resulting in the failure of several gear teeth. This led to the de-synchronisation of the camshaft with the crankshaft, allowing the connecting rods to hit the camshaft, breaking it into four sections.

History of the flight

After completing a daily inspection 'A' check, during which nothing abnormal was found, the pilot made an uneventful short flight from his home base at Barton Ashes to Popham, where the helicopter was refuelled to full tanks. He subsequently conducted an uneventful local flight before landing back at Popham, where again the helicopter was shut down. At approximately 1930 hrs, after carrying out a normal pre-flight inspection and an uneventful engine start, run-up, and hover checks, the aircraft departed Popham for the return flight to Barton Ashes.

Whilst in the cruise at an altitude of 1,800 ft, 5 nm west of Popham, with the engine running apparently well and displaying normal indications, it stopped suddenly and without warning. The pilot immediately entered autorotation, reduced airspeed to 65 mph, and selected a field for landing which had no standing crop. A landing flare was initiated approximately 30 ft above the ground at an airspeed by this stage reduced to around 30 mph and a straight and level run-on touch-down was executed. After sliding straight for approximately 2-3 skid lengths, the helicopter pitched forward and the main rotor struck the surface, causing the helicopter to skew rapidly to the left and roll onto its right side.

The pilot was restrained by his seat harness throughout the impact sequence. After releasing it, he fell into the right side of cockpit, the aircraft having come to rest on its right side. He was, however, able to extricate himself and, after retrieving his spectacles, climb out through the left side cockpit door, turning off the switches on the overhead panel as he did so. There was no fire, although fuel was leaking from the tank filler caps.

Engine examination

Preliminary examination of the engine by Rotorway's UK agent, established that it would not turn freely and that, within the little movement of the crankshaft available, no corresponding movement of the valve gear could be detected. Subsequently, a bulk disassembly of the engine under the AAIB supervision established that the aluminium camshaft drive gear teeth were stripped over a segment comprising almost a quarter of its circumference. The camshaft had fractured at three separate locations along its length internal to the crankcase, and also at a fourth location, externally, in the accessory case, immediately behind the drive gear attachment flange. Figure 1 shows the fractured camshaft and partially stripped gear, with the camshaft fractures identified and numbered one to four for reference.

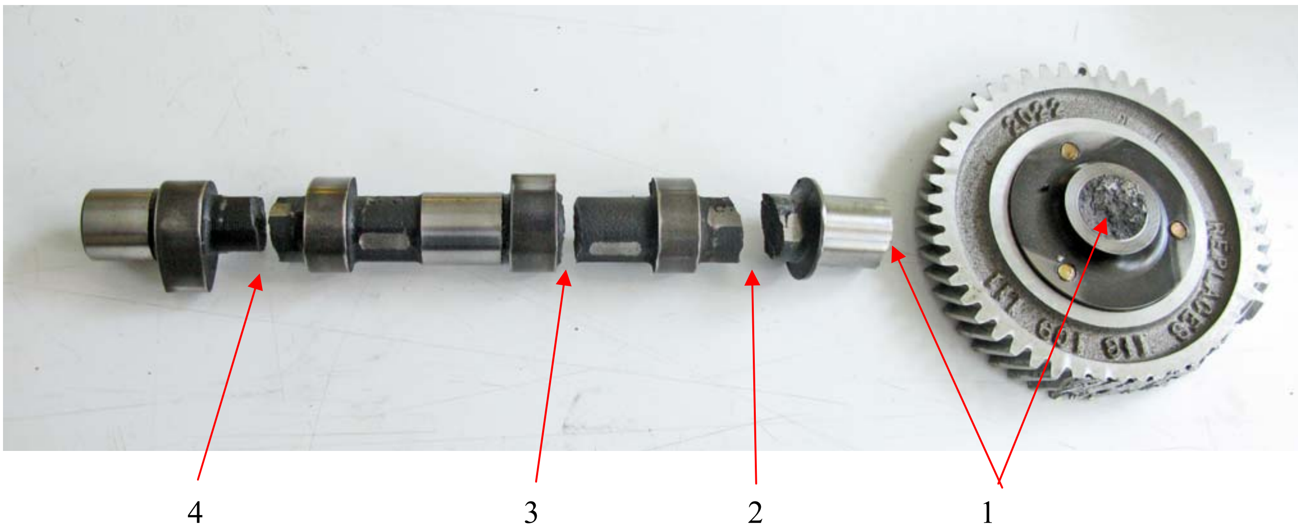

Figure 1

Camshaft fractures and gear failure

Fragments of broken gear teeth and shards of ground-up tooth material were scattered within the accessory case. The rest of the engine was undamaged and in good condition, and no evidence was found of any abnormality or failure except for minor secondary damage directly attributable to the camshaft fracture. Clean oil was present in liberal quantities internally throughout the engine, all bearings were in good condition, all valves and cam followers operated freely and the (steel) camshaft drive pinion was in good condition.

The camshaft, drive gear, and tooth fragments were taken to a specialist metallurgical laboratory where the fracture faces were subject to detailed visual and scanning electron microscopy. No evidence of fatigue cracking or any other mode of progressive failure was found either on the camshaft or the failed gear.[1] The aluminium gear was evidently a cast component that had been turned to final dimensions and then machined to produce the required tooth profiles. The quality of the casting was found to be exceptionally poor, exhibiting a very porous and open structure. Extensive voids and flaking were visible in several areas on the surface of the gear, both on the face of the gear rim and on the flanks and roots of some of the teeth.

Extensive porosity was also evident in the microstructure of two of the tooth fractures, indicating that these teeth were extremely weak and vulnerable to fracture. Also the drive flanks exhibited gross voiding and flaking, Figures 2 and 3 respectively. Despite these material defects, no evidence was found in the gear generally, of fatigue cracking or any other form of progressive failure, nor specifically in the tooth fractures that exhibited porosity and surface void defects. In summary, metallurgical examination of the camshaft and gear failed to identify any evidence of pre-existing or progressive fracture, but the poor quality of the casting would have weakened the teeth and pre-disposed them to fracture.

Upon completion of the metallurgical examination, the fractured camshaft was physically restored with adhesive permitting it to be relocated in its bearings in one half of the crankcase. This was in order to facilitate correlation of witness marks on the camshaft with the physical form and proximity of the crankshaft and connecting rods. This work was supplemented by 3-D CAD modelling of the crankshaft, camshaft, and connecting rods, which permitted an analysis of these marks, in terms of the rotational synchronisation between the camshaft and crankshaft/connecting rods, and the positions of gear tooth damage. The objective of this was to sequence the various camshaft and gear tooth failures.

Failure sequence analysis

Numerous bruise marks were evident on the camshaft at various locations along its length, consistent with it being struck by the connecting rods. The following was noted:

- Bruises were present that bridged fracture Nos 2 and 4, ie, these bruises were produced coincident with, or before, the associated fracture became physically separated.
- Bruises at positions on the camshaft beyond fracture No 2 (relative to the drive gear end) were at positions displaced slightly from their correct positions for an intact camshaft, and

Footnote

[1] Fatigue cracking in cast iron materials of the kind used for the camshaft does not always leave visable evidence, and the possibility that a fatigue crack at one or other of the camshaft fracture sites had precipitated the chain of failure could not be positively excluded on the metallurgical evidence alone.

Figure 2

Tooth fracture face, displaying extensive voiding (evidenced as bead-like features) where metal has solidified upon encountering a void

Figure 3

Flank of fractured tooth (separated piece re-positioned, showing porosity at the surface

were therefore produced after fracture No 2 had separated.

