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IMPORTANT NOTICE

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SERIOUS INCIDENT

Aircraft Type and Registration:	Boeing 737-73V, G-EZJK
No & Type of Engines:	2 CFM56-7B20 turbofan engines
Year of Manufacture:	2002
Date & Time (UTC):	12 January 2009 at 1545 hrs
Location:	West of Norwich, Norfolk
Type of Flight:	Private
Persons on Board:	Crew - 2 Passengers[1] - 2 (engineer observers)
Injuries:	Crew - None Passengers - None
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	43 years
Commander's Flying Experience:	10,716 hours (of which 7,719 were on type) Last 90 days - 56 hours Last 28 days - 9 hours
Information Source:	AAIB Field Investigation

Synopsis

A flight control manual reversion check[2] was being conducted as part of a post-maintenance check flight. During the check, the aircraft pitched rapidly nose-down, descending approximately 9,000 ft before control was recovered. A number of maintenance and airworthiness check issues were identified and six Safety Recommendations have been made.

Footnote

[1] Two observers were carried on the aircraft to monitor the check flight. They did not constitute part of the operating crew and are therefore classified as passengers.

[2] The manual reversion check is the colloquially accepted reference to the 'elevator power-off flight test' in the Aircraft Maintenance Manual (AMM).

History of the flight

The aircraft had reached the end of its lease agreement with its current operator and required a combined maintenance check and demonstration flight to confirm its serviceability before being transferred to another airline. The checks to be carried out, which were agreed between the operator and the owner, were detailed in a Customer Demonstration Flight Schedule (CDFS). The commander involved in the incident had flown the aircraft to Southend Airport for maintenance the previous month and during that flight carried out checks, in accordance with the agreed CDFS, to identify any existing defects.

The commander returned to Southend on 12 January 2009 to conduct the post-maintenance check flight and the customer demonstration flight. Before the flight he discussed with the crew chief from the maintenance provider the work that had been carried out. He recalled being told that an adjustment had been made to the elevator balance tab setting and was given extracts from the Aircraft Maintenance Manual (AMM) to assist him in conducting an in-flight elevator power-off test and to identify any asymmetrical flight control forces; both were required as part of the maintenance procedures. Prior to departure he checked the aircraft's technical log and confirmed that arrangements had been made with ATC for the flight to be conducted in the East Anglia Military Training Area (MTA). The commander and co-pilot, a first officer from the operator, were accompanied on the flight by two observers representing the aircraft owner and the airline due to take delivery of the aircraft. No problems were identified during the pre-flight preparation and the aircraft departed at 1400 hrs with the commander as the handling pilot.

The commander climbed the aircraft to FL410, conducted a series of checks and, after about 45 minutes, descended to FL150 where an APU bleed check was performed and the aircraft was configured for the flight control manual reversion check. The aircraft was flown at FL150, 250 kt[3], with the fuel balanced, the autopilot and autopilot selected off, the STAB TRIM MAIN ELEC and AUTOPILOT TRIM switches set to the CUTOUT position, and the aircraft in trim. The CDFS also required SPOILER A and B switches to be selected off. All these checks were conducted using the operator's CDFS and not the AMM extracts as the guiding reference.

Before the manual reversion check began, the individual hydraulic systems were isolated in turn by placing the FLT CONTROL switches A and B to the OFF position individually and reinstating each in turn enabling the flight controls to be checked for normal operation on a single hydraulic system. Operation was confirmed as satisfactory on both systems. The commander then released the controls and the co-pilot selected both FLT CONTROL SWITCHES (A and B) to the OFF position, removing all hydraulic assistance from the primary flight controls. As he did so the aircraft pitched rapidly nose-down. The commander pulled back on the control column with considerable force but was unable to prevent the aircraft from maintaining a nose-down pitch attitude of 2.8° and descending at up to 3,100 ft/min. The commander decided to abandon the check and reinstate the hydraulics. However, he did not wish to re-engage them immediately as he stated that he had been trained that, should the aircraft pitch up or down uncontrollably during a manual reversion check, the aircraft should be rolled to unload the pressure on the elevators and the controls released before the hydraulics are reinstated. It was his understanding that not releasing the controls prior to reinstating the hydraulics could overstress the airframe or cause serious injury to the handling pilot. He therefore rolled the aircraft left to 70° before releasing the controls and calling for the co-pilot to re-engage the flight control switches. The aircraft continued to roll to 91°.

The recording from the Cockpit Voice Recording indicates that at this point there was confusion between the two pilots. The commander believed that hydraulic power had been restored to the flight controls although there is no evidence that the FLT CONTROL switches had been moved from the OFF position. The commander retarded the thrust levers and selected the speed brakes but the spoilers had been selected OFF as part of the

Footnote

3 All airspeeds in this report refer to computed airspeed. Computed airspeed is the airspeed displayed to the crew and recorded on the Flight Data Recorder.

test procedure and the speed brakes, therefore, did not deploy. He then rolled the wings level and attempted to arrest the rate of descent. This had peaked at 20,000 ft/min with the aircraft pitched 30° nose-down after the aircraft had been rolled to the left. The control forces remained high but the commander considered this to be due to the aircraft's speed, which he observed at a maximum of 447 kt.

The commander continued to maintain backpressure on the controls and made a PAN call to ATC. The aircraft eventually recovered from the dive at about 5,600 ft amsl having entered a layer of cloud. The pilots reviewed the situation and selected the FLT CONTROL switches, which had remained OFF throughout the flight excursion, to the ON position. The control forces returned to normal.

The commander stated he had considered repeating the test, but was concerned that, as a result of the incident, the aircraft might have sustained damage. The check flight was abandoned and the aircraft returned to Southend. Considering possible structural damage, the commander kept the speed below 250 kt and configured the aircraft for landing early during the approach. The aircraft appeared to operate normally and landed without further incident at 1606 hrs.

The aircraft was inspected after landing for damage or deformation in accordance with AMM task 05-51-04 titled '*severe or unusual turbulence, stall, or speeds more than design limits – maintenance practices (conditional inspection)*'. No evidence of damage or deformation of the structure was found.

During the AAIB's investigation it was noted that the second observer's seat in the cockpit was not fitted. One of the observers confirmed that throughout the incident flight he had sat on a storage cupboard behind the commander's seat, and was not restrained by a safety harness.

Weight and Centre of Gravity

The aircraft's takeoff weight was 47,633 kg and MACTOW 20.6%. The centre of gravity remained within limits throughout the flight.

Flight Recorders and Radar

The aircraft was fitted with a 25-hour Flight Data Recorder (FDR) and 2-hour Cockpit Voice Recorder (CVR). These were both removed from the aircraft following the incident and taken to the AAIB for analysis.

Mode S Secondary Surveillance Radar (SSR) data was also recorded for the incident flight, providing information about time and position of the aircraft, and a number of aircraft airborne parameters that matched those recorded on the FDR. Figure 1 shows part of the aircraft's track derived from the radar, annotated with extracts of speech recorded on the CVR.

A time history of salient parameters from the FDR for the incident is shown at Figure 2.

The graphical presentation starts just after the aircraft was trimmed, at FL150, at a computed airspeed of 245 kt, the STAB TRIM MAIN ELECT and AUTO PILOT TRIM switches were selected to their CUTOUT positions, and SPOILER A and B switches were selected to OFF. In this trimmed condition (with zero stick force) the elevator position was about 5º trailing edge down.

The FLT CONTROL B switch was then put in the OFF position and the flight controls were moved slightly. The switch was then put back to the ON position and the FLT CONTROL A switch was then put in the OFF

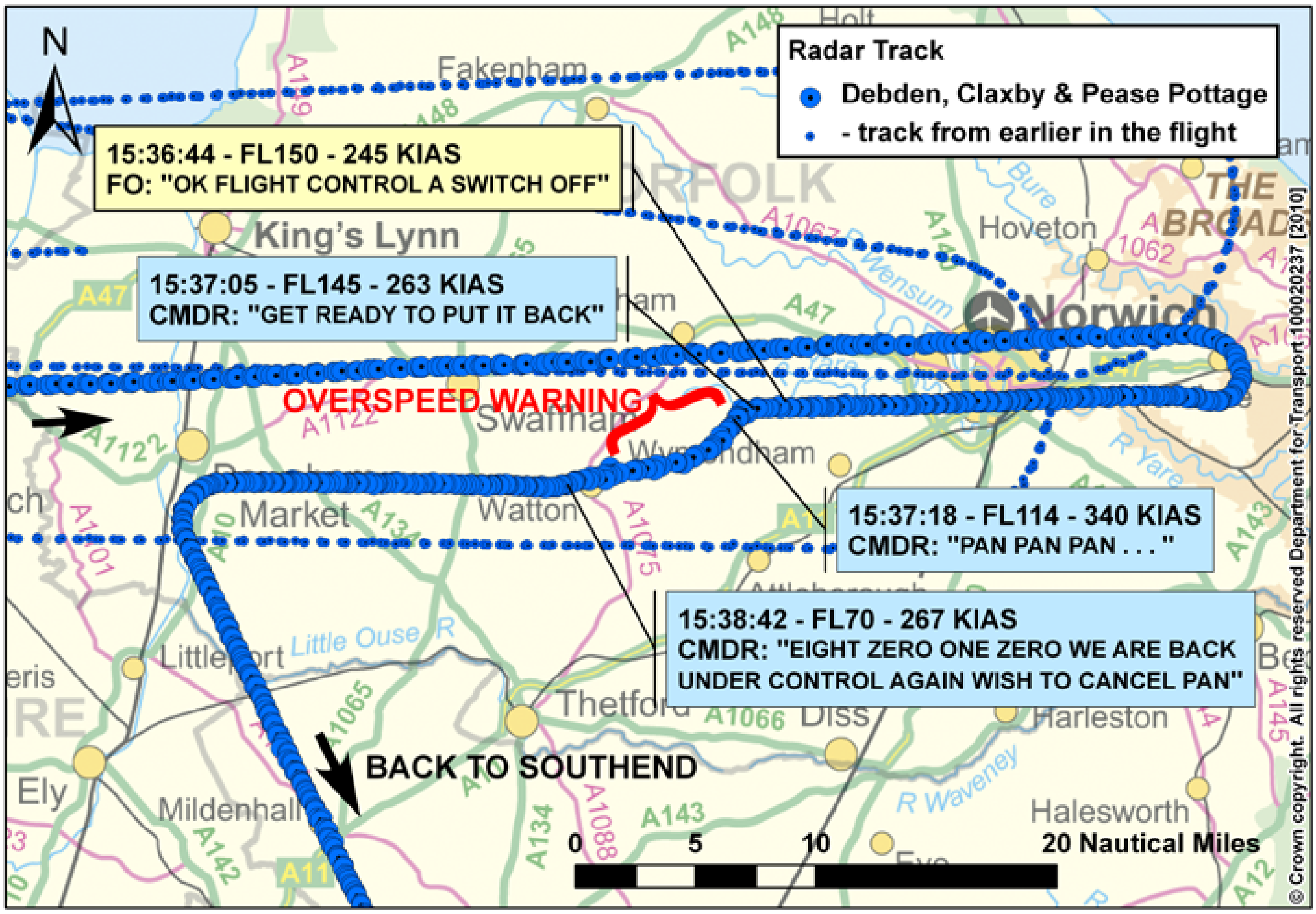

Figure 1

G-EZJK radar track with extracts from CVR

position and the flight controls again moved slightly. The co-pilot sought confirmation from the commander that he was prepared before each selection and verbally confirmed each action.

With the FLT CONTROL A switch still in the OFF position, the co-pilot asked the commander if he was ready for the FLT CONTROL B switch to be selected OFF (putting the aircraft in manual reversion). The commander replied "YES GO AHEAD". The hydraulics to the B system were turned off (time 15:36:47). The elevator position rapidly moved to just over 8° trailing edge down (an increase in 3° trailing edge down from the trimmed position), and the aircraft pitched from 2° nose up to 2° nose-down. The commander immediately pulled back on the control column, reaching full aft stick five seconds later. This was enough to return the elevators to their trimmed position. He was, however, unable to maintain this control column position and the aircraft remained in a nose-down attitude. The amount of column movement and force required with the hydraulics off increases to produce the same elevator deflection with the hydraulics on. The column force being pulled throughout this time was in excess of 170 pounds-force.

Ten seconds after system B had been selected off (time 15:36:57), the aircraft had descended almost 300 ft and was continuing to descend at a rate of about 2,200 ft/min. The airspeed had increased by 10 kt to 255 kt and was still accelerating.

The commander then rolled the aircraft to the left at a little under 8º/second and, as the aircraft passed through 50º bank angle (time 15:37:04) said "GET READY TO PUT IT BACK". The co-pilot responded with "HEY" and "SAY AGAIN" to which the commander said "AND BACK". Then, as the bank angle passed through 70º, the commander released the pressure on the control column, allowing the elevator to move back to just under 8º trailing edge down. The descent rate was now 6,000 ft/min and increasing, and the aircraft had descended a further 400 ft to FL143 while accelerating to 270 kt.

The commander pulled back on the control column, reducing the elevator deflection a little and, as the bank angle approached 91º (maximum recored), put in a wheel input to roll the wings level. The engine thrust was also reduced and the speed brakes selected but the speedbrakes did not extend as SPOILER A and B switches were still in the OFF position.

The aircraft's descent rate increased considerably, reaching a maximum of 20,000 ft/min as it descended through about FL110. At this point the bank angle was reducing through 40º, the pitch attitude was 30º nose-down, and the airspeed was 320 kt (Mach 0.60) but still accelerating. As the aircraft's descent rate started to reduce, the commander made a PAN call (time 15:37:20). This call coincided with the sounding of the aural overspeed warning which remained active for the next 48 seconds.

The maximum recorded airspeed during the recovery was 429 kt (Mach 0.719). The maximum recorded vertical acceleration was 1.6 g and the minimum recorded altitude was 5,655 ft amsl. The Mach trim was in operation above Mach 0.615 making pitch-up commands to the elevator in addition to deflections demanded by the commander's control column inputs.

There was no recorded discussion between anyone on the flight deck during the event. The first comment was recorded 76 seconds after the commander called "AND BACK" and shortly after the aircraft had levelled at 7,000 ft amsl. The commander then said "ARE THEY ALL BACK ON – PUT ALL THE [*unintelligible*] CONTROLS BACK ON". Both flight control system A and B hydraulics were then reinstated (time 15:38:27). A transmission was made by the commander 15 seconds later cancelling the PAN.

Flight 'tests' and flight 'checks'

The CAA Check Flight Handbook states that:

> *'Flight testing of aircraft provides a basis to establish compliance with certification requirements for new aircraft and changes to aircraft. Other flight testing referred to as Check Flights or in-flight surveys can be carried out periodically on in-service aircraft as one of the processes to ensure that an aircraft continues to comply with the applicable airworthiness requirements. Additionally, maintenance Check Flights may be carried out following a maintenance activity on an aircraft to provide reassurance of performance or establish the correct functioning of a system that cannot be fully established during ground checks.'*

EASA issued NPA 2008-20 in August 2008 on the subject of flight testing. This NPA introduced a proposed change to Part 21 regulations with regard to flight testing by design and production organisations. It takes the approach of defining test flights into four categories of reducing risk based on the nature of the testing being carried out. These range from initial envelope definition and expansion flights at the top end through to production and certification compliance demonstration

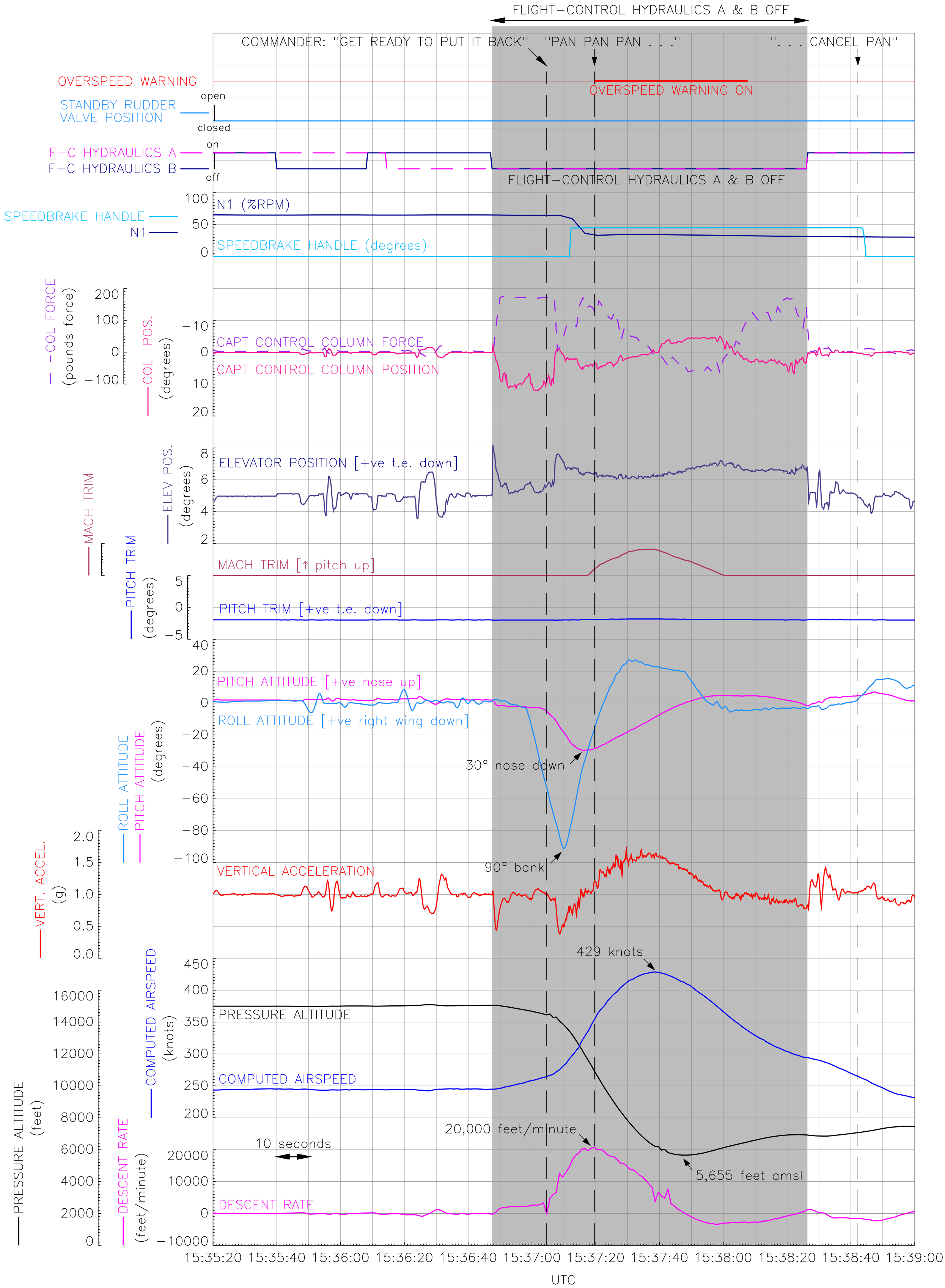

Figure 2

Salient FDR Parameters for the serious incident to G-EZJK flights at the lower end. The NPA specifies the different qualifications, competence and experience required by pilots and engineers operating these different flights. It also introduces requirements for company procedures and documentation to support their operation.

The NPA specifically states that the new proposals are applicable to design and production organisations only. The rationale behind this is explained in the NPA by drawing the distinction between flight 'tests' (performed by manufacturers) and flight 'checks' (performed by operators) as follows:

> *'Flight tests may be broadly defined as flights necessary during the development phase of a new design (aircraft, engine, parts and appliances) to show compliance to certification requirements. Therefore, during such flights there is a certain amount of "unpredictability", which does not happen in the case of check flights and acceptance flights.*
>
> *Maintenance activities should only use approved data. Therefore, flights performed after maintenance should be for the purpose of performing checks. Such checks are performed by flight crews in accordance with EU-OPS and national rules implementing JAR-OPS 3 and JAR-FCL.'*

Upset recovery technique

Several publications available to the crew contained information concerning flight upset recovery techniques. The relevant extracts are as follows:

- Aircraft QRH (see Figures 3 and 4)
- Boeing 737-700 AMM (see Figures 5 to 8)

The Boeing 737-700 AMM extract given to the crew referred to recovery techniques in the Flight Crew Training Manual to be used in the event of a pitch upset being encountered during the manual reversion test.

- CAA Check Flight Handbook.

Section 3, Tech 2, Part 10 of the CAA Check Flight Handbook, published in April 2006, covering flying control checks states:

> *'It might be possible to put some bank on the aircraft to turn a large pitch up or pitch down into a turn manoeuvre before re-powering the system. This might prevent an unusually high or low pitch manoeuvre developing.'*

The qualified test pilot who was the author of this section stated that this was intended as a banking manoeuvre conducted momentarily before re-powering the system. If conducted in accordance with the CAA schedules the availability of the rudder would ensure the ability to roll the aircraft readily which, in the pitch-down case, would ensure minimal height loss prior to re-powering the controls. The purpose of the bank in the pitch down case is to limit the effect of the pitch-up moment resulting from the re-establishing of power to the controls.

The CAA Check Flight Handbook also advises that where significant unexpected results are encountered no attempt should be made to rectify or explore them through experimentation or repetition.

Maneuvers -
Non-Normal Maneuvers

BOEING

737 Flight Crew Operations Manual

Upset Recovery

An upset can generally be defined as unintentionally exceeding the following conditions:

- Pitch attitude greater than 25 degrees nose up, or
- Pitch attitude greater than 10 degrees nose down, or
- Bank angle greater than 45 degrees, or
- Within above parameters but flying at airspeeds inappropriate for the conditions.

The following techniques represent a logical progression for recovering the airplane. The sequence of actions is for guidance only and represents a series of options to be considered and used depending on the situation. Not all actions may be necessary once recovery is under way. If needed, use pitch trim sparingly. Careful use of rudder to aid roll control should be considered only if roll control is ineffective and the airplane is not stalled.

These techniques assume that the airplane is not stalled. A stalled condition can exist at any attitude and may be recognized by continuous stick shaker activation accompanied by one or more of the following:

- Buffeting which could be heavy at times
- Lack of pitch authority and/or roll control
- Inability to arrest descent rate.

If the airplane is stalled, recovery from the stall must be accomplished first by applying and maintaining nose down elevator until stall recovery is complete and stick shaker activation ceases.

Nose High Recovery

Pilot Flying	Pilot Monitoring
• Recognize and confirm the situation	
• Disconnect autopilot and autothrottle • Apply as much as full nose-down elevator • * Apply appropriate nose down stabilizer trim • Reduce thrust • * Roll (adjust bank angle) to obtain a nose down pitch rate • Complete the recovery: - When approaching the horizon, roll to wings level - Check airspeed and adjust thrust - Establish pitch attitude.	• Call out attitude, airspeed and altitude throughout the recovery • Verify all required actions have been completed and call out any omissions.

MAN.1.6 D6-27370-73V-EZY(3V) September 18, 2008

Figure 3

Extract one from Aircraft QRH

BOEING

Maneuvers - Non-Normal Maneuvers

737 Flight Crew Operations Manual

Nose Low Recovery

Pilot Flying	Pilot Monitoring
• Recognize and confirm the situation	
• Disconnect autopilot and autothrottle • Recover from stall, if required • * Roll in shortest direction to wings level (unload and roll if bank angle is more than 90 degrees) • Recover to level flight: - Apply nose up elevator - *Apply nose up trim, if required - Adjust thrust and drag as required.	• Call out attitude, airspeed and altitude throughout the recovery • Verify all required actions have been completed and call out any omissions.

WARNING: * Excessive use of pitch trim or rudder may aggravate an upset situation or may result in loss of control and/or high structural loads.

Windshear

Windshear Caution

For predictive windshear caution alert: ("MONITOR RADAR DISPLAY" aural).

Pilot Flying	Pilot Monitoring
Maneuver as required to avoid the windshear.	

Windshear Warning

Predictive windshear warning during takeoff roll: ("WINDSHEAR AHEAD, WINDSHEAR AHEAD" aural)

- prior to V1, reject takeoff
- after V1, perform the Windshear Escape Maneuver.

Windshear encountered during takeoff roll:

- If windshear is encountered prior to V1, there may not be sufficient runway remaining to stop if an RTO is initiated at V1. At VR, rotate at a normal rate toward a 15 degree pitch attitude. Once airborne, perform the Windshear Escape Maneuver.
- If windshear is encountered near the normal rotation speed and airspeed suddenly decreases, there may not be sufficient runway left to accelerate back to normal takeoff speed. If there is insufficient runway left to stop, initiate a normal rotation at least 2,000 feet before the end of the runway, even if airspeed is low. Higher than normal attitudes may be required to lift off in the remaining runway. Ensure maximum thrust is set.

Predictive windshear warning during approach: ("GO–AROUND, WINDSHEAR AHEAD" aural)

- perform the Windshear Escape Maneuver, or, at pilot's discretion, perform a normal go–around.

Windshear encountered in flight:

- perform the Windshear Escape Maneuver.

September 18, 2008 D6-27370-73V-EZY(3V) MAN.1.7

Figure 4

Extract two from Aircraft QRH

Maneuvers

BOEING

737 NG Flight Crew Training Manual

Upset Recovery

For detailed information regarding the nature of upsets, aerodynamic principles, recommended training and other related information, refer to the Airplane Upset Recovery Training Aid available through your operator.

An upset can generally be defined as unintentionally exceeding any of the following conditions:

- pitch attitude greater than 25° nose up
- pitch attitude greater than 10° nose down
- bank angle greater than 45°
- within above parameters but flying at airspeeds inappropriate for the conditions.

General

Though flight crews in line operation rarely, if ever, encounter an upset situation, understanding how to apply aerodynamic fundamentals in such a situation helps them control the airplane. Several techniques are available for recovering from an upset. In most situations, if a technique is effective, it is not recommended that pilots use additional techniques. Several of these techniques are discussed in the example scenarios below:

- stall recovery
- nose high, wings level
- nose low, wings level
- high bank angles
- nose high, high bank angles
- nose low, high bank angles

Note: Higher than normal control forces may be required to control the airplane attitude when recovering from upset situations. Be prepared to use a firm and continuous force on the control column and control wheel to complete the recovery.

Stall Recovery

In all upset situations, it is necessary to recover from a stall before applying any other recovery actions. A stall may exist at any attitude and may be recognized by continuous stick shaker activation accompanied by one or more of the following:

- buffeting which could be heavy at times
- lack of pitch authority and/or roll control
- inability to arrest descent rate.

7.16 FCT 737 NG (TM) October 31, 2008

Figure 5

Extract one from Boeing 737-700 AMM

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Maneuvers

737 NG Flight Crew Training Manual

If the airplane is stalled, recovery from the stall must be accomplished first by applying and maintaining nose down elevator until stall recovery is complete and stick shaker activation ceases. Under certain conditions, it may be necessary to reduce some thrust in order to prevent the angle of attack from continuing to increase. Once stall recovery is complete, upset recovery actions may be taken and thrust reapplied as needed.

Nose High, Wings Level

In a situation where the airplane pitch attitude is unintentionally more than 25° nose high and increasing, the airspeed is decreasing rapidly. As airspeed decreases, the pilot's ability to maneuver the airplane also decreases. If the stabilizer trim setting is nose up, as for slow-speed flight, it partially reduces the nose-down authority of the elevator. Further complicating this situation, as the airspeed decreases, the pilot could intuitively make a large thrust increase. This causes an additional pitch up. At full thrust settings and very low airspeeds, the elevator, working in opposition to the stabilizer, has limited control to reduce the pitch attitude.

In this situation the pilot should trade altitude for airspeed, and maneuver the airplane's flight path back toward the horizon. This is accomplished by the input of up to full nose-down elevator and the use of some nose-down stabilizer trim. These actions should provide sufficient elevator control power to produce a nose-down pitch rate. It may be difficult to know how much stabilizer trim to use, and care must be taken to avoid using too much trim. Pilots should not fly the airplane using stabilizer trim, and should stop trimming nose down when they feel the g force on the airplane lessen or the required elevator force lessen. This use of stabilizer trim may correct an out-of-trim airplane and solve a less-critical problem before the pilot must apply further recovery measures. Because a large nose-down pitch rate results in a condition of less than 1 g, at this point the pitch rate should be controlled by modifying control inputs to maintain between 0 g and 1 g. If altitude permits, flight tests have determined that an effective way to achieve a nose-down pitch rate is to reduce some thrust.

If normal pitch control inputs do not stop an increasing pitch rate, rolling the airplane to a bank angle that starts the nose down should work. Bank angles of about 45°, up to a maximum of 60°, could be needed. Unloading the wing by maintaining continuous nose-down elevator pressure keeps the wing angle of attack as low as possible, making the normal roll controls as effective as possible. With airspeed as low as stick shaker onset, normal roll controls - up to full deflection of ailerons and spoilers - may be used. The rolling maneuver changes the pitch rate into a turning maneuver, allowing the pitch to decrease. Finally, if normal pitch control then roll control is ineffective, careful rudder input in the direction of the desired roll may be required to induce a rolling maneuver for recovery.

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October 31, 2008 FCT 737 NG (TM) 7.17

Figure 6

Extract two from Boeing 737-700 AMM

Maneuvers

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737 NG Flight Crew Training Manual

Only a small amount of rudder is needed. Too much rudder applied too quickly or held too long may result in loss of lateral and directional control. Because of the low energy condition, pilots should exercise caution when applying rudder.

The reduced pitch attitude allows airspeed to increase, thereby improving elevator and aileron control effectiveness. After the pitch attitude and airspeed return to a desired range the pilot can reduce angle of bank with normal lateral flight controls and return the airplane to normal flight.

Nose Low, Wings Level

In a situation where the airplane pitch attitude is unintentionally more than 10° nose low and going lower, the airspeed is increasing rapidly. A pilot would likely reduce thrust and extend the speedbrakes. Thrust reduction causes an additional nose-down pitching moment. Speedbrake extension causes a nose-up pitching moment, an increase in drag, and a decrease in lift for the same angle of attack. At airspeeds well above VMO/MMO, the ability to command a nose-up pitch rate with elevator may be reduced because of the extreme aerodynamic loads on the elevator.

Again, it is necessary to maneuver the airplane's flight path back toward the horizon. At moderate pitch attitudes, applying nose-up elevator, reducing thrust, and extending speedbrakes, if necessary, changes the pitch attitude to a desired range. At extremely low pitch attitudes and high airspeeds (well above VMO/MMO), nose-up elevator and nose-up trim may be required to establish a nose-up pitch rate.

High Bank Angles

A high bank angle is one beyond that necessary for normal flight. Though the bank angle for an upset has been defined as unintentionally more than 45°, it is possible to experience bank angles greater than 90°.

Any time the airplane is not in "zero-angle-of-bank" flight, lift created by the wings is not being fully applied against gravity, and more than 1 g is required for level flight. At bank angles greater than 67°, level flight cannot be maintained within AFM load factor limits. In high bank angle increasing airspeed situations, the primary objective is to maneuver the lift of the airplane to directly oppose the force of gravity by rolling in the shortest direction to wings level. Applying nose-up elevator at bank angles above 60° causes no appreciable change in pitch attitude and may exceed normal structure load limits as well as the wing angle of attack for stall. The closer the lift vector is to vertical (wings level), the more effective the applied g is in recovering the airplane.

A smooth application of up to full lateral control should provide enough roll control power to establish a very positive recovery roll rate. If full roll control application is not satisfactory, it may even be necessary to apply some rudder in the direction of the desired roll.

7.18 FCT 737 NG (TM) October 31, 2008

Figure 7

Extract three from Boeing 737-700 AMM

Only a small amount of rudder is needed. Too much rudder applied too quickly or held too long may result in loss of lateral and directional control or structural failure.

Nose High, High Bank Angles

A nose high, high angle of bank upset requires deliberate flight control inputs. A large bank angle is helpful in reducing excessively high pitch attitudes. The pilot must apply nose-down elevator and adjust the bank angle to achieve the desired rate of pitch reduction while considering energy management. Once the pitch attitude has been reduced to the desired level, it is necessary only to reduce the bank angle, ensure that sufficient airspeed has been achieved, and return the airplane to level flight.

Nose Low, High Bank Angles

The nose low, high angle of bank upset requires prompt action by the pilot as altitude is rapidly being exchanged for airspeed. Even if the airplane is at a high enough altitude that ground impact is not an immediate concern, airspeed can rapidly increase beyond airplane design limits. Simultaneous application of roll and adjustment of thrust may be necessary. It may be necessary to apply nose-down elevator to limit the amount of lift, which will be acting toward the ground if the bank angle exceeds 90°. This also reduces wing angle of attack to improve roll capability. Full aileron and spoiler input should be used if necessary to smoothly establish a recovery roll rate toward the nearest horizon. It is important to not increase g force or use nose-up elevator or stabilizer until approaching wings level. The pilot should also extend the speedbrakes as needed.