- One of the bruises that bridged fracture No 2 also produced significant smearing of the fracture edges, consistent with the strike that produced it having caused this fracture. The other bruises at this location, therefore, were produced prior to fracture.

The evidence above indicated clearly that fracture Nos 3 and 4 were secondary failures, occurring after fracture No 2, and that fracture No 2, at least, was caused directly by a connecting rod strike. Since a connecting rod strike will not occur whilst the camshaft and crankshaft are correctly synchronised, it follows that fracture Nos 2, 3 and 4 were all produced after synchronisation was lost, and that the primary failure was either the fracture at position No 1, or drive gear tooth failure(s).

Analysis of the various connecting rod strikes on and around fracture No 2 showed that several strikes at this location, including strikes on opposing sides of the camshaft, corresponded with positions of the gear where teeth were intact, ie, at positions where the gears

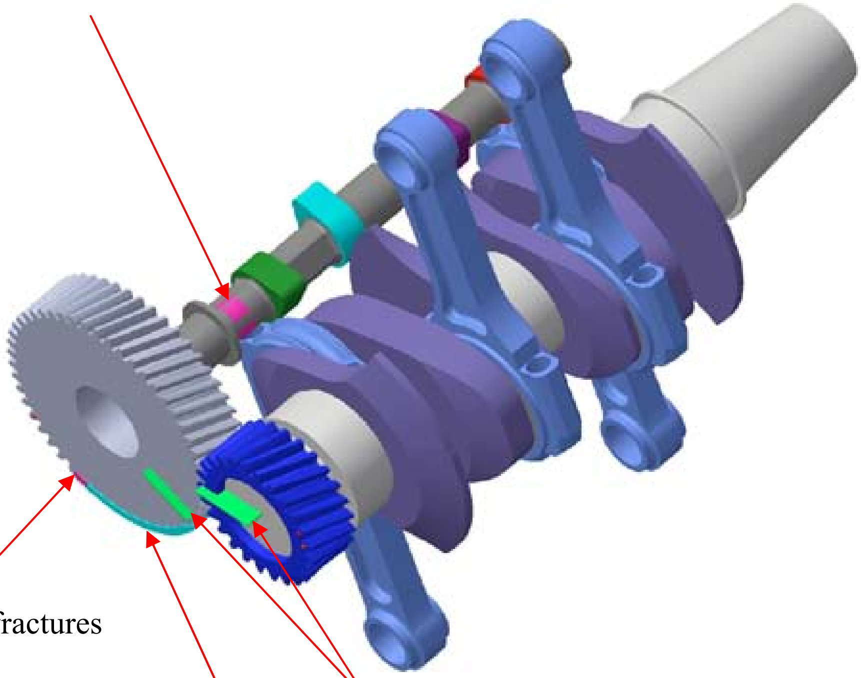

Figure 4

Typical example of connecting rod strike on the camshaft and associated loss of synchronisation

were in a viable state of mesh, albeit not synchronised. Figure 4 shows an example of once such contact. Given that a mechanical drive must have been present in the time interval between these strikes, in order for the cam lobes to have been turned against the reaction load imposed by the valve springs, it follows that all connecting rod strikes occurred before fracture No 1 occurred. Therefore, the initiating event must have been a gear tooth fracture.

As no evidence of fatigue, or any other mode of progressive fracture, was found at the initial tooth failure sites, it is considered most likely that the tooth failed spontaneously under normal in-service loading as result of an inherent weakness caused by material defects in the casting.

Safety action

Premature failures of the camshaft drive gear have occurred previously and are the subject of Mandatory Compliance Bulletin M-14, issued by the helicopter kit manufacturer on 2 January 1997, which states:

> *'In a few instances the cam gear in the engine has had teeth break off, causing engine failure. This gear, made of aluminium, has failed for various reasons: improper valve adjustments, sticky valves or excessive backlash between the cam gear and crankshaft gear.'*

The remedial action specified in this Bulletin was to reduce the service life of the gear from 500 hrs to 250 hrs. In this case, the gear failed at less than

100 hrs, apparently as a result of a manufacturing defect.

In addition, the manufacturer issued a Service Letter on 16 June 2005 which stated, in part, the following:

> *'Starting with engine number 6353, built in 1999, both of the timing gears have been made of steel. At approximately the same time, the steel gears were supplied for parts requests for compliance to the bulletins. With the experience of service, Rotorway International has raised the replacement time of the steel timing gears from 250 hours to 400 hours. Rotorway will continue to evaluate the serviceability of the timing gears for further increases in service life.'*

The UK agent for the kit manufacturer has advised that, since steel timing gears became available in 1999, there are very few Rotorway Exec, Exec 90 and Exec 162F helicopters flying with the aluminium gear fitted and that, as the remaining items achieve their 250 hour life, they will all be removed from service.

ACCIDENT

Aircraft Type and Registration:	Westland Bell 47G-3B-1, G-BFYI
No & Type of Engines:	1 Lycoming TVO-435-B1A piston engine
Year of Manufacture:	1965
Date & Time (UTC):	4 August 2009 at 1130 hrs
Location:	Bagby Airfield, North Yorkshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Tips of both tail rotor blades damaged
Commander's Licence:	Private Pilot's Licence
Commander's Age:	45 years
Commander's Flying Experience:	179 hours (of which 44 were on type) Last 90 days - 13 hours Last 28 days - 3 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The helicopter was lifted into the hover in a strong and gusting tailwind. It yawed rapidly to the right and, before a stable hover could be re-established, the tail rotor struck the ground. Due to significant vibration through the tail rotor control pedals, the pilot carried out a running landing on to a grass area and shut down the helicopter.

History of the flight

The pilot and his passenger had flown from Windemere to Bagby Airfield. The weather was good, with a strong surface wind at Bagby from 100° at 20 kt, gusting 30 kt. The pilot approached into wind and came to a normal hover before executing a turn to the right and hover-taxiing downwind to the refuelling point. He experienced no difficulties during the hover-taxi and, having landed facing the fuel pump, shut down G-BFYI. After refuelling the helicopter, he and his passenger visited the clubhouse for refreshments.

Before re-boarding the helicopter, the pilot considered the possible effects of the tailwind on his departure from the pump area. Given his uneventful downwind hover taxi to the fuel pump, he believed that conditions were within his personal limits and those of the helicopter. The pilot started the helicopter for the return flight to his home base and completed the normal checks. He lifted the helicopter into the hover and, when stable, initiated a sideways hover-taxi to the right. At this point, the wind seemed to catch the vertical tail surface of the helicopter and the nose yawed rapidly to the right. The pilot applied full left pedal, to try and control the yaw whilst applying more collective pitch to increase his height above the ground. At the same time, he attempted to maintain the helicopter in a level pitch attitude but, despite these actions, the tips of the tail rotor blades contacted the concrete surface of the parking area. As the helicopter's nose pointed into wind, the yaw stopped. The pilot felt a severe vibration through the tail rotor control pedals and carried out a running landing on to the grass area ahead and shut down the helicopter.

Pilot's Notes

The Pilot's Notes for the helicopter type contain the following information regarding windspeed:

> *'Operation Vs Allowable Wind*
>
> *Helicopter flight and landing operations can be safely accomplished with wind conditions up to 20 mph (32 kph) however this is not to be considered a limiting value as maximum operating wind velocities have not been established.'*

Analysis

The pilot considered that the cause of the accident was the strong and gusting wind acting on the vertical tail surface of the helicopter which resulted in it yawing to the right. The suddenness and rapid nature of the event surprised him and he was unable to control the yaw or maintain the tail rotor clear of the ground, despite using significant control inputs.