Upset Recovery Techniques

It is possible to consolidate and incorporate recovery techniques into two basic scenarios, nose high and nose low, and to acknowledge the potential for high bank angles in each scenario described above. Other crew actions such as recognizing the upset, reducing automation, and completing the recovery are included in these techniques. The recommended techniques provide a logical progression for recovering an airplane.

If an upset situation is recognized, immediately accomplish the Upset Recovery maneuver found in the non-normal maneuvers section in the QRH.

Figure 8

Extract four from Boeing 737-700 AMM

Maintenance Background

The operator was beginning the process of handing back aircraft previously on lease. To minimise disruption to their operation, the operator and their base maintenance provider (referred to as MRO A) put in place various contracts with third party companies to carry out and supervise any associated maintenance as discrete packages of work. These contracts included a second Part 145 approved MRO (referred to as MRO B) and two project management and oversight consultancy companies (referred to as consultancy companies A and B). These arrangements are shown schematically in Figure 9. The consultancy companies each placed an on-site representative at MRO B's facility where the work was to be carried out. (The Representatives are referred to as Rep A and Rep B, where A and B correspond to the consultancy companies they represent.) These representatives were contracted by the consultancy companies to manage the day-to-day progress of the maintenance input and to handle any additional work requests.

Manual reversion test

The manual reversion test schedule (included in the CDFS) is carried out by switching off hydraulic systems A and B (removing power from the flight controls) and then trimming the aircraft in pitch using the manual trim wheel to determine the amount of adjustment required to trim the aircraft for level flight. The AMM limit, for aircraft configured as in this case, was 12 turns.

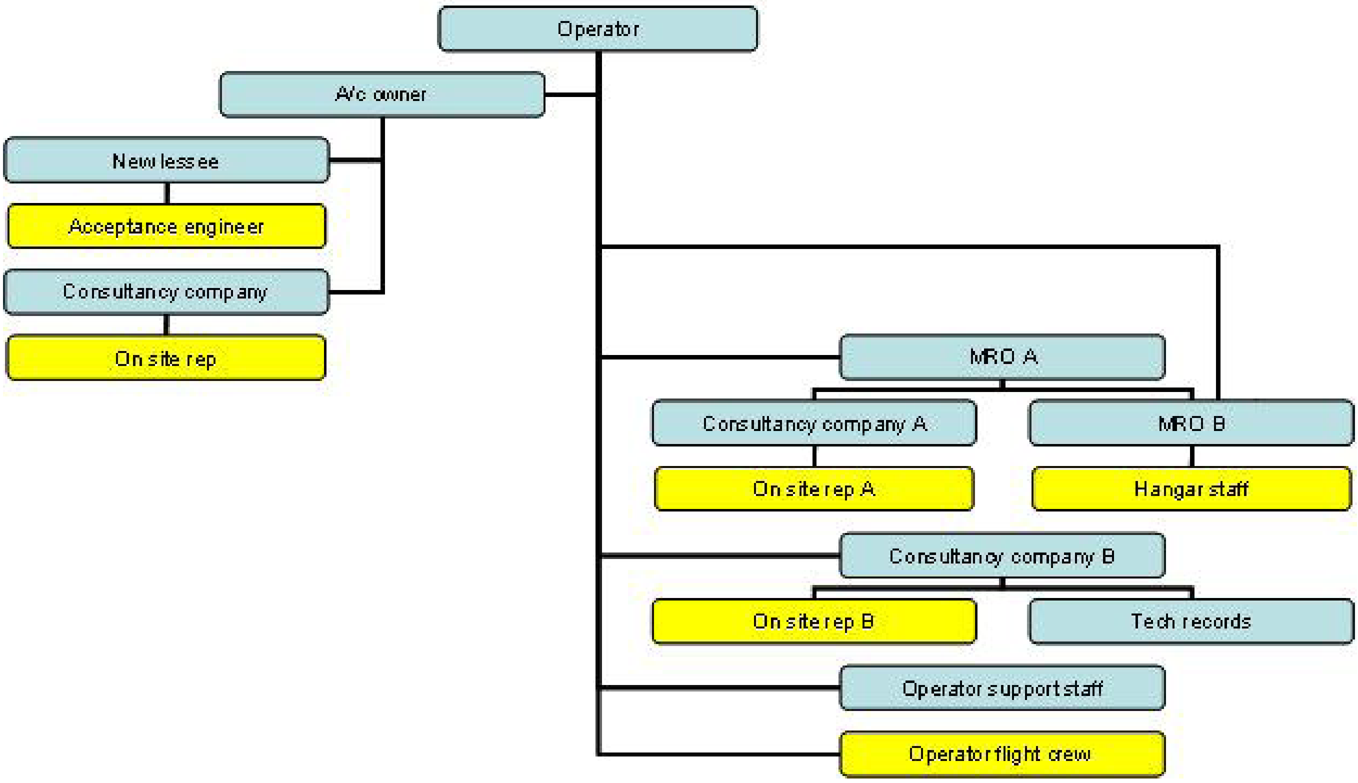


Figure 9

Chart of parties involved in aircraft hand-back (direct involvement in the incident is highlighted in yellow.)

Check flight documentation

The commander of the flight stated that he found the AMM to be poorly constructed and difficult to follow. He also believed that the operator's own check schedule (CDFS) encompassed the requirements of the check and therefore chose not to use the AMM, either before or during the flight check.

Comparison of the AMM with the operator's CDFS identified a number of differences.

The most significant related to the AMM procedure requiring the selection of the cockpit switches for hydraulic systems A and B to be placed directly to the STANDBY RUDDER position during the test. This removes hydraulic power to the flying controls, except the rudder as it requires control forces that are too great for manual control.

In contrast, the operator's CDFS called for the switches to be selected to the OFF position, as part of an additional, unrelated test. The CDFS did not then require them to be selected to the STANDBY RUDDER position prior to conducting the manual reversion test, thereby rendering the rudder inoperable by the pilots during the incident.

In addition, the AMM procedure called only for the autopilot stabiliser trim cutout switch to be selected to the CUTOUT position, whereas the operator's CFDS called for the main autopilot switch to be selected to the CUTOUT position as well. Operation of the stabiliser trim autopilot function during the test would interfere with the manual wheel crank procedure. The main trim, however, should be available to assist recovery during an upset.

Maintenance delivery flight

The aircraft was ferried to Southend for its end-of-lease maintenance on 1 December 2008. During this flight the crew used their CDFS to carry out checks to identify any previously unrecorded defects and allow rectification work to be planned into the forthcoming maintenance input. One of the checks was a manual reversion test. During the test the commander identified that 11.5 turns of nose-up trim were required to trim the aircraft for level flight in the test configuration.

Technical log entries

The operator's policy was not to include 'for information' items in the technical log. The commander considered the policy was applicable to the maintenance delivery flight and, as the manual reversion test result had been within the prescribed AMM limits, he did not record the results of the test he carried out. However, he did record in the margin of the check schedule, next to the manual reversion test item, the words:

> *'11.5 NU [nose up] turns reqd.'*

and on the following page of the CDFS he circled the limits applicable to the CG and wrote '*11.5 act*'.

Post-flight handover

When the aircraft arrived at Southend the commander delivered the aircraft to the MRO B facility and spoke to Rep B as he was representing the operator. (It is possible that Rep A and a member of staff from MRO B were also present for some or all of this discussion.) They discussed the CDFS check findings and the commander reported the result of the manual reversion test, before handing over a copy of his annotated check schedule.

Both Rep A and Rep B recalled the commander suggesting that as the test result of 11.5 turns was close to the limit of 12 turns it should be examined and rectified during maintenance.

After the incident, the commander explained that the results of the manual reversion test could be variable and his comments were focused on his concerns that if the aircraft trim was not adjusted, a repeat test during the end-of-lease acceptance flight might identify the aircraft as out of limits and subsequently be rejected by the lessor. Later the commander stated that he only highlighted the result of the test and did not request that any rectification work should be carried out.

Rep B considered the information provided by the commander to relate to an issue which was present before the aircraft commenced the hand-back process. He therefore judged that it was the responsibility of MRO A to deal with the problem and thus it was a task to be managed by Rep A on their behalf. Rep B stated that he placed the copy of the flight schedule, given to him by the commander, on his desk and did nothing further with it.

Staff communications and company procedures

The quality manager for MRO B reported that it was normal to have a full debrief between their staff, the representatives and the flight crew following a check flight at the end of a maintenance input at their facility. As this was a pre-input delivery flight, which they had not been briefed would include a shakedown check, no debrief meeting was scheduled. He also reported that the aircraft commander had not discussed the pitch trim issue with any of their staff after the flight, and that no MRO B staff had seen or been given a copy of the commander's annotated schedule until after the incident.

Rep A reported that he saw the commander in the hangar after the ferry flight. The commander verbally recounted the results of the manual reversion test, and reportedly suggested this was something that needed to be 'addressed'. Rep A then continued with his day-to-day tasks and did not immediately write down the information provided by the commander during their conversation. He also stated that he had been unaware of the commander's annotated flight schedule and did not see a copy until after the incident flight. About 10 days later, the Rep A remembered the conversation with the commander and raised the subject at a review meeting. As the issue was still outstanding, he compiled a customer request form annotating the task description box with the words:

> *'Ref crew report I/B to Southend stab trim requires 11 turns nose down. Carry out adjustment and check during maintenance input.'*

Rep B was not available for consultation at this time and Rep A submitted the form directly to MRO B staff for action. The form was reviewed and signed by individuals from MRO B's production, commercial and planning departments on 19 December 2008. No additional technical review of the task took place.

MRO B's planning staff raised a work card for the adjustment task the same day, transcribing the description given in the customer request form directly onto a work card. Rep B reported that he remembered inspecting this work card in the rack next to the aircraft, but only to ensure that the work had been raised and would be carried out, not to check the technical content.

The work card was actioned by the maintenance team responsible for the aircraft on 10 January 2009. The

Work Performed section of the work card was annotated with the following:

> *'Elevator tab rods shortened by half a turn at eye end i.a.w. AMM 27-31-00.'*

The licensed engineer amended the work card by hand to include a duplicate inspection task and a flight check task in accordance with the AMM. The duplicate inspection was then carried out, a technical log item was raised to complete the required flight check and the card was certified complete.

The AMM task for the elevator power-off flight test includes troubleshooting steps to be taken in the event of an out-of-limits result, before adjustment of the pushrods is directed. By referring only to the AMM task for adjusting the tab pushrods these steps were overlooked.

MRO B management and hangar staff reported that a request for this type of work was unusual in that it did not relate to a defect in the aircraft technical log and was not accompanied by any source data (eg a crew report). However, as it was in the form of a signed customer request, they carried out the work as specified. Although routinely used, the customer work request form process had not been defined within MRO B's procedures and existed only as a contractual requirement. As such there was no definition of what supporting source data was necessary for a request to be accepted by their production and planning staff.

Following completion of the maintenance input, a combined post-maintenance check flight and end-of-lease customer demonstration flight was scheduled. The engineering team from MRO B printed extracts from the AMM relating to the post-tab adjustment flight check and gave these to the commander of the aircraft prior to the flight.

Previous incident

The CAA MOR database revealed four other reported incidents where the incorrect adjustment of the elevator balance tabs of B737 aircraft had led to an uncontrolled pitch-up or pitch-down during the subsequent check flight. In all cases the aircraft had been safely recovered. This was achieved in two of the incidents by reinstating the hydraulic systems and in a third incident by use of the trim system. In one of the nose-down events there was a reported altitude loss of 900 ft.

The fourth event had occurred to the commander involved in this incident when, in November 2005, he experienced an uncommanded pitch-up during a manual reversion test on a B737-36N with the same operator. Although a different MRO carried out the maintenance and the contributory factors were not the same, the cause of the incident was identified as an incorrect adjustment of the elevator balance tabs. This resulted in a large pitch-up reaction when the hydraulics were switched off during the flight check at FL350. The commander had, in response, rolled the aircraft through about 65° before releasing the controls and reselecting the hydraulics. He was able to re-establish control and repeated the test, this time managing to control the pitch, before landing. The commander informed the CAA Flight Test Department of the event and subsequently received a letter from the CAA's Chief Test Pilot congratulating him on the handling of the situation.

As a result of this incident the commander had acquired a procedure of unknown origin which purported to define a visual check of the elevator balance tabs, intended as part of the post-maintenance walk round checks, to show that they were correctly rigged.

Subsequent incident

The same operator suffered a further incident on 19 May 2009 during another post-maintenance air test to check asymmetrical flight control forces to another Boeing 737-73V, G-EZJN. This was to be conducted together with a Customer Demonstration Flight as the aircraft was about to be returned to its owner at the end of its lease. The crew was composed of three management captains; one of these was the commander of the incident involving G-EZJK who acted as the co-pilot on this occasion. The commander of this flight reported that prior to departure there had been confusion between the three pilots as to which procedure should be followed to conduct the asymmetrical check. After consultation by telephone with the Air Operations Check Flight Manager, the commander finally opted to use the appropriate AMM procedure rather than the check contained in the CDFS.

During the check, some of the required procedures were unintentionally missed and the aircraft experienced a large pitch-down and a moderate roll to the right. The crew were unsure how to proceed with the AMM procedure under these circumstances and opted to use the CFDS instead. In doing so they again unintentionally omitted one of the procedures which resulted in the rudder PCU being un-powered. This made attempts to correct the roll using rudder trim unsuccessful.

B737-700 pitch control system

Description

The B737-700 is fitted with tabs on the trailing edges of the elevator control surfaces. These act as balance tabs to reduce the control forces required to move the elevators and are critical for manual control of the aircraft in the event of a double hydraulic system failure. Two control rods link each tab to the elevator control system such that when the elevators are deflected the tabs also deflect. The position of the tab relative to the elevator is controlled by the length of the rods. Coarse adjustments to the pushrod length are made by rotating the 'eye' end of the pushrods, fine adjustments are made by rotating a vernier fitting (see Figure 10).

Maintenance adjustment

Based on the pilot's report, a 0.05 inch trailing edge down adjustment of the tab was required to achieve neutral trim (although the aircraft was within AMM limits). A review of the adjustment task completed by MRO B staff, as a consequence of the information provided in the customer work request, showed that they calculated an adjustment of 0.105 inch trailing edge up was necessary to achieve neutral trim. The AMM recommends that the tab is only rigged to the nearest 0.01 inch. They noted that a half turn adjustment of the rod 'eye' end gave a 0.1 inch adjustment in the tab trailing edge position, and so elected to round down to this figure to avoid the need to adjust the vernier bushing. A duplicate inspection of the task was completed in line with requirements, but this did not identify any issues. However, the difference between the required and actual adjustment of the tab trailing edge position was roughly equivalent to applying 18 nose-down turns of the trim wheel to a balanced aircraft.

System testing

Currently, the only means of assessing the effect of the balance tab rigging on aircraft trim is to conduct an in-flight check. The procedure for carrying out this elevator power-off flight check is documented in the aircraft manufacturer's AMM. The AMM is primarily an engineering document and is not used routinely by flight crew. The schedule format differs from the types of checklists and schedules normally used by flight crews in that it also contains engineering information.

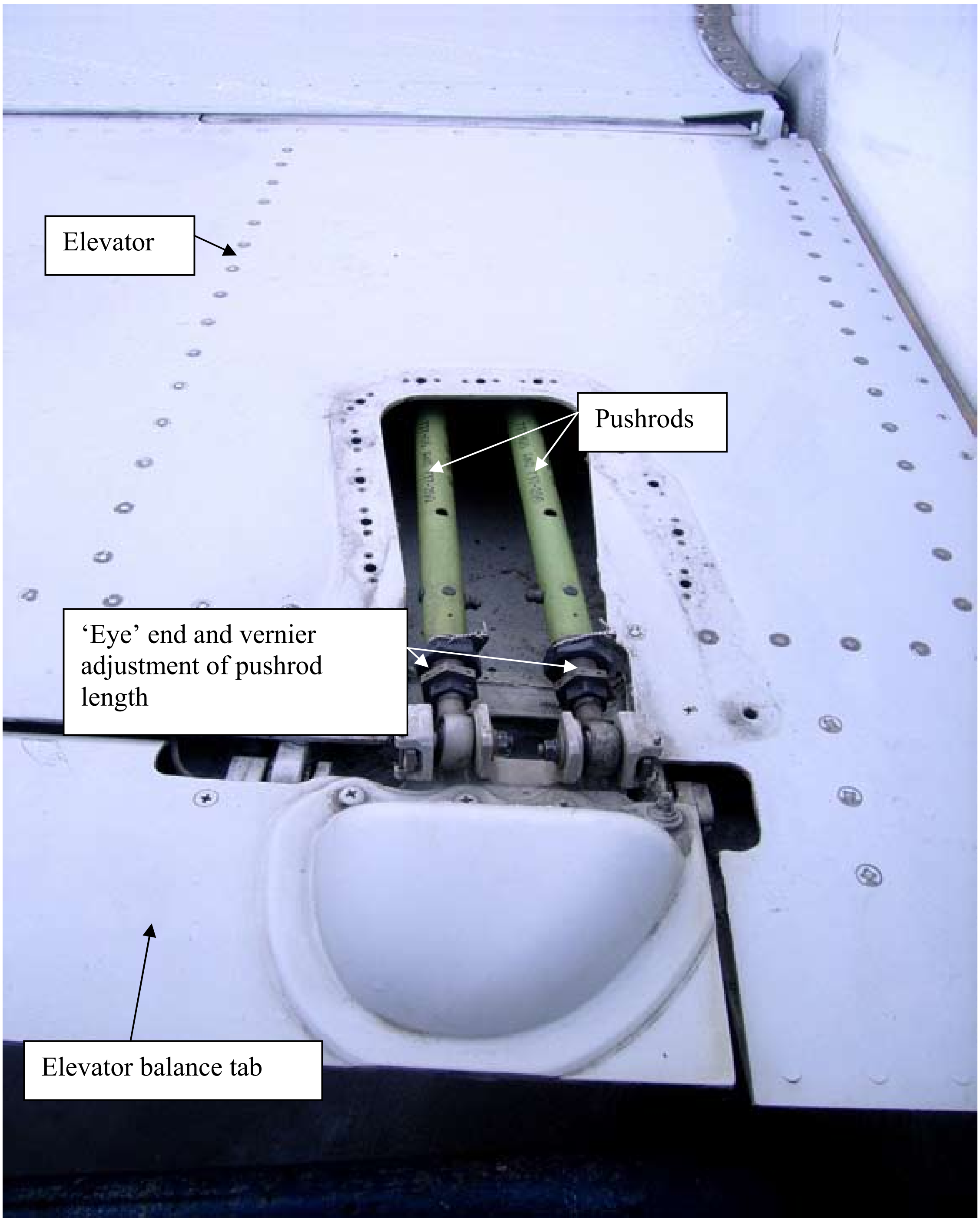


Figure 10

Elevator tab pushrods

Maintenance contractual agreements

A general terms agreement was signed between MRO B and the operator for the end-of-lease work being carried out. This agreement contained several relevant clauses:

- The operator was required to appoint a local representative who had power to act on behalf of the operator in respect to all aspects of the contract.

- MRO B would afford reasonable access to the operator's quality department to perform quality surveillance and audits pursuant to the obligations of the operator's AOC approval.
- The UK CAA was the responsible authority with regard to the contract.
- No unscheduled defect rectification could be deferred or carried out by MRO B unless prior approval was granted by the operator.
- Any check flights were to be performed in accordance with the operator's Continuing Airworthiness Management Exposition (CAME).

The agreement was signed by both parties and accepted by the UK CAA, but had nothing which clearly identified the process, specific approval requirements or responsibilities for technical decision making. The operator's Technical Procedures Manual (TPM) had a whole chapter covering outsourced maintenance and the selection of suppliers. However, these related only to Part 145 maintenance providers. The TPM also had a provision for exchange of information during outsourced maintenance, with a table of required meetings to cover various topics and a schedule of when they should be carried out. This included the requirement for technical review meetings, but did not define a schedule for when these meetings should take place. It was reported that no technical review meetings were carried out during the maintenance input for G-EZJK although daily meetings addressed the progress of the maintenance input.

Additionally, the operator's CAME contained only very brief references to conducting test/check flights. It referenced the TPM, but this also contained no detail regarding how, when, and by whom these flights should be carried out. The operator's Operations Manual covered, in more detail, the flight operations aspects of conducting check flights, but there was no detail concerning the requirements for interfacing with the maintenance organisations involved.

The operator has since produced a detailed Flight Check Supplement in line with advice issued by the UK CAA and has included detailed requirements for check flights in their TPM.

MRO B was audited by the operator's quality department before the first aircraft underwent 'end-of-lease' maintenance. There were no significant findings.

End-of-lease maintenance activity

MRO A and MRO B developed an interface document to cover the end-of-lease maintenance activity. The document covered, in detail, the paperwork, roles and responsibilities, and planning aspects of the working relationship between the two MROs and the operator. It made extensive provision for quality processes and auditing and defined the role of the on-site representative for MRO A. The clause relating to this stated that the representative (Rep A) was required to 'monitor the technical activity of base maintenance work' at MRO B but then expanded this point in terms of planning and progress chasing activities only. It also identified that although MRO A's technical department was responsible for the preparation of engineering orders and repair schemes for the aircraft, the operator's technical department was responsible for in-service issues being raised at the pre-input meeting; Rep A was the 'only person authorised to accept/agree additional work'.

The document referenced a specific procedure for raising additional work requests but this related to the planning and paperwork aspects only. As with the operator's agreement, no reference was made specifically regarding the technical decision making process. The only item requiring additional approval from MRO A's design office related to structural repairs. The document appendices did contain a communication plan that stated incoming defects should be taken from the technical log for the aircraft on the first day of the maintenance input.

Continued airworthiness check flights

Prior to 28 September 2005 all UK registered aircraft were required to undergo periodic check flights to demonstrate their continued airworthiness in accordance with British Civil Airworthiness Requirements (BCARs). These requirements provided information on flight checking for the following purposes:

- Flight testing for type certification
- Flight checking for the issue of a certificate of airworthiness
- Flight checking for the renewal of certificates of airworthiness
- Flight testing after modification or repair

Flight tests required under BCARs are overseen by the CAA which publishes appropriate flight test schedules for the purpose and provides approvals for pilots undertaking the tests. All non-CAA pilots seeking approval are required to undergo a briefing by a CAA flight test specialist. Those pilots checking aircraft at or above 5,700 kg AUW are, in addition, required to have flown an Aircraft Flight Test Schedule on the relevant type with a CAA test pilot.

From 28 September 2005, BCARs no longer applied to those aircraft subject to EASA regulations (this included all variants of the Boeing 737). These aircraft became subject to European Regulations 1702/2003, incorporating Part 21, and 2042/2003, incorporating Part M. This brought about considerable change in the requirement and conduct of airworthiness flight testing, which the CAA attempted to summarise in a document published in April 2006 entitled '*CAA Check Flight Handbook*'.

One of the principal changes was that aircraft regulated by EASA were not subject to the systematic programme of continuing airworthiness flight test (CAFT), previously carried out under the CAA regime at the time of the Certificate of Airworthiness (CofA) renewal or to an agreed flight test sampling programme, under BCAR A/B 3-5. The EASA regulations do, however, place obligations on the CAA, as the National Airworthiness Authority, in respect of aircraft continuing airworthiness monitoring (Part M M.B.303). This can include, as one element, in-flight surveys, although EASA has not published guidance material to define their scope. The CAA has repeatedly sought such guidance from EASA but in the absence of such guidance has not re-introduced in-flight surveys.

The CAA considered withdrawing the flight test schedules from other than their own use but have reconsidered doing so following demands from operators. The schedules remain available together with guidance on their use. This guidance warns of the applicability of schedules which might not have remained valid due to changes to aircraft modification states, especially those from other EASA states.

CAA guidance material

When discussing crewing of check flights the CAA guidance emphasises the importance of the crew fully understanding the significance and intent of the tests, as well as the techniques used to minimise any associated risks. It also warns of the continued suitability of pilots who might have been previously authorised by the CAA, but who will not have been subject to their continued oversight. It recommends that the minimum crew is supplemented by at least one additional person to help record the results and carry out additional tasks such as helping with the lookout. Where additional personnel are carried it also states they should be:

- capable of performing the relevant duties on the Check Flight,
- familiar with the checks to be carried out and their own duties in relation to such checks,
- adequately insured,
- briefed on emergency procedures and use of safety equipment.

Regulatory requirements

The various requirements relating to operator and MRO responsibilities with regard to maintenance and continuing airworthiness are laid out in EU OPS 1, Part M Section A, sub-parts A and G and Part 145. These regulations detail the roles and responsibilities of the operator and any delegated Continuing Airworthiness Maintenance Organisation (CAMO) to which the operator sub-contracts work.

The local CAA surveyor completed an audit of MRO B in May 2008. All findings were closed prior to the start of work on the incident aircraft.

Operator oversight

The company Operations Manual stated that test flights would be performed in accordance with programs issued by the technical department (in effect the Boeing fleet's Technical Captain) in agreement with the flight operations department. It further stated that crews would be assigned by the Flight Policy and Standards Manager. Responsibility for all these functions had, however, been delegated to the commander of the incident flight.

The commander had developed the CDFS and been responsible for the selection and training of pilots conducting flight checks. The processes involved in developing and undertaking check flights appear to have been conducted on a largely informal basis by the operator and there is no evidence that they were subject to audit, either internally or by the CAA.

Check pilot selection and training

Commanders

The commander had first conducted check flights whilst employed as the chief pilot of an air taxi and aircraft maintenance company between 1990 and 1994. He had been approved to conduct Air Worthiness Flight Checks on light aircraft after a day's briefing by the CAA.

He had subsequently been employed as a co-pilot on the Boeing 737 for another operator where he had flown in this capacity on CofA renewal and post-maintenance check flights. He had gained promotion to Captain and then moved to his current operator, where he volunteered to become involved in company aircraft flight check operations.

In 2005 this had led to his approval by the CAA to conduct CofA flight checks. This involved further briefing by the CAA and conducting a check flight under their supervision. At this time the operator also implemented a policy of simulator training for all pilots involved in flight checking. The commander had undertaken two such simulator sessions. This policy was, however, not documented and was later discontinued.

The commander believed that he had conducted approximately 150 flight checks on the B737. At the time of the incident he was the operator's only qualified flight-check captain current on the Boeing 737.

Co-pilots

Selection of co-pilots for undertaking flight checks was done on an informal basis by selecting from a pool of First Officers who had volunteered and been deemed suitable. There were no required qualifications or training for the role. The co-pilot for the incident flight had recently volunteered and had been selected on the basis that he had once flown as a co-pilot during a post-maintenance check flight on an ATR 72 with a previous company. He had received no formal training to conduct such flights but had been sent a copy of the CDFS and some briefing notes prior to the flight. He had also been briefed by the commander during their two-hour taxi journey to the maintenance facility at Southend.

Customer Demonstration Flight Schedule (CDFS)

The operator had previously used the continued airworthiness flight test schedules published by the CAA as their CDFS. However, the operator stated that there was no appropriate schedule available for the Boeing 737-73V at that time.

The commander, as part of his delegated role organising flight checks, had produced a new CDFS based on Boeing document D541A015 737 '*Next Generation Series Production Flight Test Procedures*', Revision G Nov 2003. This was the schedule used by the manufacturer to check aircraft after production prior to their delivery. The schedule is specific to each aircraft at the time of the check and is carried out by qualified test pilots.

The manufacturer is unwilling to release flight check information without assurance that the information is relevant to the specific aircraft under test and that the test is conducted by appropriately qualified pilots. They were therefore not prepared to release a copy of this document to the operator, who acquired an uncontrolled copy unofficially from another source. This was then adapted to serve the purpose of the customer demonstration flights. The operator stated that, to reduce risk, certain items deemed unnecessary, including all single engine tests, pressurisation leak check and some configuration checks near the ground, were removed from their adapted version of the schedule. The finished document was provided in paper form to the pilots conducting the test. The format did not provide specific boxes next to the relevant text for the recording of information required. Instead this was intended to be recorded on a separate sheet of paper attached to the front of the document.

FAA Safety Alert for Operators 08024

This safety alert, released in October 2008, stated that over the past decade approximately 25% of accidents to turbine powered aircraft have occurred during non-revenue flights.

Other current investigations

The AAIB is currently investigating a fire which occurred whilst a Falcon 2000 aircraft was undergoing tests to establish the cause of a braking defect (AAIB

Ref EW/C2009/11/03/03). The investigation identified various issues including suitability of the crew for the task, the status of the tests conducted and the manner in which the test was carried out. This had resulted in a sustained brake fire causing extensive damage to the aircraft.

The French Bureau d'Enquêtes et d'Analyses (BEA) are investigating an accident on 27 November 2008 to an Airbus A320 in which all seven occupants were killed. The aircraft had been on a demonstration flight in France as part of the hand-back process at the end of its lease, when the crew lost control and the aircraft flew into the sea off the coast of Canet-Plage. An interim report was released in 2008 (ISBN: 978-2-11-098614-6) which made the following three recommendations:

'● *that EASA detail in EU-OPS the various types of non-revenue flights that an operator from an EU state is authorised to perform,*

● *that EASA require that non-revenue flights be described precisely in the approved parts of the operations manual, this description specifically determining their preparation, programme and operational framework as well as the qualifications and training of crews,*

● *that as a temporary measure, EASA require that such flights be subject to an authorisation, or a declaration by the operator, on a case-by-case basis.'*

Analysis

At the time of the incident the aircraft had been undergoing a combined post-maintenance and end-of-lease check flight. The investigation considered the requirement for and conduct of these flights.

Customer demonstration flights

Customer demonstration flight checks result from contractual arrangements between different parties and stem from the desire to demonstrate that the aircraft is in an acceptable condition. The extent of the demonstration varies depending on the agreement, but it is likely that the aircraft will be flown with systems deliberately degraded, situations unfamiliar to most pilots. Indeed the demonstration, or elements of it, may duplicate the tests undertaken by the manufacturer at the end of each aircraft's production to satisfy themselves, and their customers, that it is functioning properly.

Airbus and Boeing both consider it necessary to use trained test pilots to conduct these production test flights. This attitude conflicts with the widespread practice of operators producing their own generic demonstration flight schedules, which are then likely to be flown by pilots without any formal flight test qualifications.

Manufacturers are reluctant to provide test schedules suitable to demonstrate the condition of in-service aircraft because they are unable to exert the same control over the procedure that they would themselves if conducting the same tests. There remains a current need for operators to demonstrate an aircraft's state of serviceability under certain circumstances.

Operators have few options other than to devise their own demonstration schedule that meets with the required aims. The CAA airworthiness flight test schedules have proved a popular basis so long as one for the appropriate type exists. Copies of manufacturer's test schedules are also used unofficially. This raises concern as to whether the schedules actually in use have been produced by those with an appropriate depth of knowledge and that they have been subjected to proper scrutiny.

In this incident, the operator was using an out-of-date document obtained unofficially and not subject to any control. The schedule appears to have been produced by one individual and it is unclear what level of scrutiny was applied. It is apparent, however, that elements were not clearly understood, as demonstrated by the switching conducted prior to the test.

This switching left the rudder unpowered. The significance of doing so was that any subsequent rolling manoeuvre was reliant on the ailerons alone, which is less effective. This was of significance when considering the CAA advice in their Check Flight Handbook, valid at the time of the incident, to bank the aircraft to prevent unusually high or low pitch manoeuvres developing.

The switching also resulted in the main trim being unavailable for use during recovery from any pitch upset, the use of which is referred to in relevant sections of the aircraft QRH and Flight Crew Training Manual.

AMM flight test schedule

The anomalies with the customer delivery schedule should not have been a factor in this incident as the flight was intended to carry out a post-maintenance check for which the correct schedule existed and was available. It is of significance therefore that the commander chose not to use it. His main reason for not doing so was that he found the layout of the AMM schedule unclear. This lack of clarity stems from the inclusion of engineering information which may not be directly relevant to the pilot undertaking the test. The following Safety Recommendation is made:

Safety Recommendation 2010-071

It is recommended that Boeing review their published B737 flight test schedules to improve their clarity and suitability for use by pilots conducting such tests.

Flight crew selection and qualification

The nature of the flight being conducted at the time of the incident did not require it to be undertaken by specifically trained or qualified pilots and neither pilot involved had any formal flight test qualification. The commander had been involved in check flights for several years, but had only received one day's briefing from the CAA Flight Test Department with whom he had also carried out a supervised airworthiness flight test. The CAA test pilot who had conducted the commander's briefing stated that the full relevance of the section on flying control checks in the CAA Check Flight Handbook would have been explained to the commander. This was some years prior to the incident, during which time there had been no further briefing or evaluation by the CAA.

The commander's recollection of the CAA briefing was that a banking manoeuvre was necessary to recover from either a nose-up or a nose down unusual attitude. This was reinforced both by the wording of the CAA Check Flight Handbook and the letter he received condoning his handling of his previous pitch-up incident.