ACCIDENT

Aircraft Type and Registration:	RAF 2000 GTX-SE, G-CBCJ
No & Type of Engines:	1 Subaru EJ22 piston engine
Year of Manufacture:	2002
Date & Time (UTC):	9 October 2008 at 1755 hrs
Location:	2 nm north of Henstridge Airfield, Somerset
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 (Fatal) Passengers - N/A
Nature of Damage:	Destroyed
Commander's Licence:	Private Pilot's Licence (Gyroplanes)
Commander's Age:	57 years
Commander's Flying Experience:	Total hours unknown Gyroplane 146 hours (of which 146 were on type) Last 90 days - 5 hours Last 28 days - 5 hours
Information Source:	AAIB Field Investigation

Synopsis

During a descent at close to the never-exceed speed (V_{NE}) the gyroplane rotor struck the aircraft's propeller and rudder. An in-flight break up ensued and, during the impact that followed, the pilot received fatal injuries. No pre-existing defects on the aircraft were identified.

History of the flight

The pilot planned to fly the aircraft from Henstridge Airfield, Somerset to Little Rissington Airfield in Gloucestershire, for its Permit to Fly annual inspection, returning later that day. G-CBCJ departed Henstridge several hours later than intended and arrived at Little Rissington at about 1315 hrs. On completion of the annual inspection, the pilot refuelled the aircraft to full and departed Little Rissington at approximately 1607 hrs. He planned to fly at an altitude of 2,000 ft, at an IAS of 60 mph and expected to achieve a ground speed of 50 mph and a flight time to Henstridge of 87 minutes. Henstridge Airfield closed at 1800 hrs.

Another gyroplane, flown by Pilot B, had accompanied the aircraft on the inbound flight and flew in company with G-CBCJ back to Henstridge. Pilot B recalled that during the return flight the two gyroplanes were flying at an altitude of 2,500 ft and cruising at about 55-60 mph. This resulted in a ground speed of approximately 35 mph and he was concerned about their slow progress. Sunset was at 1730 hrs and Pilot B commented that, from about

1700 hrs, it became very cold and damp and, despite wearing gloves, his fingertips became numb.

Both aircraft were equipped with radios and the pilot of G-CBCJ transmitted all the radio calls, on behalf of both aircraft. Pilot B reported that everything seemed normal when they transferred from the Bristol Radar frequency to the Henstridge Radio frequency. Thereafter, he heard no further calls from the other pilot.

The flight proceeded without incident and, after passing the A303 (a trunk road orientated east-west) and approximately five nm north of Henstridge, G-CBCJ commenced a descent which Pilot B followed. It was about 1750 hrs and getting dark, with unlit ground features becoming indistinct. During the descent G-CBCJ accelerated to about 65 mph and Pilot B matched the descent and speed increase. Pilot B then slowed his aircraft slightly to take up a position astern of G-CBCJ to allow it to land at Henstridge Airfield first. Using G-CBCJ's tail light as a reference, Pilot B then accelerated to maintain his distance. In order to do so, Pilot B had to increase his IAS to 95 mph. Almost immediately, Pilot B became concerned that his airspeed was above the V_{NE} of 70 mph and reduced speed.

Pilot B attempted to call G-CBCJ on the Henstridge Radio frequency but received no reply. Approximately one nm further on he looked towards the airfield and checked his flight instruments before looking again towards where he expected to see G-CBCJ. He could not see the other gyroplane and, concerned that he may have caught up with it, he turned to the right and reduced speed. As he did so, he looked to his left and saw what he believed to be a white blade spiralling down in an eccentric circle at 60-120 rpm. He also recognised the colour of G-CBCJ's airframe and watched the aircraft descend until it reached the surface of the field below. He considered that it was too dark to conduct a safe field landing and continued on to Henstridge Airfield where he landed safely and contacted the emergency services.

Numerous witnesses around the village of Kington Magna reported hearing noises like misfiring or pinking, followed by what sounded like a very large backfire. The witnesses who were immediately below the flight path described seeing a gyroplane much lower and louder than normal, hearing a loud bang and seeing a cloud of debris fall from the sky. Several witnesses went immediately to the large field into which the aircraft had descended, arriving within minutes of the accident. The pilot had suffered fatal injuries.

A witness in the village of Buckhorn Weston, about 1 nm north of the accident site, reported seeing a pair of gyroplanes fly overhead. The witness was concerned that one was "swaying" from side to side. However, based on the witness's description, it appears this was not the accident gyroplane but the one flown by Pilot B. This witness described the accident gyroplane as flying straight and not giving cause for any concern.

Gyroplane description

The RAF 2000 is a kit-built, two-seat gyroplane powered by a 130 hp Subaru-carburetted engine driving a three-bladed 'Warp Drive' carbon fibre propeller. It is fitted with a two-bladed glass-fibre main rotor which rotates in an anti-clockwise direction when viewed from above. The side-by-side cockpit is fully enclosed although, following an earlier Mandatory Permit Directive (MPD 2006-013), the RAF 2000 is required to fly with the doors removed. The throttle is to the left of the pilot's thigh and the pilot's left hand is exposed to the airflow when it is on the throttle. The base of the rotor mast is fixed to a keel beam at the rear of which is attached the fin and rudder assembly, together with a small tail wheel.

Pitch and roll control is effected by means of a cyclic control stick which operates on the rotor head via a series of control rods; trim springs allow the control forces to be offset. A conventional rudder, operated by pedals connected via cables to the control surface, is used for yaw control.

The RAF 2000 type is not approved for night flying and G-CBCJ had neither cockpit lighting nor illuminated flight instruments. See Figure 1.

Figure 1
G-CBCJ cockpit

Maintenance records

G-CBCJ was constructed in 2002, and had completed 107 airframe hours and 108 engine hours, up to the day of the accident.

Its Permit to Fly, issued by the Light Aircraft Association (LAA), was effective until 9 October 2008. The purpose of the flight to Little Rissington had been to carry out an annual inspection as part the renewal of the Permit to Fly. This had been completed satisfactorily by an LAA Inspector and the Permit Flight Release Certificate signed. A flight test, which could be performed by the pilot/owner, was required as part of the renewal. This had not been completed on G-CBCJ at the time of the accident.

Wreckage and impact information

The gyroplane had struck the ground in an open area to the west of the village of Kington Magna. The impact was consistent with a near vertical descent, with no forward speed. However, there was evidence that the gyroplane had been on a southerly track. The impact occurred with the gyroplane in a nose-up attitude, resulting in the propeller and engine being buried in the soft ground. The tail boom and a portion of the fibreglass fin were found in the same field, approximately 50 m to the north. Further pieces of wreckage, comprising the remainder of the fin and the rudder, were spread along a trail, in a northerly direction from the main wreckage site, up to a distance of 600 m. The tail wheel was found approximately 100 m to the west of the main wreckage. Figure 2 shows the wreckage distribution.

Evidence from ground marks indicated that the rotor blades had not been rotating at impact. However, there was evidence along the length of the blades of multiple impacts with the propeller blades, together with paint transfer arising from impact with the fin and rudder. Reconstruction of the fin and rudder pieces recovered from the wreckage trail indicated that there had been three strikes from the main rotor blade. The first strike had been at the top of the fin/rudder, the second mid-way down, and the third at the base of the rudder, resulting in the detachment of the tailwheel and most of the keel beam. See Figure 3.