The commander had also undertaken in-house training with the operator but again this was some time prior to the incident. Information on dealing with unusual aircraft attitudes was contained in the aircraft QRH and it should therefore be expected that he would have had knowledge of this.

The co-pilot for the flight had been briefed on the flight during the taxi journey to the maintenance base but had otherwise not received any additional training. He had only previously conducted one post-maintenance check flight.

Qualification as a test pilot requires considerable time and expense and as a result is normally limited to military and production applications. The commander was not a qualified test pilot and lacked the depth of knowledge and understanding that such a qualification would confer and which cannot be replaced by experience alone. The distinction between test pilot qualification and experience was not necessarily fully applied by the operator and pilot. Courses exist which are designed to meet the needs of commercial aviation maintenance check flights. Some operators also choose to create small dedicated departments to undertake such tasks staffed by test pilots who obtained their qualifications prior to joining.

Operations management oversight

It is considered that the operator's perception of the commander's experience and technical knowledge of the Boeing 737 led to them relying on him to oversee the fleet check flights more or less single-handedly. The level of oversight afforded to normal operations within the company did not seem to have been applied to this area, despite the increased risk presented by operating outside the normal flight regime. As an example, the commander was not able to supply the source of the visual check used by him for correct adjustment of the flying controls post-maintenance.

This lack of oversight extended to the regulatory bodies which see this area of operation as falling outside their area of competence. This is reflected in the sparse detail required and supplied on non-revenue flights in the company's operations manual.

The operator adopted various measures intended to address these matters after the incident. The subsequent incident to G-EZJN occurred when it was operated by the minimum crew required to conduct the tests, which included an observer to note all the required readings. They were all management pilots involved in the conduct of such testing within the company, yet despite this, there was still a lack of clear understanding about which checklist should be used. Equally, they were unsure how to progress the AMM checklist when the result of the test was not as expected. This lack of full understanding also potentially contributed to their oversight in not complying with the procedures required in the AMM and possibly the CFDS.

Conduct of the flight

Various elements of the flight demonstrated practices which would have been deemed unacceptable in normal operations. The commander was unaware until the last moment which observers would be joining the flight and there was no formal briefing or recognition of their role during the check. This possibly explains why the commander accepted that one observer remained unsecured on the flight deck and without a seat for the duration of the flight, a position he would not have entertained on a normal revenue flight. This was particularly hazardous considering the subsequent nature of manoeuvres conducted as part of the flight.

To allow the co-pilot to concentrate on the flight schedule the commander took on the flying, navigation and radio tasks which in normal events would have been shared. This, in part, was to compensate for the co-pilot's lack of familiarity with that type of flight. The independence of the commander's actions became apparent when things started to go wrong. There was a lack of positive communication when trying to re-establish hydraulic power to the flying controls. This was followed by a lack of any kind of communication between the four people occupying the flight deck for over 1¼ minutes, covering the duration of the event. The co-pilot only realised something was seriously wrong when he heard the commander make a PAN call.

Co-operation amongst the crew would have been enhanced had they all shared a similar level of training and understanding of the procedures they were undertaking. By carrying an observer engaged in the check on the flight deck this would have freed the co-pilot to take a more active role in the flight, allowing him to relieve the commander of some of his workload. The need to carry any more personnel on the flight would be questionable due to the potentially increased risk associated with test/check flights.

Aircraft response during the incident

During the incident flight, the elevator response was always normal when the hydraulics were selected on. The control force provided by the hydraulic system was easily sufficient to overcome the aerodynamic force generated by the elevator tab, giving a level flight position of the elevator of 5° trailing edge down. However, when both hydraulic systems were selected off, the control force applied to the control surface was reduced to that provided by the pilot on the control column. This was insufficient to resist the aerodynamic load caused by the incorrectly rigged balance tab, which subsequently moved the elevator to a zero hinge moment position of 7° to 8° trailing edge down, creating a nose-down pitching moment on the aircraft. Consequently, the aircraft settled at a constant -2.8° pitch attitude with a corresponding increasing airspeed, despite the commander applying as much back column force as he was able.

The commander reported that he did not use the manual trim wheel during the attempted recovery, because he did not want the aircraft to be grossly out of trim when hydraulics were reselected. Movement of the trim wheel changes the angle of incidence of the horizontal stabiliser and therefore the angle of attack of the horizontal stabiliser and elevators for a given airflow. Use of the stabiliser trim would have reduced the incremental lift force generated by the tail and thus decreased the nose-down moment acting on the aircraft. Use of trim is recommended in the AMM to assist recovery and is also a fundamental aspect of this particular test.

Following the commander's roll input, the aircraft banked 91° to the left. In the absence of any other control inputs, this resulted in the continued reduction in pitch attitude and corresponding increase in rate of descent and airspeed. After several seconds the commander began to roll the aircraft level and pull back on the control column again. He applied the same rearward force on the controls as previously but the increased aerodynamic load on the elevators, due to the higher airspeed of the aircraft, meant that control column movement was now less than half of that he had achieved in response to the initial pitch moment after the hydraulics were removed. The commander could not apply sufficient force to the elevator controls to overcome the airloads generated as a consequence of the balance tab position and the high speed of the aircraft. Had no other factors assisted in the recovery, the commander's actions alone would not have been sufficient to prevent the continued descent.

The manufacturer advised the investigation that the aircraft requires an increasing trailing edge down elevator position to maintain level pitch attitude with increasing aircraft speed, otherwise the aircraft will gradually pitch up. During the recovery the commander managed to maintain a constant elevator position of approximately 6° trailing edge down by pulling back on the control column. As the speed increased the aircraft slowly began to pitch nose-up, thereby gradually reducing the forces on the control column and arresting the rate of descent. Once the commander considered that the aircraft attitude had recovered sufficiently, he assessed the switch positions and reinstated hydraulic power to the flying controls to recover the aircraft fully.

Systemic maintenance issues contributing to the incident

This incident raised several systemic issues. The organisational structure created by the large number of individual elements was fragmented and lacked coherence. The key individuals involved, to a greater extent, defined their own boundaries of responsibility and completed only the tasks they felt were encompassed by those boundaries.

From a regulatory perspective the Continuing Airworthiness Management remained with the operator. They complied with this responsibility but the management focus was weighted on the project management aspects of the arrangement rather than the technical elements. The technical decision making responsibilities were devolved to a number of unconnected organisations without a clear organisational structure or adequate definition of interfaces, reporting lines, roles and responsibilities.

The interface document between MROs A and B covered most of the necessary elements but did not provide a clear review or approval process for technical decision making. MRO A placed this responsibility in the hands of an individual on-site representative, who was sub-contracted by a sub-contract company. The situation was compounded by the existence of a second technical representative who had a similar level of responsibility and authority, but was sub-contracted through a separate arrangement with the operator and had a completely unconnected line of report. The interaction and roles and responsibilities of these two individuals were not defined in any common agreement or procedure and clearly became a significant factor leading to the incident.

The consultancy companies and their representatives considered that as they were working under the structure and authority of the operator and MRO, they had no need for their own quality system or procedures. It also meant that neither the companies nor their staff were ever directly audited or assessed by any competent Airworthiness Authority. This placed the burden of responsibility on the contracting customers to have in place defined procedures and roles and responsibilities for the sub-contract staff and to maintain close oversight to ensure integration and compliance with these procedures.

The existing procedures in the operator's TPM covering selection of sub-contract suppliers and outsourcing of maintenance specified that all the companies involved would be fully approved Part 145 organisations. A level of technical competency and existence of a quality system could be assumed by virtue of the competent Airworthiness Authority granting Part 145 approval. The procedures did not take into account unapproved organisations operating in conjunction with an approved company. As such, any assumptions regarding a default level of technical competency for the consultancy companies were no longer valid. This resulted in a high level of technical autonomy in the role of the representatives that lacked any cross-checks or approval processes to address the potential for human factor issues. Quality audits took place during 2008 which assessed MRO B's operation in isolation, but no audits were carried out, either by the operator, the authority or MRO A, which assessed procedures used by the consultancy company representatives or those requiring interaction of the multiple sub-contract organisations in combination.

The tiered sub-contract arrangement for the maintenance meant that MRO B was only contracted to complete specific packages of work. They adopted an unquestioning approach to customer maintenance requests, thereby negating any benefit that may have been gained from their technical expertise or quality system as an approved Part 145 organisation. Had they been more integrated into the hand-back process or had a more robust and properly defined procedure regarding customer work requests, this may have provided the necessary additional checks that could have identified the discrepancy in the wording of the maintenance task instructions.

The lack of coordination of the disparate roles and responsibilities of individuals within all the companies involved resulted in poor communication of important issues and prevented a cohesive response. This allowed a single human factors issue to progress unchallenged through the entire maintenance process to affect a critical aircraft system, almost resulting in the loss of the aircraft.

The UK CAA maintained a responsibility as the nominated competent authority to ensure that delegation of responsibility through sub-contract arrangements met the necessary standards. In this case the operator and MROs were well established and individually had organisations and procedures which were fully compliant, as confirmed by various CAA audits. However, the contractual agreement documents viewed by the CAA did not cover in detail all aspects of the arrangement, particularly the level of involvement of the consultancy companies. The CAA was therefore unaware of the degree of complexity in the organisational structure and the lack of integration.

The oversight of the organisational structure by the UK CAA was not sufficiently informed or detailed enough to have identified the potential issues. This is an area authorities need to be aware of when reviewing future sub-contract arrangements, particularly when responsibility for key technical decision making is delegated to sub-contract staff from companies which would not otherwise be audited or assessed by an airworthiness authority. However, the regulations and regulatory guidance provided by EU OPS 1, Part M and Part 145 do not specifically cater for arrangements involving multiple levels of sub-contracted companies, despite this being common-place within the industry, and particularly relating to non-core activities such as lease hand-backs. The following Safety Recommendation is therefore made:

Safety Recommendation 2010-072

It is recommended that the European Aviation Safety Agency review the regulations and guidance in OPS 1, Part M and Part 145 to ensure they adequately address complex, multi-tier, sub-contract maintenance and operational arrangements. The need for assessment of the overall organisational structure, interfaces, procedures, roles, responsibilities and qualifications/competency of key personnel across all sub-contract levels within such arrangements should be highlighted.

Specific maintenance issues contributing to the incident

At a simplistic level the sequence of events leading to the in-flight incident can be directly attributed to the wording of the customer request form, which recorded the aircraft was out of trim in the nose-down direction rather than the nose-up direction identified by the pilot.

Incorrect transcription of maintenance paperwork is a common human factors problem. Robust procedures and organisational safeguards should prevent the point being reached where aircraft safety is put at risk as a consequence. In this incident the circumstances which initiated the sequence of events can be traced to the fact that the pre-maintenance delivery shakedown flight was not adequately planned, controlled or communicated between the operator and the MROs. There was no written procedure available to all parties that defined the process or the key personnel and their roles and responsibilities. No formal[4] mechanism or controlled paperwork existed for recording test results or significant information during the flight, there was no requirement or procedure for formally debriefing the crew with key maintenance personnel present and no procedure for storage of test results in a controlled manner for future reference. The process relied on single individuals' actions, with no cross checks or approval processes, where critical airworthiness issues were involved. The following Safety Recommendation is therefore made:

Safety Recommendation 2010-073

It is recommended that the European Aviation Safety Agency require AOC operators to have, and comply with, a detailed procedure and a controlled test schedule and record of findings for briefing, conducting and debriefing check flights that assess or demonstrate the serviceability or airworthiness of an aircraft.

The commander and operator had previously experienced a similar check flight loss of control incident following adjustment of the elevator balance tabs on another of their B737 aircraft, although a different MRO carried out the maintenance. A number of other mis-rigging incidents have also occurred in the UK across several operators. The inability to identify mis-rigging of the tab, either physically or procedurally, prior to flight, was common to this incident. As identified earlier under the section 'B737-700 pitch control system', adjustment of the tab trailing edge by just tenths of an inch can have a significant effect on the power-off handling characteristics of the aircraft. The additional safeguard of a duplicate inspection adds no benefit unless a meaningful assessment of the maintenance changes made can be made based on guidance from the AMM. At present the AMM task provides no assistance or advice in identifying mis-rigging of what is a critical flight control system. The AMM task also allows alteration of the tab rigging throughout the entire range of adjustment in a single maintenance action. This creates the potential for gross adjustment errors to be made. Such errors will result in a much more severe 'upset' incident during the subsequent check flight system test. The following Safety Recommendation is therefore made:

Footnote

4 In this context 'formal' is defined as being a controlled/approved process or format, that all parties involved are/were familiar with prior to the flight and anticipate(d) as a deliverable from the flight.

Safety Recommendation 2010-074

It is recommended that Boeing develop an Aircraft Maintenance Manual procedure to identify mis-rigging of the B737 elevator tab control system and amend the Aircraft Maintenance Manual tab adjustment procedure to limit the amount of trim adjustment on any one maintenance input.

Notice of Proposed Amendment - NPA 2008-20 – 'Flight Testing'

This NPA draws a distinction between flight tests and flight checks as described earlier in this report under the section 'flight 'tests' and flight 'checks''. In particular it states that:

> *'during such [test] flights there is a certain amount of unpredictability which does not happen in the case of check flights and acceptance flights.'*

The evidence identified during this investigation and those linked to it, show that whilst this may hold true for the majority of check flights, where no aircraft defects or issues arise, the same level of unpredictability and risk can exist in maintenance and customer demonstration flights when unidentified defects are present or the techniques used by the crew are inappropriate to the situation. The findings from the investigations also show that the existing regulatory requirements in the quoted regulations and the level of oversight of operator compliance are insufficient to prevent serious incidents and accidents occurring.

If the changes discussed in the NPA are considered a minimum standard for the design and production community, (where the level of specialist flight crew training and experience relating to test and check flying is already typically much higher than amongst operator flight crews), this would support a need for the introduction of similar or more restrictive requirements and oversight for operators conducting check flights. This is particularly pertinent given that the potential consequences of operating these flights have proven to be equally severe.

The following Safety Recommendation is therefore made:

Safety Recommendation 2010-075

It is recommended that the European Aviation Safety Agency provide guidance on minimum crew proficiency requirements and recommended crew composition and training for those undertaking check flights that assess or demonstrate the serviceability or airworthiness of an aircraft.

Continuing airworthiness testing requirements

This incident occurred to an operator with a positive safety culture. Evidence from this and the other referenced investigations suggest that this reflects a much wider issue within the aviation community, highlighting the vulnerability of operating outside the normal boundaries of commercial flights.

There exists an EASA requirement for operators to demonstrate and NAAs to monitor the continuing airworthiness of their aircraft. Previously well established methods of doing so, such as those operated by the CAA, have fallen into disuse due to the lack of regulatory guidance. The manufacturers too, maintain a cautious approach to the issue for the reasons explained in the Customer Demonstration Flight Schedule section. This incident and the accident to the Airbus A320 in France on 28 November 2008 point to the inherent dangers of the industry attempting to conduct this type of operation without suitable guidance. The following Safety Recommendation is therefore made:

Safety Recommendation 2010-076

It is recommended that the European Aviation Safety Agency provide guidance to National Airworthiness Authorities on monitoring continuing airworthiness.

From such work it should be possible to determine a means to provide the reassurance sought when returning aircraft to their owners, whilst limiting the requirement for associated air tests.

Safety action

The following safety action has been taken since this incident occurred:

- Boeing has amended the wording of the flight test task in the latest revision of the AMM designed to improve ease of use and reduce the likelihood of incorrect interpretation.
- Boeing has issued Service Letter 737-SL-27-211 which provides further advice on rigging the elevator tabs and conducting post-adjustment check flights.
- The UK CAA has published Airworthiness Communication (AIRCOM) 2009/03 to raise awareness of the issues relating to the co-ordination between operators and maintenance organisations surrounding the conduct of maintenance check flights. It has also issued Flight Operations Division Communication (FODCOM) 15/2009 regarding the definition, preparation and conduct of check flights. It also advises on crew qualification requirements and the need for co-ordination with relevant maintenance organisations to ensure information is formally documented and distributed.
- The operator has carried out an internal investigation into the incident. This identified the causal and contributory factors discussed in this report and made 38 safety recommendations.
- The UK CAA has re-written Section 3, Tech 2, Part 10 of the CAA Check Flight Handbook to ensure its previous advice in dealing with a pitch down incident is not misinterpreted.
- MRO(B) conducted an internal investigation which addressed the formalisation of the customer work request procedure and introduced a procedure to improve flightcrew/maintenance interface.

SERIOUS INCIDENT

Aircraft Type and Registration:	Boeing 737-86N, SE-RHX
No & Type of Engines:	2 SNECMA CFM 56-7B turbofan engines
Year of Manufacture:	1999
Date & Time (UTC):	9 May 2010 at 0034 hrs
Location:	Vienna, Austria
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 7 Passengers - 189
Injuries:	Crew - None Passengers - None
Nature of Damage:	Left wing firewire failed insulation check, ruptured flexible duct on right air conditioning pack
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	50
Commander's Flying Experience:	11,660 hours (of which 985 were on type) Last 90 days - 93 hours Last 28 days - 9 hours
Information Source:	AAIB Field Investigation

Synopsis

During the departure from Sharm el Sheikh, the left WING-BODY OVERHEAT caption illuminated and the crew shut down the left air conditioning pack in accordance with the non-normal checklist. After approximately 3.5 hours, the right air conditioning pack failed and cabin pressurisation was lost. The crew performed an emergency descent and diverted to Vienna.

An engineering investigation determined that the left WING-BODY OVERHEAT indication was spurious and the failure of a hose in the right pack had caused the loss of pressurisation.

History of the flight

The aircraft departed Manchester Airport at 1411 hrs on a charter flight to Sharm el Sheikh arriving at 1928 hrs. The flight was uneventful and following a short delay during the turnaround and refuel, it departed at 2054 hrs on the return flight to Manchester. The takeoff was from Runway 04R, in good weather with a radar vectored departure and climb initially to FL320 before a further climb to the final cruising level of FL360. The aircraft commander was seated in the right seat and was carrying out line training for the captain in the left seat who was the pilot flying for the sector.

As the aircraft passed an altitude of 6,500 ft, the master caution illuminated and a left WING-BODY OVERHEAT caption illuminated on the air conditioning control panel. The crew performed the non-normal checklist items which required them to close the isolation valve, select the pack valve to OFF and close the engine bleed valve. Having confirmed that the checklist was complete, the crew reviewed their options whilst continuing the climb and satisfied themselves that there was no likelihood of structural heat damage occurring. There were no limitations imposed by the non-normal checklist or the Minimum Equipment List for operating with a single pack once airborne. They elected to continue to Manchester following the flight planned route and levels with regular checks of the pressurisation system.

Approximately 3.5 hours into the flight, the commander noted that the cabin differential pressure had reduced to 7 psi and the cabin altitude had risen to 9,000 ft with the outflow valve indicating fully closed. The commander was the handling pilot at this time because the captain had left the flight deck on a comfort break. As the captain returned to his seat, the master caution caption illuminated and the CABIN ALTITUDE audio warning sounded. The commander checked the position of the outflow valve which indicated closed and the cabin altitude which was climbing past 9,000 ft. Both crew members donned their oxygen masks and as the commander was still the pilot flying, he initiated an emergency descent, declared a MAYDAY and deployed the passenger oxygen masks. The descent was made straight ahead using the level change and heading modes of the autopilot with speed brakes deployed. Control of the aircraft was passed to the captain whilst the commander established that the Minimum Sector Altitude (MSA) was 8,700 ft. The crew agreed to set an initial level off altitude of 12,000 ft on the Vienna QNH of 1010 mb, which the captain selected using the altitude selector on the mode control panel.

During the descent the commander made an announcement to the cabin crew using the public address system notifying them of the emergency descent. He also reviewed the cabin altitude warning and emergency descent procedures and checked the pressurisation panel to see if he could manually control the pressurisation, but this was not possible. The aircraft was levelled off at 10,000 ft and the commander and the captain removed their oxygen masks. Following a short discussion, they requested a diversion to Vienna. ATC provided radar vectors for an ILS approach to Runway 34 and descended the aircraft in order to position it.

The commander called the Senior Cabin Crew Member (SCCM) to the flight deck and having established the wellbeing of the passengers and cabin crew, explained the nature of the problem, his intentions, the time scale for arrival in Vienna and that there were no special requirements. This is commonly referred to as a NITS briefing. The SCCM had no questions and returned to brief her colleagues and prepare the cabin for landing.

The weather at Vienna at 0020 hrs was 310°/05 kt, visibility 30 km, cloud few at 4,100 ft, broken at 5,000 ft with an OAT of +12°C and a dew point of 9°, QNH of 1009 hPa. The aircraft made a straight-in-approach and normal landing on Runway 34 at Vienna before taxiing to the parking stand and closing down.

Following the incident, the aircraft was flown unpressurised by a ferry crew, without passengers, to the maintenance organisation at Lasham Airport.

Flight Recorders

The aircraft was equipped with a flight data recorder (FDR) and cockpit voice recorder (CVR) capable of recording a minimum duration of 25-hours of data and 120 minutes of audio respectively. Recorded information relating to the left and right air conditioning system included the pack on/off status, pack flow mode and engine bleed air switch positions.

FDR data was available for the entire flight, with the CVR record commencing one hour twenty minutes prior to the activation of the cabin pressure warning and ending shortly after the aircraft had landed. The CVR record did not include the time period when the left wing body overheat warning had occurred. In addition to the incident flight, the FDR also contained records of four previous flights and the subsequent positioning flight from Vienna to Lasham Airport. A time history of the relevant parameters during the incident flight is provided in Figure 1.

The takeoff was uneventful, but as the aircraft climbed through 6,500 ft, the master caution was activated. Shortly after, the number one engine bleed air switch was selected OFF, in accordance with the QRH left wing-body overheat procedure. The QRH procedure also required that the left air conditioning pack be selected OFF. The left pack flow mode parameter subsequently changed from the low flow to the high flow/off indication, as would be expected if the pack had been selected OFF, but the left pack on/off parameter continued to indicate that the left pack was still ON; a defect was subsequently identified in the left ECS, whereby the pack falsely indicated that it was ON when set to the OFF position.

During all six flights, the right pack had continually indicated that it was in the high flow mode, but this was later confirmed as being an indication fault.

System description

The aircraft is equipped with two air conditioning packs, which are independently controlled and provide conditioned, pressurised air to the cabin. The cabin pressure is regulated by the position of the outflow valve, which allows air in the cabin to vent to atmosphere. This valve, and hence the cabin pressure, is controlled by one of two redundant Cabin Pressure Controllers when the automatic mode is used and directly by flight crew when the manual mode is used.

Each pack is provided with bleed air taken from the 5th and 9th stages of the engine compressor, with the 9th stage providing compressed air at low engine speeds and the 5th stage at high engine speeds. The High Stage Regulator (HSR) automatically opens a valve to switch between the two sources of air. The air then passes through the Pressure Regulating and Shutoff Valve (PRSOV), which controls the flow of air to the pneumatic manifold (duct). An Isolation Valve in the duct isolates the left and right side of the duct such that in normal operation the left engine provides air to the left pack and the right engine to the right pack. A Flow Control and Shutoff Valve (FSOV) allows pressurised air in the duct to enter each pack.

The air conditioning packs can operate in one of two modes, 'low' and 'high flow'. Normally the packs are selected on auto and will operate in 'low flow'. If one pack fails, or is selected OFF, then the remaining pack will automatically switch to 'high flow' provided the flaps are not extended. The flight crew can also switch each pack manually to 'high flow'.

The pneumatic manifold runs from each engine, along the wing leading edge to the air conditioning packs, which are located at the bottom of the fuselage, outside

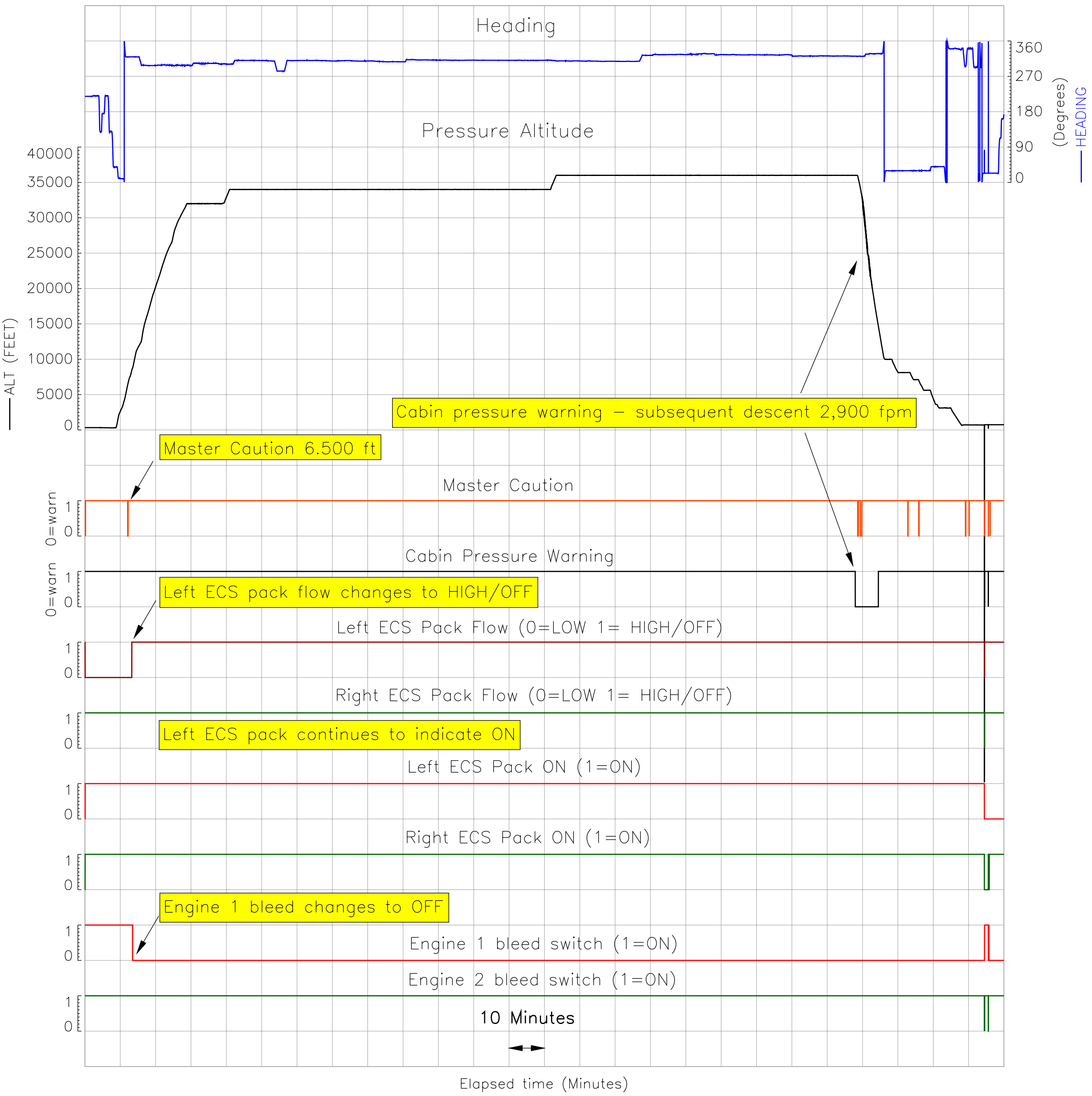


Figure 1

Salient FDR parameters (SE-RHX 9 May 2010) the pressure hull. A firewire, routed alongside the duct, provides the flight crew with an overheat warning.

Engineering examination

Passenger and crew oxygen

The AAIB undertook an initial examination when the aircraft landed at Lasham. All the oxygen masks in the cabin had deployed and all the oxygen generators had activated. The 'Pass Oxygen' switch on the flight deck had been operated. The 'crew oxygen' contents gauge read 1,400 psi.

Fault finding

An engineering investigation undertaken by the operator identified the following faults in the cabin pressurisation system:

- BITE check on the CPC showed fault Code 30 appearing on alternate legs over the last 20 flights. The Boeing fault-finding chart attributes the possible cause to *'low pack flow, low pneumatic pressure, or excessive fuselage leakage'*.

- BITE check carried out on the Wing Body Overheat Module showed fault Code 14. Firewire M268, located along the left wing leading edge, failed the insulation check. The fault was cleared by replacing the firewire.

- An air leak was found from a split in a flexible hose (AS1505-18A0042) located on the right pack between the Air Cycle Machine and the Condenser. The fault was cleared by replacing the flexible duct.

- A confidence check carried out on each air conditioning pack (AMM 21-00-05-780-801) found that the duct pressure was outside the published limits. With the engines at idle, the minimum duct pressure should have been between 18 and 20 psi, but was found to be 8 psi and 15 psi for the left and right engines respectively. At an engine speed of 72% N_R (33%N_2), the minimum duct pressure should have been 26 psi, but was found to be 15 psi and 24 psi. The left engine PRSOV and the HSR on both engines were replaced and the aircraft passed the confidence check.

The operator also carried out an investigation to establish why the indications on the FDR showed the right pack at 'high flow' during both the accident flight and the five previous flights, and the reason why the left pack indicated ON after the crew stated that they had turned it OFF. The investigation discovered:

- There was an open circuit in the cable (W410-0489-24) between the No 1 Flight Management Computer and the right Air Conditioning Accessory Unit, which provides the signal to indicate if the right pack is in 'high' or 'low flow'. The fault was traced to a connection in the avionics bay where a pin had come out of its connector (Pin 3, DFD1002A). The fault was cleared by replacing the pin.

- With the left pack switched OFF, and the duct still pressurized, the pack would indicate ON and the indication would only change to OFF when the right pack, or APU, was turned OFF. The fault was cleared by replacing the left FSOV.

Examination of right duct flexible hose

The flexible hose from the right pack had evidence of abrasion on the top and sides of the folds (concertinas) where the failure had occurred, (Figure 2). There was also evidence that the reinforcement metal rings had cut through the hose.

The hose had been correctly fitted to the pack and there was nothing in the vicinity that might have caused the abrasions, (Figure 3). It is suspected that the some of the abrasions might have occurred as a result of the folds on the hose rubbing against each other.

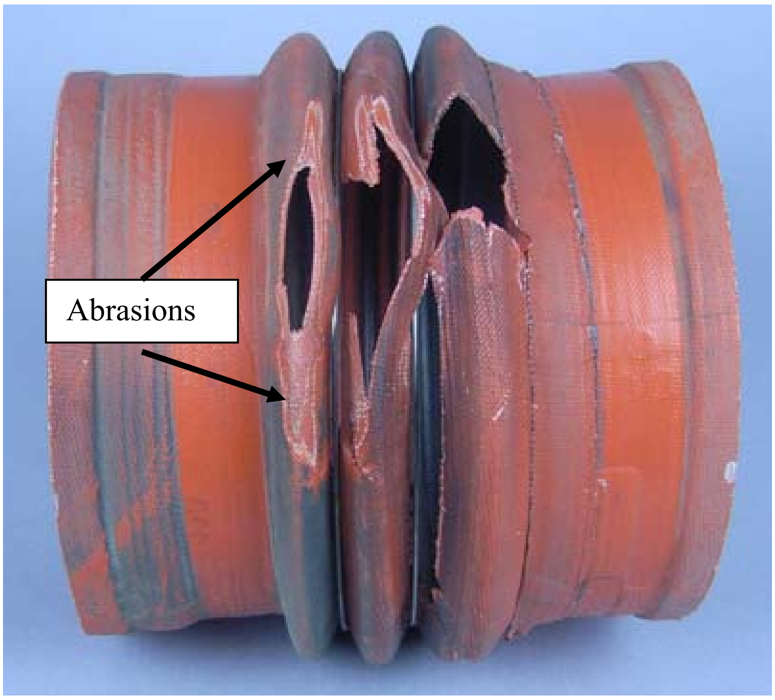


Figure 2

Failed flexible hose from right air conditioning pack

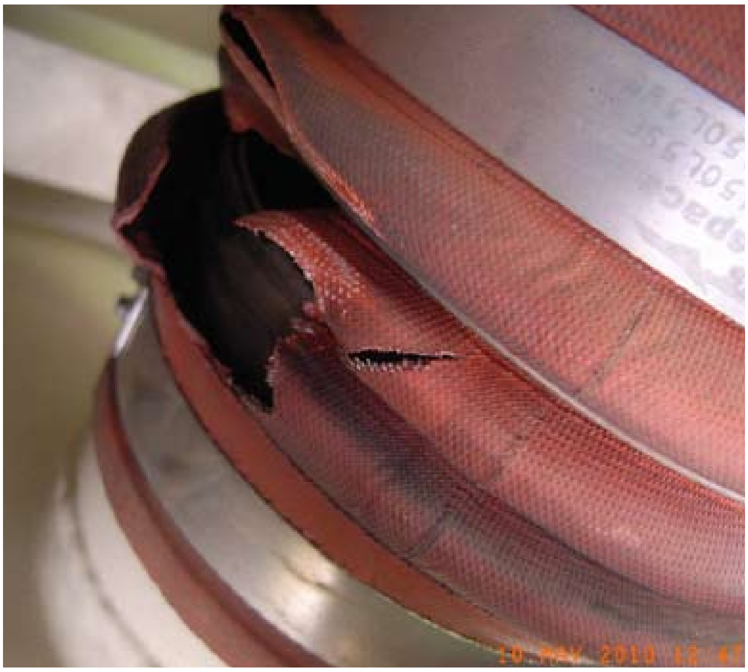


Figure 3

Flexible hose installed on the right air conditioning pack

Previous occurrences

The aircraft manufacturer advised the AAIB that there have been three reported failures of this hose since 2004. However, they were only able to inspect one of these hoses and attributed the failure to

> *'the reinforcement metal rings wearing away the silicone and reinforcing fibreglass at several locations in the hose.'*

Analysis

The engineering investigation determined that the incident occurred as a result of two separate faults in the aircraft air conditioning system. As the aircraft reached 6,500 ft the left wing body overheat light, and the master caution, illuminated as a result of a fault in the firewire. The crew acted in accordance with the QRH by shutting down the left air conditioning pack, which would have resulted in the right pack automatically changing to 'high' flow. The aircraft continued to climb to its cruising level and approximately 3.5 hours later, whilst at FL360, a flexible hose in the right pack failed. The leak was such that the single pack could no longer maintain the cabin pressure, which slowly dissipated. The investigation was unable to establish the initiating factor that caused the hose to fail.