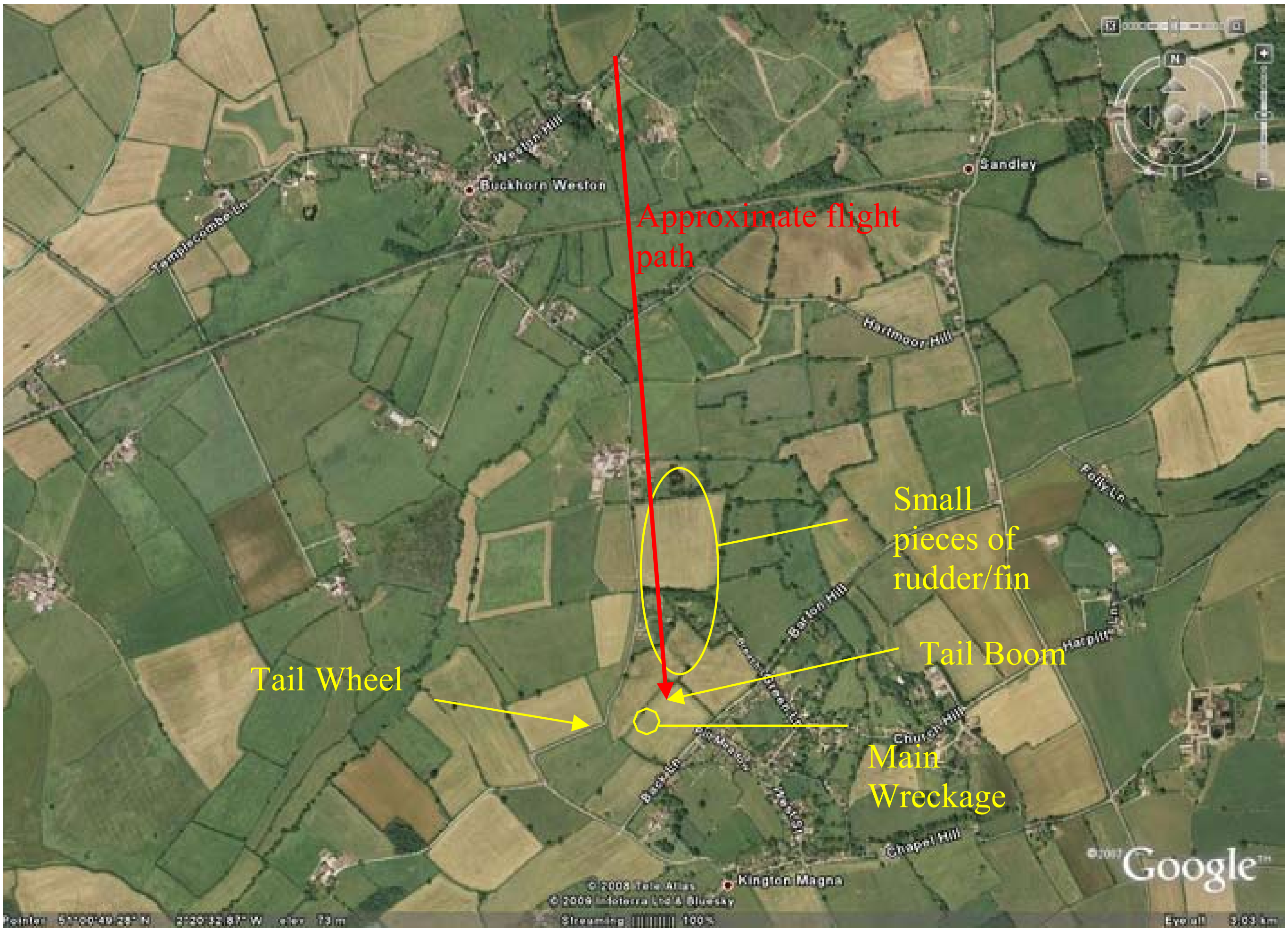

Figure 2

Wreckage distribution
(Copyright Google Earth ™ mapping service/Infoterra Ltd & Bluesky/Tele Atlas)

The gyroplane had been extensively damaged in the impact and the main wreckage was surrounded by pieces of the canopy; the doors had not been fitted. The fuel tank, located beneath the pilot's seat, had ruptured and there was a strong smell of fuel at the accident site.

All the propeller blades were found within the crater formed by the impact, although only one had remained attached to the hub. The propeller blades showed evidence of rotation and impact with the rotor blades and subsequent examination of the engine revealed no pre-impact mechanical damage. The carburettor heat air box on the top of the engine was in the HOT position.

An examination of the flying controls showed that there were no pre-impact disconnections and all the failures were consistent with the impact; the trims were in their mid positions.

Previous accidents

The report on the investigation into the fatal accident involving G-REBA, also a RAF 2000 GTX-SE, (see AAIB Bulletin 9/2007) showed similar damage to G-CBCJ, including:

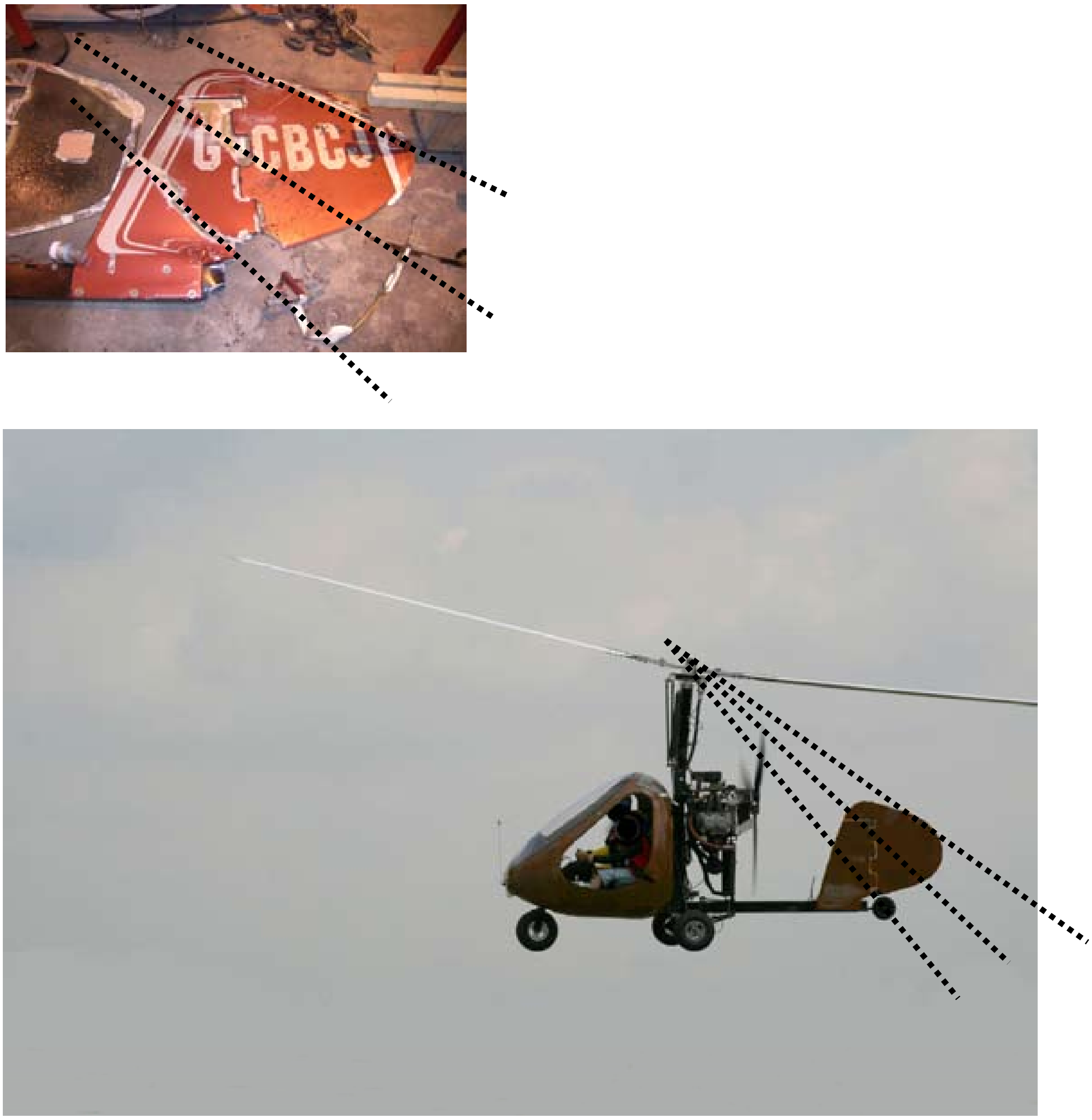

Figure 3

Illustration of the three strikes on the fin and rudder by the main rotor

> *'When the rudder and fin were reconstructed there was evidence that the tail section had been struck three times by the main rotor blades. The evidence consisted of a clean cut at the trailing edge of the top part of the fin; a shadow along the left side of the fin and an indentation along the rear wheel trailing arm.'*

Witnesses to that accident stated that the gyroplane was in steady flight and not executing any violent manoeuvres before:

> *'It then appeared to be caught in a crosswind, the rotor blades came together above the gyroplane and the engine cut out at about the same time.'*

Mandatory Permit Directive (MPD)

Following a series of fatal accidents involving gyroplanes, including two RAF 2000s, G-CBAG (see AAIB Bulletin 9/2003) and G-REBA, the UK CAA conducted flight tests on the RAF 2000.[1]

The tests revealed that, although the RAF 2000 manufacturers claimed a V_{NE} of 100 mph, at 70 mph natural turbulence caused a divergent phugoid which had a period of approximately five seconds and a time to double amplitude of approximately 10 seconds. Testing was curtailed after eight seconds to prevent excessive pitch attitudes being reached. Maintaining a constant pitch attitude ±4° at 70 mph was considered to be *'very difficult'*, requiring continual small (2mm) inputs to the cyclic.

At 80 mph the test pilot rated the handling qualities as six on the Cooper-Harper scale[2]; this is equivalent to:

> *'very objectionable but tolerable deficiencies. – Adequate performance requires extensive pilot compensation.'*

In the report the test pilot commented:

> *'Given poor visual cueing it would be extremely difficult for an inexperienced pilot to fly the aircraft at speeds in excess of 70 mph and momentary distractions to tune radios, IFF, operate trim wheels etc could lead to a large pitch excursion going unnoticed.'*

Following this a MPD 2006-013 was issued by the CAA on 1 December 2006 which, together with other restrictions, limited the RAF 2000's V_{NE} to 70 mph.

Pitch excursions are hazardous to gyroplanes for several reasons. The rotors on a gyroplane are constantly in autorotation and require a relative airflow up through the rotor to maintain Rotor RPM (N_R) As a gyroplane pitches nose-down, the angle of the relative airflow decreases thus reducing the N_R. In a severe case, the relative airflow could pass down, rather than up, through the rotor, causing it to slow rapidly. As the rotor relies on centrifugal force for its rigidity, the slower the N_R the more flexible the blades become, allowing the blades to flex to the point where they can strike the propeller or the tail.

The AAIB report on the accident involving G-REBA stated:

> *'Power pushover*
>
> *Whilst the numerical analysis of gyroplane pitch stability is relatively recent, the gyroplane community has long been aware of what it has termed the 'Power pushover'. This is commonly described as being due to the propeller thrust acting above the vertical CG of the gyroplane and tending to pitch the gyroplane nose down. In normal flight, the lift or rotor thrust developed by the main rotor blades opposes the propeller thrust and balances the nose down pitching moment. If the gyroplane is disturbed in pitch, either by turbulence or control input, this may result in a 'pushover' or 'bunt' manoeuvre. As the normal 'g' reduces, the rotor thrust also reduces proportionately allowing propeller thrust to become the dominant force. If the onset of the*

Footnote

[1] CAA Flight test report FTR12550P.

[2] The Cooper-Harper scale is a set of criteria used by test pilots to evaluate the handling qualities of aircraft. The scale ranges from 1 to 10, with 1 indicating the best handling characteristics and 10 the worst.

bunt manoeuvre is rapid, loss of rotor thrust is also rapid and with a high propeller thrust setting the propeller thrust causes the fuselage to pitch nose down and the tail to rise. If this situation occurs, the main rotor blades may flap back or if the pilot makes a large aft cyclic input to correct the situation, the blades are able to strike the tail surface and the propeller. It is notable that the Glasgow University research has found a strong coupling between pitching motion and rotorspeed, since reduced rotor speed adversely affects rotor disc stability.'

In 2008 the CAA approved a modification for the RAF 2000 that added a horizontal stabiliser to the aircraft. The test pilot reported[3] that, with this modification:

'The aircraft's longitudinal dynamic stability was markedly improved and was stable and compliant with Section T[4] up to 80 mph.'

G-CBCJ was not equipped with this horizontal stabiliser.

Pilot experience

The pilot was reported to have had considerable fixed-wing and flex-wing microlight experience. He had held a Private Pilot's Licence (Aeroplanes) (PPL(A)), which had lifetime validity, since 1994. He commenced gyroplane training in 1998 and flew approximately 50 hours before carrying out his first solo flight in March 2000. He completed the course and was issued with a Private Pilot's Licence (Gyroplanes) (PPL(G)), including a 'single engine' rating, on 21 June 2000, also with a lifetime validity. He flew another 50 hours up to July 2001.

The pilot temporarily ceased flying gyroplanes and restarted training in June 2007. This was recorded in a logbook which only contained his gyroplane flying. He completed a further 30 hours of flying instruction up to November 2007 and, following a break of three months, successfully revalidated his licence in May 2008. His instructor noted that he made satisfactory progress and experienced no particular problems during training. Subsequently, he conducted about nine hours of solo flying before the accident flight.

Of the pilot's total gyroplane flying experience, 60 hours were conducted outside the training environment and he had completed fewer than ten hours of solo flying in the previous seven years.

Medical

An aviation pathologist reported that:

'The autopsy examination did not reveal any evidence of significant pre-existing natural disease which could have caused or contributed to the accident. The pilot held a valid NPPL medical declaration. Toxicology revealed no evidence of drugs or alcohol being present.

While the pilot was wearing a reasonable degree of thermally protective clothing…. (The pilot) *was not wearing any gloves, and it is likely that* (the pilot's) *left hand in particular would have been subjected to a marked degree of convective cooling.'*

Footnote

[3] CAA FTR12746P.

[4] British Civil Airworthiness Requirements (BCAR) section T contains the minimum requirements and constitutes the basis for the issue of Permits to Fly for Light Gyroplanes.

The pathologist further commented:

> *'While it is unlikely to have been a direct factor in the causation of this accident, it is likely that the environmental conditions were such as to have caused cold discomfort of* (the pilot's) *hands which may have produced a source of distraction, and it is recommended that the need to dress appropriately for the anticipated weather conditions in aircraft that do not provide substantial environmental protection be publicised...'*

Weather

Met Form 214, the *UK Low-Level Spot Wind Chart*, for 1800 hrs on 9 October 2008, valid for flights between 1500 hrs and 2100 hrs, gave the latest forecast winds that would have been available before the aircraft departed from Little Rissington. The wind on the aircraft's route, at an altitude of 2,000 ft, was forecast to be from between 200° and 220° at 10 to 25 kt (11.5 to 28.5 mph).