Although the air conditioning pack confidence checks established that the duct pressures were below the specified minimum, the flow from the right pack was sufficient to maintain the cabin pressure for almost 3.5 hours. Therefore, the faults on the PRSOV and the HSR were not considered to be causal to this incident.

The flight crew successfully carried out the emergency descent actions in accordance with the non-normal checklist and the operator's Standard Operating Procedures resulting in an uneventful diversion and landing.

ACCIDENT

Aircraft Type and Registration:	Bombardier CL600-2B19 CRJ200, D-ACHA
No & Type of Engines:	2 General Electric CF34-3B1 turbofan engines
Year of Manufacture:	2000
Date & Time (UTC):	13 November 2008 at 0900 hrs
Location:	Manchester Airport
Type of Flight:	No flight planned
Persons on Board:	Crew - None Passengers - None
Injuries:	Crew - N/A Passengers - N/A Others - 1 (Serious)
Nature of Damage:	Nose landing gear damaged
Commander's Licence:	N/A
Commander's Age:	N/A
Commander's Flying Experience:	N/A
Information Source:	AAIB Field Investigation

This occurrence did not meet the description of an accident or serious incident, as detailed in The Civil Aviation (Investigation of Air Accidents and Incidents) Regulations 1996. However, considering the air safety lessons which could be drawn from it, the Chief Inspector ordered an investigation under Regulation 8(4) of those Regulations.

Synopsis

Whilst a technician was rectifying an under-inflated tyre, a pressure of approximately six times the normal tyre pressure was developed. The tie bolts on the wheel failed, the assembly exploded and the technician was seriously injured.

Two Safety Recommendations are made.

Background

During the pre-departure inspection on the aircraft, before an evening flight, one of the flight crew noted a small cut in a main-wheel tyre tread. He reported his findings to his company's main engineering control centre in Cologne. They determined that the damage was beyond acceptable limits and advised the crew. The flight was cancelled and preparations were made to rectify the defect.

A technician from one of the operator's bases in Germany was tasked with carrying out a wheel change and also directed to carry out the five-day maintenance check which was shortly due on the aircraft. He travelled to Manchester the following morning, taking with him a wheel-change kit and a spare main-wheel with a tyre already fitted. The latter was inflated to the standard low figure of approximately 50 psi, as released from the company tyre bay.

Following his arrival, the technician was met by staff of a local line maintenance company and was taken, with the spare wheel/tyre and the wheel change kit, to the remote stand to which the aircraft had been towed. A nitrogen pressure rig, the property of the company, was also taken to the aircraft in anticipation of the requirement to inflate the replacement tyre fully once it was fitted to the aircraft.

As the technician worked on the aircraft, another company employee occupied its cabin, performing unrelated tasks.

The maintenance task

The technician elected to carry out the five-day maintenance check before the wheel change. This included a check of all tyre pressures, using a gauge carried within the wheel-change kit. He determined that the right nosewheel tyre was slightly under-inflated and utilised the nitrogen pressure rig to replenish it. The technician was unfamiliar with the rig and had difficulty operating it. He subsequently informed the BFU (German Federal Bureau of Accident Investigation) that he initially opened the valve of one of the bottles using the special spanner provided. He did not check the pressure gauges on the regulator valve, nor did he adjust the valve. Before making the connection to the tyre he confirmed that gas was flowing from the inflator when its lever was activated.

He stated that he then screwed the adaptor into the nosewheel tyre valve. He briefly pressed the inflator lever twice and had the impression no nitrogen entered the tyre. He unscrewed the adaptor and checked the tyre pressure again using the gauge brought with the wheel-change kit. He found that the tyre pressure had decreased by 5 psi. He then re-connected the adapter to the tyre valve. He pressed the inflator lever once or twice again and the wheel burst.

Wheel fragments were scattered across the apron and serious injuries were inflicted on the technician. On hearing the explosion and feeling the aircraft move, the other company employee exited the cabin and noted the sound of escaping gas as he went to the assistance of the injured technician.

Design of wheel and pressure rig

Wheel

The wheel was one of a pair mounted on a common axle on the nose leg of the aircraft. It consisted of two forged halves joined by eight tie bolts. It was small in diameter (approximately 29 cm) and the tyre cross-section was also small (approximately 10 cm x 10 cm). The normal inflation pressure was 163 psi. (Tyre pressures, as well as all system pressures, are quoted in psi in the CRJ 200 manufacturer's maintenance manuals and other technical documentation.)

Provision for an over-inflation pressure relief valve was present in the wheel design. Incorporation of this feature was an operator option but it was not fitted to either of the nosewheels on this aircraft. The wheel manufacturer stated that, during development, an uninstalled wheel/tyre combination was subjected to an over-inflation test. Following steady inflation with two three-second pauses, the wheel failed at 997 psi pressure as a result of tensile rupture of all eight tie bolts.

Pressure Rig

The origin of the pressure rig could not be established; no external type identification was present and the owning company were not able to state when or by whom it was built. It did not appear to be a standard proprietary design in that nobody was able to identify any other identical rigs at Manchester or elsewhere.

The unit consisted of a light trailer carrying two horizontally orientated nitrogen cylinders and a locker containing pneumatic components. Each cylinder incorporated a standard, spanner-operated shut-off valve and had a rated pressure of 230 bars (3,335 psi).

The rig had only one adjustable regulator controlling both cylinders. A flexible hose from each cylinder was connected to a manifold, from which a single pipe was routed to the regulator positioned directly above. Both the manifold and the regulator were housed in the locker. The regulator incorporated two gauges, one measuring the pressure supplied from the gas bottles, the other measuring the delivery pressure to a long flexible hose supplying the inflator. The regulator was of a widely used type and did not incorporate any annotations by which the position of the control knob could be referenced; pressure setting relied on rotating the knob until the observed delivery pressure on the appropriate gauge reached the desired figure. The regulator was configured to be capable of delivering gas at pressures of up to 1,500 psi.

The inflator, incorporating a valve operated by a trigger lever, supplied a shorter flexible delivery hose. The hose was connected to the inflator via a bayonet fitting, with a tyre valve connector at its opposite end. A pressure gauge was mounted on the inflator unit, metering the pressure downstream of the lever operated valve. Two delivery hoses were available, with alternative end fittings, enabling different sizes of tyre valves to be serviced.

The pressure gauge, metering the supply from the gas bottle(s) in use and mounted on the regulator valve, was calibrated from 0 to 4,500 psi, with a co-incident scale in bar. The other gauge on the regulator valve, metering the delivery pressure to the inflator, was only annotated in the range 0 to 400 bar. The gauge on the inflator was calibrated in the range from 0 to 350 psi.

The design of the inflator incorporated internal galleries of small cross-section to limit the rate of rise in tyre pressure. The manufacturer stated that it was intended to be used with an in-line regulator. It was labelled accordingly but no regulator characteristics were specified. The inflator manufacturer also stated that their units were supplied to both builders of rigs and as stand-alone inflators to airlines and aircraft maintenance companies. The manufacturer, a supplier of tyre inflation equipment to the aviation industry, indicated that the gauge on the inflator would suffer permanent deformation of the pressure capsule at applied pressures above 500 psi.

Although an annual overhaul of the inflator was recommended by the manufacturer, their records showed that this inflator had not been returned to them since build. The inflator was supplied to the line maintenance company on 13 April 2005.

No operating instructions or warnings were visible on the rig. The only annotation was the name of the owning company.

Examination of aircraft wheel and pressure rig damage

The right hand nosewheel of the aircraft had failed in such a way that the outboard wheel-half had been ejected, with a section of its rim separating either during wheel failure or at subsequent impact. The inner wheel-half had shattered into a large number of fragments. These were scattered widely around the apron. The central nut securing the wheel to the axle had separated in a manner consistent with being driven axially along the thread by a substantial force. Seven of the eight tie bolts had failed and their parts were distributed about the apron. Subsequent metallurgical analysis revealed that each bolt had suffered staged tensile rupture near the run-out of the thread forms. The tyre was lying nearby having sustained no significant damage.

Overload failure of all but one of the tie bolts was the initial mechanism of the failure. No pre-existing defect was identified in the wheel, tyre or bolts. The characteristics of the failures were consistent with a series of increasing tensile loads which eventually exceeded the yield point of the bolt material.

The rig was examined some hours after the accident and it was noted that the supply pressure gauge to the regulator from the manifold was registering 500 psi; conversation with a flight-crew member from the operator, who made his way to the aircraft following the accident, revealed that it had been noted as reading 700 psi shortly after his arrival. The delivery gauge pressure from the regulator valve was reading zero. The gauge on the inflator was registering 30 psi and remained at that figure.

During the initial examination, the gas continued to escape audibly from some part of the system. One of the rig owner's technicians, familiar with the rig, was asked to make it safe. It was observed that he screwed the regulator valve fully shut and used the spanner provided to shut off the gas bottle.

The delivery hose, incorporating the smaller of two tyre valve connectors which had been in use at the time of the accident, was severely damaged in the event. The fitting of the bayonet connection between the output end of the inflator and the delivery hose had fractured, leaving one end of the inflator still lodged within the body of the hose end fitting. The remains of the tyre valve were identified within the other end fitting. The delivery hose had failed at both swaged joints to the end fittings, ie at the inflator end and at the tyre valve end. The supply hose to the inflator, from the regulator valve, was not damaged.

Further examination and testing

An examination of the inflator and its connections to the supply and delivery hoses was carried out by the inflator manufacturer, in the presence of the AAIB. It was noted that a number of components were not of the type manufactured or utilised by the inflator manufacturer and that the last assembly of the unit had used sealants which differed from those invariably used by them for manufacture or during overhaul of units returned to them. Also, the felt type air filter was excessively contaminated suggesting that it had been subjected to prolonged use without replacement.

Examination of a newly assembled inflator was carried out, followed by a functional demonstration. This showed that once the delivery hose was connected to the valve of an inflated tyre, the pressure of that tyre registered on the gauge mounted on the inflator. Once the lever on the inflator was slightly depressed, the pressure in the tyre was lowered as a result of a small flow of nitrogen venting from the body of the inflator. The decreasing tyre pressure continued to register if the lever remained slightly depressed and also registered if the lever was released.

With the lever further depressed, pressure was supplied to the tyre. Whilst this pressure was delivered, porting within the inflator isolated the gauge, preventing it from registering any pressure figure. On release of the lever the newly increased pressure registered on the gauge.

The damaged inflator was then dismantled and its parts examined. It was noted that a secondary seal was severely worn and one of two ring seals was absent from the main spool valve.

The inflator was re-assembled using its same internal components but with a new pressure gauge and replacements for the fractured and damaged external components. The re-assembled unit was then connected to a supply hose, with an appropriate regulator, and to a delivery hose. It was functionally tested.

Once the delivery hose was attached to the valve of an inflated tyre, it was noted that the tyre began to deflate immediately in the same way as it had done when the lever on a correctly functioning inflator was slightly depressed, ie with nitrogen escaping from the inflator unit. During this process the gauge continued to register the decreasing tyre pressure. With full depression of the lever, the tyre inflated in the normal way and the inflator mounted gauge did not register.

Subsequent testing of the regulator unit in the manufacturer's high pressure facility confirmed that the gauges mounted on it remained accurate. Adjustment of the control knob enabled the delivery pressure to be reduced progressively to lower figures until complete shut-off was reached. No delivery pressure creep was observed when the valve was left for a period at mid settings with a high pressure supply connected.

Technical personnel

The technician who was injured had been employed as an aircraft maintenance engineer with the operator, in his native Germany, for 16 years. He had accrued 10 years experience as a LCT (Large Civil Transport) aircraft mechanic holding the highest qualification, Cat B1 Licence, on four types of aircraft. He was fully familiar with the task of inflating aircraft tyres and familiar with the use of pressure rigs. However, he subsequently stated that he had not previously encountered the type of pressure rig in use on this occasion.

General

The local line maintenance company had no approvals or qualified personnel enabling them to provide technical support on the aircraft type, other than supplying general purpose tools and equipment. This was their role at the time of the accident. Documentation supplied by them indicated that the two gauges on the regulator, as well as that on the inflator, had all been calibrated by a qualified company during the previous 12 months. The gauges were annotated accordingly. No records were kept of the usage pattern of the rig. Therefore, the setting of the regulator at the time the work on D-ACHA's nosewheel began was unknown.

The manufacturer of the inflator stated that its records indicated that the component had been supplied to the third party maintenance company three years before the accident. They had no record of it being returned to them for overhaul/repair in the intervening period. They did not publish overhaul manuals for their inflator for distribution outside their own organisation, nor did they supply spares to enable overhaul to be undertaken by other organisations. Thus, without returning inflators to the manufacturer on an annual basis, their recommendations could not be carried out.

Those which were periodically returned for overhaul were frequently noted as being in the possession of organisations other than the original customers. Airline bankruptcies and company take-overs complicated the task of tracing the whereabouts of inflators once they had been delivered to airlines and maintenance companies as stand-alone items. It was not, therefore, feasible for the inflator manufacturer to successfully notify operators when the overhaul dates became due.

Examination of other pressure rigs

Mobile pressure rigs are categorised as tools and are not subject to regulation of design, maintenance and operation by the airworthiness authorities, in the same way as aircraft. All such equipment and working practices in the UK are subject to regulation by the Heath and Safety Executive (HSE). They advised that the Health and Safety at Work Act 1974 and the Provision and Use of Work Equipment Regulations 1998 (PUWER) encompass the use of this type of equipment. These regulations only apply in the UK.

Use of high pressure air supplies involves potential risk and it is important that pressures higher than the maximum design pressure are not supplied to pressure vessels, including tyres. Civil aircraft tyres rarely operate at pressures exceeding 300 psi, whereas certain other pressure vessels on aircraft, such as hydraulic accumulators and landing-gear struts, can have rated pressures of many times this figure. Numerous types of pressure supply equipment are used on airport aprons and in maintenance facilities worldwide. Some items are dedicated to special purposes, with appropriate pressure capabilities, whilst others are general purpose rigs designed to supply any pressure up to the maximum needed by the components with the highest pressure ratings in any aircraft. In general, rigs of a type used for both tyre inflation and inflation of higher pressure components have separate controls and individual regulators for each pressure range. They are usually appropriately annotated and often colour coded to prevent inadvertent connection of the higher pressures to tyres and other vessels requiring only low pressures.

Some aircraft manufacturers supply man-portable, dedicated tyre inflation rigs. These have maximum pressure capabilities, limited to figures only slightly in excess of rated tyre pressures and below the maximum that tyres and wheels on their aircraft types are capable of sustaining.

Wheel and tyre design considerations

Federal Aviation Regulations (FAR) Part 25 – '*Airworthiness Standards: Transport Category Airplanes'*, Section 731 - *'Wheels'* recognises the hazard caused by excessive pressure in aircraft tyres and stipulates the requirement for overpressure burst prevention. The regulation states:

> *'Means must be provided for in each wheel to prevent wheel failure and tire burst that may result from excessive pressurization of the wheel and tire assembly.'*

An identical regulation is contained in the EASA's document CS 25 – *Certification Specifications for Large Aeroplanes*, Subpart D – *Design and Construction*, paragraph CS25.731 - *Wheels*.

These are requirements which apply to the certification of new designs but were not in force at the time the CRJ 200 was certificated.