An aftercast indicated that there was a region of high pressure over Northern France resulting in a light to moderate south-westerly gradient over southern England. The estimated surface visibility for the area of the accident was between 25 km and 45 km. High level cirrus cloud covered the region but there was little low level cloud and Pilot B did not recall encountering any during the return flight. The likely average wind for the route, at an altitude of 2,500 ft, was estimated to be 240° at 17 to 22 kt.

An automatic weather observation at 1750 hrs at Yeovilton, 12 nm west of the accident site, recorded a surface wind of 160°/03 kt, greater than 10 km visibility and no detected cloud. The surface temperature was 10°C and the dew point was 9°C.

From observations taken at other nearby airfields, generally the surface winds were less than 10 kt, visibility was 10 km or greater and there was no cloud below 3,000 ft agl.

Flight Planning

An A4 laminated pilot navigation log (plog), an A5 knee board and a CAA aeronautical chart marked with a route were recovered from the accident site. The route covered a return flight from Henstridge to Little Rissington. The return leg log indicated the following:

From	To	Distance	Ground Speed	Time
Little Rissington	N'Leach VRP	6.4	53	7
N'Leach VRP	Junction A417/A429	9.9	50	12
Junction A417/A429	Kemble	5.3	51	6
Kemble	Junction M4/A46	17.6	51	21
Junction M4/A46	Junction A4/A46	7.1	51	8
Junction A4/A46	EGHS	28.4	51	33

(selected columns displayed)

Safety Sense

The UK CAA publishes a series of General Aviation Safety Sense Leaflets. Safety Sense Leaflet 1, entitled *Good Airmanship Guide*, states:

> *'Plan to reach your destination at least one hour before sunset unless qualified and prepared for night flight…'*

Recorded data

There was no recorded primary radar coverage in the area of the accident, no operating transponder on the accident aircraft and its GPS unit was destroyed. The GPS equipment on Pilot B's gyroplane did not record speeds or position and time information from which average groundspeeds could be derived. The data that was available was restricted to the aircraft's ground track. This indicated that, generally, the planned route was followed with minor deviations adding a few track miles to the planned distance.

Although Pilot B stated that he was flying at 95 mph for a brief period, it was not possible to calculate an accurate speed for G-CBCJ during that phase of the flight.

Analysis

The evidence suggests that the pilot had planned the flight with an airspeed of 60 mph, a groundspeed of 50 mph and an airborne time of 87 minutes for the return flight to Henstridge. Leaving Little Rissington at 1607 hrs meant an ETA at Henstridge of 1734 hrs. This would have been four minutes after sunset and 26 minutes before official night flying, which begins 30 minutes after sunset. The forecast wind conditions, which were confirmed by the aftercast, indicated that the aircraft's groundspeed would have been less, at 40 mph, with a flight time to Henstridge of 112 minutes. Thus a more realistic ETA at Henstridge was 1759 hrs.

During the flight the pilot would have had sufficient information to show that the aircraft would reach Henstridge near to the time that the airfield was due to close, 1800 hrs, which coincided with the start of official night flying. The weather was suitable for the aircraft to divert en route and land at a nearby airfield or return to Little Rissington. However, the air temperature and the exposed position of the pilot may have caused a certain amount of discomfort and been something of a distraction.

Pilot B's evidence that he had to fly at 95 mph, while manoeuvring to maintain position astern of G-CBCJ, indicates that the latter aircraft's speed was probably in the region of its V_{NE}, 70mph. Beyond that speed it had been demonstrated that:

> *'Given poor visual cueing it would be extremely difficult for an inexperienced pilot to fly the aircraft at speeds in excess of 70 mph and momentary distractions to tune radios, IFF, operate trim wheels etc could lead to a large pitch excursion going unnoticed.'*

A pitch excursion could potentially cause the rotor blades to strike the tail surface and the propeller.

There was no evidence of any pre-existing fault with the aircraft and witness statements suggest that the aircraft was flying normally approximately one minute before it broke up in flight. The carburettor heat system was found in the HOT position. This could have been the result of a normal selection during descent or in response to a carburettor icing encounter. If there had been any carburettor icing, the engine may have run roughly as it cleared.

It is possible that the pilot was distracted by something, either within or external to the gyroplane, which may have had an affect on his control input. There was, however, insufficient evidence to indicate whether or not this was the case.

The damage to the empennage and distribution of the wreckage was consistent with the main rotor blades having struck the propeller, fin and rudder whilst the gyroplane was airborne and the engine was producing power. The noises reported by witnesses were probably confirmation of this. The damage to the rotor blades and loss in rotor rpm would have resulted in a high rate of descent and near vertical impact with the surface. This in-flight break-up bore strong similarities with the accident involving G-REBA.

Following that and other gyroplane accidents, an optional modification to the RAF 2000 was approved by the CAA. It involved the addition of a horizontal stabiliser which improved the aircraft's dynamic longitudinal stability. G-CBCJ was not fitted with this modification.

Summary

The gyroplane was destroyed by a pitch excursion causing the main rotor to contact the propeller, fin and rudder assembly. The unmodified RAF 2000, without a horizontal stabiliser, has demonstrated dynamic longitudinal instability at speeds in excess of 70 mph. The reduced V_{NE}, applicable in the UK, avoids the most objectionable aspects of its handling characteristics but a loss of control due to a pitch excursion remains possible below this speed. Any distraction or technical problem that could have caused such an excursion to go unnoticed may have been transient in nature and left no evidence. The long, cold flight and impending darkness might also have been a factor.

ACCIDENT

Aircraft Type and Registration:	Rans S6-ES Coyote II, G-BZYL
No & Type of Engines:	1 Jabiru Aircraft Pty 2200A piston engine
Year of Manufacture:	2002
Date & Time (UTC):	14 February 2009 at 1424 hrs
Location:	Brimpton airstrip near Aldermaston, Berkshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 (Serious) Passengers - None
Nature of Damage:	Aircraft destroyed
Commander's Licence:	National Private Pilot's Licence
Commander's Age:	65 years
Commander's Flying Experience:	165 hours (of which 121 hours were on type) Last 90 days - 1:25 hours Last 28 days - 0:35 hours
Information Source:	AAIB Field Investigation

Synopsis

The pilot of G-BZYL was carrying out solo circuits at a small grass airfield. Following a 'touch-and-go', and at a height of about 180 ft, the aircraft appeared to stall. The left wing dropped and the aircraft entered a steep descent. It rotated left through approximately 310° and the pilot was unable to regain control before the aircraft hit the ground.

History of the flight

G-BZYL took off from a small grass airfield for a local flight. The pilot had conducted the majority of his flying in G-BZYL and from that airfield. The flight in the local area was uneventful, after which the pilot returned to fly some circuits.

The circuits and accident were witnessed by a number of people at the airfield. The first circuit was flown close to the airfield at a height judged to be lower than 800 ft, the usual downwind height. The second circuit followed a more normal pattern. When on base leg, the pilot was heard to transmit "FINAL 07 TOUCH AND GO" followed by further speech which, with hindsight, a witness believed might have been "EARLY TURNOUT". The approach, landing and 'touch-and-go' appeared normal and, as G-BZYL climbed away, at a point two-thirds of the way along the runway, it was seen at "between 30 and 50 ft, and in the correct attitude". The aircraft continued climbing and everything appeared normal to those watching.

According to the eyewitnesses, shortly after crossing the departure end of the runway, at a height of about 200 ft above the ground, G-BZYL "pitched nose-down and recovered, during which it also turned left, then pitched nose-down again with a wing drop to the left". A "fluttering of the wings" was "noticeable but not dramatic". There was no change to the sound of the engine to accompany this motion. When the left wing dropped, the aircraft "turned on its wingtip", during which the top surface of each wing was visible to the witnesses standing alongside the runway. G-BZYL descended steeply and rotated left through approximately 310° before impacting the ground. One witness stated "the wings started to level out slightly before impact". The aircraft came to rest 140 metres from the departure end of the runway and 90 metres to the left of the centreline.

The first witness to arrive at the aircraft turned off the electrical switches and ignition and lowered the flap lever to free the pilot. Later, he disconnected the stall warner from its battery supply because the horn was sounding continuously. The fire service and an air ambulance attended the scene, the pilot was cut free from the wreckage and flown to hospital.

Information from the GPS

Information from the GPS showed the ground speed was approximately 40 kt during the climb-out. Witnesses reported that there was a tail wind of "a couple of knots", suggesting an indicated airspeed of approximately 38 kt, or 44 mph.

Information from the pilot

The pilot remembered only parts of the accident flight but was able to remember more general information about how he operated G-BZYL.

While on base leg, the pilot decided the next circuit would be a "tight circuit" where he would climb to about 300 ft and execute a "sharp turn" downwind. He had flown such a circuit about 10 times before, although not recently, and the aim was to simulate a problem that necessitated a quick return to the runway in use. He vaguely remembered opening the throttle for the go-around but remembered nothing after that.

The stall warner would normally sound about 5 mph before the stall but the pilot did not remember whether or not it came on prior to the impact. In a power-off, flaps-up stall, the stall warner could be expected at 40 mph with a stall at 35 mph. Following a wings-level entry to the stall, the aircraft would "flutter down" substantially wings level and be controllable in roll using the rudder.

Takeoff was normally flown with flaps up but, occasionally, two stages of flap would be used. Carburettor heat would be selected to HOT on the downwind leg and three stages of flap would be extended on base leg. The pilot stated that the carburettor heat had negligible affect on the power delivered by the engine. During a touch-and-go, the flap lever would be lowered, retracting the flaps, the carburettor heat would be selected to COLD and the throttle would be opened. The pilot would rotate the aircraft at between 45 and 50 mph and climb at between 55 and 60 mph.

Aircraft performance

The Rans S6 Build Manual contains information for pilots on the operation and handling of the aircraft. The section on stalling states:

'Stalls have a warning buffet due to turbulent air from the wing root flowing over the elevator. The stall occurs with a definite break. Rudder may be needed to hold the wings level. Recovery is instant with the release of back pressure. Turning, accelerated power on and power off stalls all demonstrate the slight buffet and quick recovery.'

The manual states that, as each kit-built aircraft is unique, builders should expect their aircraft's performance to be unique. Flight test data was not available for G-BZYL but data for a similarly configured aircraft suggested that the use of full flap would reduce the speed at the onset of buffet, and at the stall, by two to three knots.

Stalling in the approach configuration

The stalling characteristics of a single-engine piston aircraft are typically more marked with flaps down and at high power settings. The airflow from the propeller can lead to a lower stalling speed but, when the stalling angle of attack is reached, the stall may be abrupt. In addition, the high engine power may cause the aircraft to yaw and a wing to drop. As the Jabiru engine rotates clockwise when viewed from the pilot's seat, the yaw and wing drop would tend to be to the left. G-BZYL was reported to remain substantially wings level during a power-off stall, which suggests it might suffer a left wing drop during a power-on stall.

Autorotation

When a wing drops at the stall, it meets the airflow at an increased angle of attack compared to the other, rising, wing. The increased angle of attack causes increased drag and the aircraft yaws in the direction of the lower wing. The dropping wing now moves more slowly through the air than the rising wing and its lift reduces further, which reinforces the original wing drop. The aircraft simultaneously rolls towards the lower wing and yaws in the same direction. This motion is autorotation and, if not arrested, will stabilise itself as a spin.

Examination of the aircraft

Impact conditions

The aircraft crashed onto soft ground adjoining the airfield at a position approximately 140 metres beyond the upwind end of Runway 07 and 90 metres to the left of its extended centre line. At impact, the aircraft was heading 120°, pitched approximately 30° nose-down and banked slightly to the left with a high rate of descent and negligible forward speed, consistent with it having been in a fully stalled condition. There was no evidence of significant momentum about the yaw axis, suggesting that the initial rotation reported by witnesses, and implied by the aircraft's heading at impact, had been stopped, but there was insufficient height to complete the recovery.

Wreckage examination at the site

Examination of the wreckage at the site established that the aircraft was intact at impact. All flying control surfaces were securely attached and free of restrictions, and all associated control circuits were intact and connected at impact. The flap control, a handbrake-type lever positioned between the two seats, was set to the first stage flap position. One of the rescuers had reported releasing this lever and lowering it somewhat (to prevent further injury to the pilot), suggesting that immediately post-impact it was in the 2nd, or possibly the 3rd stage position. There was some potential for the lever to have been driven upwards by impact forces, and the post-accident position of the lever alone did not therefore provide a reliable indication of the flap setting immediately before impact.

Fuel was present in both fuel tanks and the in-line filter in the supply line to the engine was substantially full. The fuel selector was in the OFF position but it was reported that it, together with the magneto switches, had been turned off by rescuers immediately after the accident. The throttle and choke controls were both found in the fully open position, and the carburetter heat control was in the HOT position. All operating cables and end-connections were intact. There was potential for these controls to have been disturbed from their pre-impact position by impact forces, and by people attending the injured pilot.

Fragments of broken propeller were spread over a wide area forward of the impact point. The degree of fragmentation and distribution of the propeller pieces, combined with the pattern of fracture exhibited by the broken propeller stubs, was consistent with significant power at impact.

Detailed examination of the wreckage

The wreckage was recovered to the AAIB facility at Farnborough for further, more detailed, examination.

Airspeed indication and stall warning

The pitot probe, which comprised a tube projecting from the wing leading edge, was clear of obstruction, the plastic tubing connecting it to the airspeed indicator (ASI) was intact and free of obstruction, and the ASI needle responded to pressure applied to the pitot port. There was a slight leak at the tubing's connection to the ASI; it was not possible to establish whether this leak was present prior to impact as it was insufficiently large to have had any material effect on the performance of the ASI. Function testing and strip examination of the ASI showed that the instrument itself was free of leaks and was mechanically serviceable, and that it performed satisfactorily throughout the relevant speed range.

The stall warning vane, mounted on the wing leading edge, moved freely but the vane itself was deformed in the impact and the airspeed at which it operated could not be determined. Rescuers had reported that the stall warner horn was sounding during their attempts to extract the pilot until its battery was disconnected.

Flap position

The flap operating system comprised a single push-pull cable from the flap control lever, running aft to a position behind the seats where it split into two separate push cables - one for each flap surface. The system was intact except for an impact-induced fracture through the end-fitting of the single cable section, at the point of bifurcation.

The selected flap position was maintained by a set of substantial detents in the control lever mechanism, into which a spring loaded retractable lock-bar, operated by a push button in the end of the lever, engaged. The geometry of the detents provided a substantial and positive stop preventing the lever from being lowered without first pressing the release button, but allowed the lock-bar to ride up out of its detent and snap into the next one if the lever was raised. Thus, the post-impact position of the lever was not a reliable indication of the flap setting prior to impact.

Impact deformation of the fuselage structure below and immediately forward of the flap lever suggested that the cockpit floor or parts of the control column layshaft could have been driven upwards during the impact, moving the flap lever, before relaxing back to a position clear of the lever. The flap lever mechanism was removed and studied in detail, both generally and microscopically, for any impact witness marks or other evidence. No positive determination of the flap setting prior to impact could be made, but it appeared on a balance of probability that some flap extension was present at impact.

Throttle operating mechanism

The throttle cable was actuated from a layshaft mounted at floor level immediately forward of the seats, from which projected upwards and forwards a pair of long throttle levers, one to the left of each seat squab. Both throttle levers were thus susceptible to disturbance, both by impact forces and during attempts to extricate the injured pilot, and it was not possible to determine the throttle setting at impact.

Carburettor heat

The carburettor heat control comprised a conventional push/pull knob on the instrument panel, connected to a cable which moved a crank on the flap valve. This valve switched the carburetor air supply between COLD and HOT sources. An over-centre spring, attached to the crank, assisted the valve to snap firmly into either the fully HOT or fully COLD position, as appropriate, once it moved beyond the mid-travel position.

The control knob was found very close to the fully hot position. Its cable was intact and connected to the crank of the hot air valve, and the valve flap itself was fully seated in the HOT position. The valve-operating mechanism, and the related parts of the air-box, were undamaged and there was no evidence to suggest that the mechanism had been displaced during the impact. The nipple on the end of the operating cable at its connection to the crank was not fully in contact with the inner face of its clevis fitting, but its protruding end did abut the side face of the crank (Figure 1) consistent with the crank being 'over-ridden' by the operating cable during the final stage of valve movement into the HOT position. This could have occurred due to the inherent tendency of the spring to snap the valve onto its seat in advance of the operating knob and cable becoming fully retracted. Alternatively, it could , possibly, have been due to impact forces driving the valve crank into the HOT position.

Analysis of the geometry of these components within the engine compartment, and bench operation of the mechanism showed that the position of the carburettor heat control at impact could not be established with certainty, but on a balance of probability, the evidence pointed to it having been in the HOT position.

Analysis

Evidence from witnesses suggested that the aircraft stalled, with a left wing drop leading to autorotation from which there was insufficient height to recover. Evidence from the wreckage suggested the aircraft

Figure 1

Operating mechanism for engine carburettor heat impacted the ground with low forward speed and high rate of descent, consistent with this analysis. It is probable that the flaps were extended and that the carburettor heat was set to HOT. The engine was delivering significant power and the aircraft appears to have been serviceable before it hit the ground.

It was not possible to prove the actual sequence of events but it was possible to suggest a plausible sequence. The pilot would have been thinking, on the previous circuit, about the early turn following the 'touch-and-go' and it is likely he transmitted his intention while on base leg. He carried out a 'touch-and-go', during which he would normally select carburetor heat to COLD and raise the flaps before applying power. It is probable that he carried out neither of these actions. It is conceivable that he was thinking ahead to the manoeuvre he was about to carry out, which he had not flown recently, and that this distracted him.

The GPS-derived climb airspeed of approximately 44 mph was lower than the usual climb speed of 55 to 60 mph and would have reduced the margin above the stall speed. It is possible that, when the pilot began his "sharp" turn downwind, he pulled the aircraft through the margin to the stall itself and the high power setting would probably have caused the left wing to drop and the aircraft to autorotate to the left. Evidence from the wreckage suggested the pilot managed to stop the yaw before impact but did not have sufficient height to un-stall the wings.

ACCIDENT

Aircraft Type and Registration:	Team Minimax 91A, G-BXCD
No & Type of Engines:	1 Rotax 503 piston engine
Year of Manufacture:	1998
Date & Time (UTC):	12 December 2009 at 1430 hrs
Location:	Field near Ellerholme, Cumbria
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 (Minor) Passengers - N/A
Nature of Damage:	Right wing and forward fuselage destroyed
Commander's Licence:	National Private Pilot's Licence
Commander's Age:	34 years
Commander's Flying Experience:	53 hours (of which 16 were on type) Last 90 days - 3 hours Last 28 days - 0 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

After a prolonged engine warm-up period, the pilot completed his pre-takeoff checks and began the takeoff run. The aircraft was pointed towards the sun that was low on the horizon, the pilot was unable to see the aircraft instruments clearly. He rotated the aircraft at the 'normal' point on the runway but it failed to climb, yawed to the right and ended up 90° to the runway heading. The aircraft then stalled at low level, coming to rest in an adjacent field. The pilot sustained minor abrasions and was able to leave the aircraft unaided. Several witness subsequently told the pilot that that the engine appeared to have been running roughly, but he had been unaware of this during the takeoff run. The weather conditions at the time of the accident were found to be conducive to serious carburettor icing at low engine power settings.

The pilot attributed the accident to inexperience, which resulted in the takeoff being continued when he could not clearly see the instrumentation, rotating the aircraft based on its position on the runway rather than at the correct airspeed, and a lack of anticipation of the possibility of carburettor icing occurring prior to taking off.

BULLETIN CORRECTION

AAIB File:	EW/A2009/03/01
Aircraft Type and Registration:	Boeing 757-236, G-LSAA
Date & Time (UTC):	2 March 2009 at 1327 hrs
Location:	FL390, 30 nm north-east of Athens, Greece
Information Source:	Aircraft Accident Report Form submitted by the commander, and further enquiries by the AAIB

AAIB Bulletin No 2/2010, page 25 refers

In final paragraph of the **History of the flight** section of this report it stated:

After landing and parking on stand, the doors could not be opened until the outflow valve had been re-opened and the external and internal cabin pressures had equalised. The commander reported that it took some considerable time for this to be achieved.

These two sentences should have read:

The commander reported that after landing the cabin remained pressurised. The outflow valve was manually opened and he reported that it then took some considerable time for the pressure to equalise, thereby enabling the doors to be opened when the aircraft arrived on its parking stand.

FORMAL AIRCRAFT ACCIDENT REPORTS ISSUED BY THE AIR ACCIDENTS INVESTIGATION BRANCH

2008

6/2008 Hawker Siddeley HS 748 Series 2A, G-BVOV
at Guernsey Airport, Channel Islands
on 8 March 2006.

Published August 2008.

7/2008 Aerospatiale SA365N, G-BLUN
near the North Morecambe gas platform, Morecambe Bay
on 27 December 2006.

Published October 2008.

2009

1/2009 Boeing 737-81Q, G-XLAC,
Avions de Transport Regional ATR-72-202, G-BWDA, and
Embraer EMB-145EU, G-EMBO
at Runway 27, Bristol International Airport
on 29 December 2006 and
on 3 January 2007.

Published January 2009.

2/2009 Boeing 777-222, N786UA
at London Heathrow Airport
on 26 February 2007.

Published April 2009.

3/2009 Boeing 737-3Q8, G-THOF
on approach to Runway 26
Bournemouth Airport, Hampshire
on 23 September 2007.

Published May 2009.

4/2009 Airbus A319-111, G-EZAC
near Nantes, France
on 15 September 2006.

Published August 2009.

5/2009 BAe 146-200, EI-CZO
at London City Airport
on 20 February 2007.

Published September 2009.

6/2009 Hawker Hurricane Mk XII (IIB), G-HURR
1nm north-west of Shoreham Airport, West Sussex
on 15 September 2007.

Published October 2009.

2010

1/2010 Boeing 777-236ER, G-YMMM
at London Heathrow Airport
on 28 January 2008.

Published February 2010.

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http://www.aaib.gov.uk