Additional information

This type of occurrence does not meet the internationally agreed definition of an aircraft accident and it has not been possible to determine the rate at which such events occur. However, one manufacturer of large aircraft, on becoming aware of two related events, circulated a message to operators advising them of two fatalities, one occurring in 1998 and another in 2006, which took place during tyre inflation operations. Reference was made to safety training information that was available.

Safety action

The HSE undertook to establish actions that the line maintenance company, which owned the nitrogen pressure rig, should take in relation to the design of the rig and the procedures for its use, to prevent a recurrence of this accident. This included a means of separating the higher pressure (0-1,500 psi) and lower pressure (0-400 psi) functions, and the need for the delivery pressure gauge to be marked in units of psi. The HSE also stated its intention to bring the accident to the attention of the HSE sector that advises HSE Inspectors who deal with airports, to capture the high pressure gas rigs that exist at other maintenance firms in the UK.

Discussion

It has been deduced from the extent and nature of the wheel damage and the method of separation of the securing nut from the axle, together with the metallurgical features of the failed tie bolts, that the accident occurred when the internal tyre pressure reached too high a figure. The characteristics of the failures were consistent with a series of increasing tensile loads which eventually exceeded the yield point of the bolt material. This was probably the consequence of briefly releasing and then re-applying hand pressure to the inflator operating trigger lever as the tyre pressure approached the figure required to fail the tie bolts.

Manufacturer's tests had previously demonstrated that wheel failure by a similar mechanism to that occurring in this accident takes place at a tyre pressure of approximately 1,000 psi (approximately six times the normal tyre pressure). Similarly, the permanently elevated position of the inflator gauge indication following the accident confirmed that pressure in excess of 500 psi had been applied at some stage. The fact that the wheel/tyre combination was carrying a proportion of aircraft weight and the wheel was secured to the axle by the nut at its centre, probably accounted for the slight difference in failure mechanism from that reported during the wheel manufacturer's qualification test.

It follows that the regulator on the rig was set to deliver a pressure of the order of 1,000 psi or above, permitting the cylinder in use to supply such a high gas pressure to the inflator. The technician reported that he did not alter the regulator setting and, since the usage pattern of the rig is not recorded, it was not possible to establish when the regulator was last adjusted or to what maximum delivery pressure figure it was set.

Although the inflator was designed, by means of passages of small cross-section, to limit the flow rate of nitrogen to the tyre, this did not prevent over-inflation on this occasion. Inflation of large tyres using this type of inflator would normally result in a relatively slowly rising tyre pressure and a correspondingly slow increase in indicated pressure on the inflator mounted gauge on each occasion the lever was released. By contrast, the low volume of the nosewheel tyre on this aircraft type would have resulted in a much more rapid rise in pressure as the trigger lever on the inflator was depressed.

The restriction created by the limited internal dimensions of the inflator appears not to have slowed the flow rate sufficiently on this occasion for the technician to become aware of the pressure rise and release the lever in time. The absence of the O-ring seal on the main spool valve, within the inflator, resulted in the tyre deflating when the lever was released, as well as when it was lightly depressed. With partial depression of the lever, the tyre would have continued to deflate, rather than inflate. The technician might not have expected this. It is probable that on the second occasion of the two short pressure applications that the lever was depressed further. This would have permitted full supply pressure to be delivered to the tyre.

Without the regulator being set to reduce the cylinder pressure to a figure near the rated pressure of the tyre, a moderately lengthy period spent with the lever fully deflected would have enabled the pressure in the small tyre to rise far above its rated value. A process by which the grossly elevated tyre pressure failed the wheel tie bolts can thus be envisaged.

It is not unusual for aircraft maintenance companies to use high pressure nitrogen supplies for a variety of purposes as well as for tyre inflation. It is usual to use clear annotations to ensure that only appropriately regulated pressures are delivered to tyre valves and the higher pressure supplies are restricted to use for accumulators, oleo struts etc.

The original purpose of the rig used on this occasion could not be determined, but personnel from the owning company have stated that it was only used for inflating tyres. It bore no annotation, however, drawing the attention of operators to the fact that it was capable of delivering pressures far in excess of that required for tyre inflation. Also, the delivery pressure indication on the rig was in bars while all other annotated pressures (as well as most quoted aircraft tyre pressures) were in psi.

The movement of the needle on the delivery pressure gauge on the regulator valve, required for normal tyre inflation, was a small proportion of full scale deflection. A technician unfamiliar with the rig may not have appreciated that a setting of the regulator which gave an output pressure reading on the gauge well below the full-scale value was nonetheless capable of transmitting a pressure many times in excess of that which was required. The use of a scale in bars, where the full-scale reading of 400 was in the region of twice the numeric value associated with tyre pressure range on typical airliners (invariably in the range 150 to 250 psi), may also cause an operator to assume it is calibrated in the widely used and familiar psi units. Operators may not notice the very small annotation of the word ‘bars’ on the face of the gauge. Therefore, the technician could have left the regulator to supply nearly 15 times the pressure he assumed was available.

Although the first observation of the supply pressure, noted some time after the accident, was 700 psi, the occupant of the aircraft cabin recalled the sound of escaping gas immediately he exited the aircraft, following the explosion. It can be surmised that considerable gas escaped between the accident and the first occasion that the gauge reading was noted. The pressure available from the cylinder in use at the time of the wheel failure is, therefore, not known but may have been in excess of the 700 psi figure observed by the company pilot and possibly up to the region of the 3,335 psi of a newly replenished cylinder. The regulator would have restricted the pressure supplied to the wheel to a maximum of 1,500 psi.

The requirement for overpressure burst protection exists for wheels and tyres on new aircraft complying with FAR Part 25 and the EASA’s CS 25. In view of the lack of consistent regulation covering pressure rigs to be found on airfield aprons worldwide, any attempt to control the risk of wheel/tyre explosions during tyre inflation would have to centre on wheel/tyre design. Consequently, extension of the FAR Part 25 and CS 25 requirements to all aircraft which fall into this category, but were certificated prior to the requirement, should be considered. Had overpressure burst protection been fitted to this aircraft, it is probable that the accident would not have occurred. This is not the first occasion on which such bursts have happened and previous such events have resulted in fatalities.

The following Safety Recommendations are made:

Safety Recommendation 2010-069

It is recommended that the Federal Aviation Administration review the number of occurrences of the overpressure failure of tyres or wheels on Transport Category Airplanes and consider retrospectively applying the requirements of Federal Aviation Regulations Part 25.731, for Overpressure Burst Protection on the wheels of Transport Category Airplanes.

Safety Recommendation 2010-070

It is recommended that the European Aviation Safety Agency review the number of occurrences of the overpressure failure of tyres or wheels on Large Aeroplanes and consider retrospectively applying the requirements of CS 25.731, the Certification Specifications for Large Aeroplanes for Overpressure Burst Protection on wheels.

SERIOUS INCIDENT

Aircraft Type and Registration:	1) Citation 525, D-ITAN 2) Boeing 777 300ER, TC-JJA
No & Type of Engines:	1) 2 Williams International FJ-44-1A turbofans 2) 2 GE90-115B1L turbofans
Year of Manufacture:	1) 2000 2) 2007
Date & Time (UTC):	27 July 2009 at 1440 hrs
Location:	London TMA (terminal control area)
Type of Flight:	1) Civil (Executive) 2) Commercial Air Transport (Passenger)
Persons on Board:	1) Crew - 2 Passengers - 1 2) Crew - 16 Passengers - 232
Injuries:	1) Crew - None Passengers - None 2) Crew - None Passengers - None
Nature of Damage:	1) None 2) None
Commander's Licence:	1) Commercial Pilot's Licence 2) Airline Transport Pilot's Licence
Commander's Age:	1) 49 years 2) Not known
Commander's Flying Experience:	1) 4,300 hours (of which 1,250 hours were on type) Last 90 days - 60 hours Last 28 days - 30 hours 2) Not known Last 90 days - not known Last 28 days - not known
Information Source:	AAIB Field Investigation

Synopsis

The crew of D-ITAN were cleared to depart London City Airport on a DVR 4T SID, which required them to climb initially to 3,000 ft amsl. They read back their cleared altitude as 4,000 ft, an error that was not noticed by the Tower controller. At about the same time, TC-JJA was cleared to descend to an altitude of 4,000 ft while turning onto a southerly heading prior to intercepting the ILS for Runway 27R at Heathrow Airport. D-ITAN climbed through 3,000 ft while turning right and passed TC-JJA on a nearly reciprocal heading approximately 0.5 nm away and 100 to 200 ft below. TC-JJA generated three TCAS RAs in short succession but the aircraft did not follow the commands. D-ITAN was unable to generate RAs. The crew of D-ITAN saw TC-JJA in time to take effective avoiding action. Five Safety Recommendations are made.

History of the flights

Cessna Citation 525; D-ITAN

D-ITAN was due to depart London City Airport on a DVR 4T Standard Instrument Departure (SID) from Runway 27 (see Figure 1). The procedure was to climb to and maintain an altitude of 3,000 ft until reaching a range of 25.5 nm on the 076° radial from the LON VOR, following which the aircraft would be cleared to climb to an altitude of 4,000 ft.

The crew requested clearance to start engines from the Tower controller but were given both start and ATC clearances in the reply. The ATC clearance was:

> "DOVER FOUR TANGO DEPARTURE MAINTAIN ALTITUDE THREE THOUSAND FEET"

After a delay of five to six seconds the crew read back:

> "FOUR TANGO DEPARTURE CLIMBING FOUR THOUSAND FEET".

Although the Tower controller noticed and corrected the omission of the word 'Dover', he did not notice the incorrect readback of the cleared altitude. D-ITAN taxied to the runway and was cleared for takeoff at 1436 hrs.

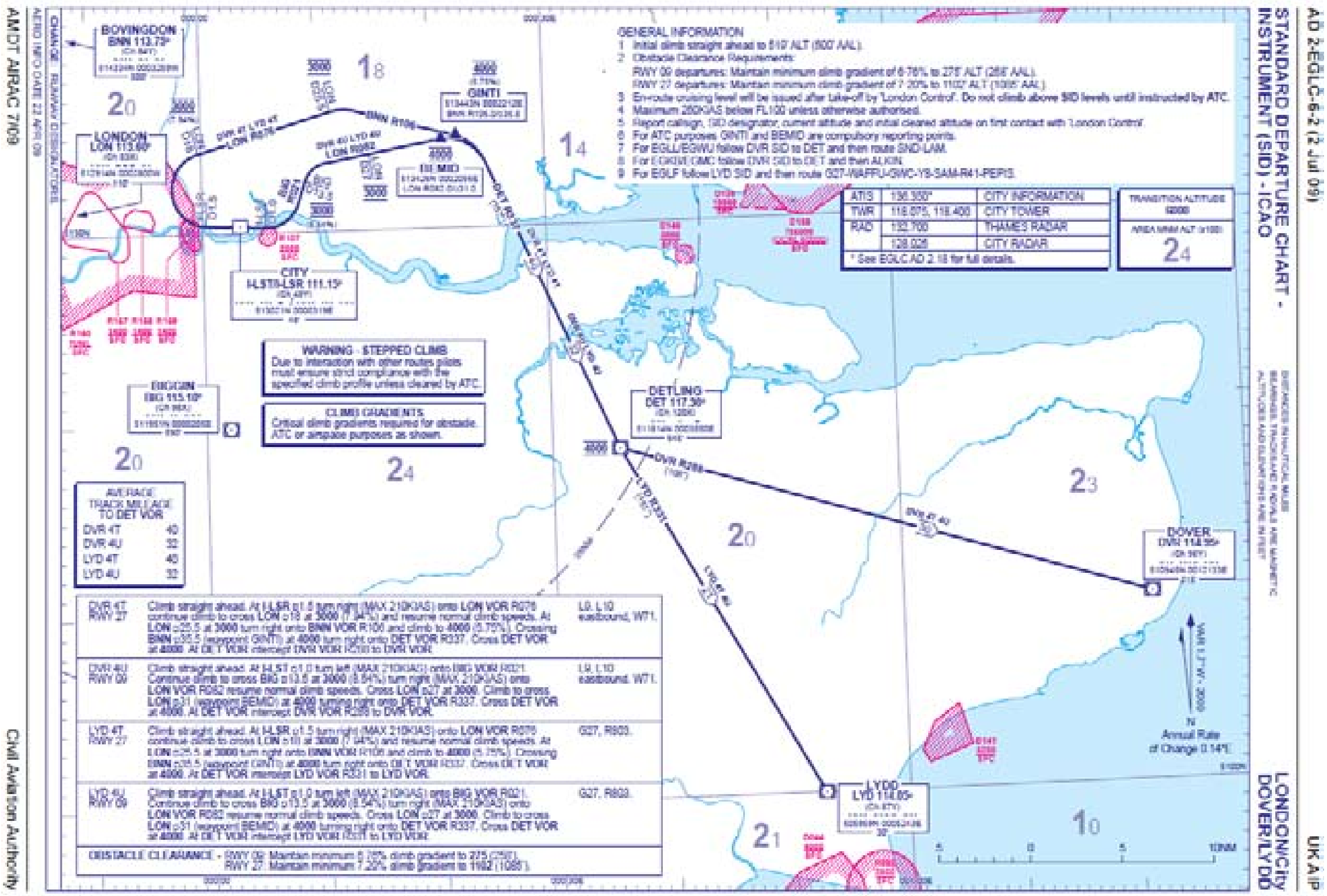


Figure 1

DVR 4T SID

After takeoff, the aircraft maintained a heading of 270° until 1437:27 hrs when it began to turn right (Figure 2). As it passed an altitude of 1,300 ft, the aircraft was climbing at a rate of just under 3,000 ft/min and as it passed 3,000 ft, the rate was 3,300 ft/min. At 1437:28 hrs, the crew was instructed to contact Thames radar, which they did at 1438:16 hrs. During the intervening period, there were two gaps in radio transmissions, one of four seconds and one of two seconds. At 1438:19, D-ITAN was heading north at an altitude of between 3,800 and 3,900 ft when it passed TC-JJA on a nearly reciprocal heading. D-ITAN was approximately 0.5 nm to the west of TC-JJA and 100 to 200 ft below it. At 1438:32, the radar controller transmitted:

> "DELTA ALPHA NOVEMBER REPORT YOUR ALTITUDE. DELTA ALPHA NOVEMBER DESCEND IMMEDIATEDLY DESCEND TO ALTITUDE THREE THOUSAND FEET".

The crew of D-ITAN acknowledged and complied with the instruction although by then their aircraft was clear of TC-JJA. At 1439:40, the radar controller instructed D-ITAN to:

> "CLIMB TO ALTITUDE FOUR THOUSAND FEET"

which was acknowledged by the crew.

Boeing 777-300ER; TC-JJA

TC-JJA, callsign Turkish Airlines 1991, was being vectored for an ILS approach to Runway 27R at London Heathrow Airport. The commander was the Pilot Not Flying (PNF) and the co-pilot, who was under training, was the Pilot Flying (PF). They were flying in VMC at 180 kt IAS and were cleared to descend to an altitude of 4,000 ft. At 1437:38 the aircraft was at an altitude of 4,900 ft and was instructed to turn right onto a heading of 185°. As the pilot transmitted his acknowledgement, a TCAS Traffic Alert (TA) was generated. At 1438:05, he transmitted:

> "WE HAVE A TRAFFIC ALERT"

but during the transmission a TCAS 'crossing descend' Resolution Advisory (RA)[1] was generated. The Heathrow controller replied:

> "AFFIRM. HE'S BUST HIS LEVEL. CAN YOU CLIMB CLIMB[2] TO MAINTAIN FIVE THOUSAND FEET?"

During this transmission, a TCAS 'increase descent' RA was generated. Following this, a TCAS 'reversal climb' RA was generated between 1438:11 and 1438:15. TC-JJA levelled briefly at an altitude of 4,000 ft before starting to climb and it was while the aircraft was at 4,000 ft that it passed D-ITAN at 1438:19.

During a conversation with the controller at 1438:50, the pilot of TC-JJA transmitted:

> "WE HAD TO DO A RESOLUTION HERE"

which was acknowledged by the controller.

London City Tower controller

The London City Tower controller reported to the internal National Air Traffic Services (NATS) enquiry that he recalled D-ITAN requesting both start and ATC clearance at the same time, which was usual for private aircraft. The controller was not sure whether he mis-heard the pilot's readback of the altitude restriction or whether he did not hear it at all due to his attention being focussed on correcting the omission of the word "Dover".

Footnote

[1] An RA which takes the aircraft through the threat aircraft's altitude.

[2] Intentional repeat of the word 'climb'.

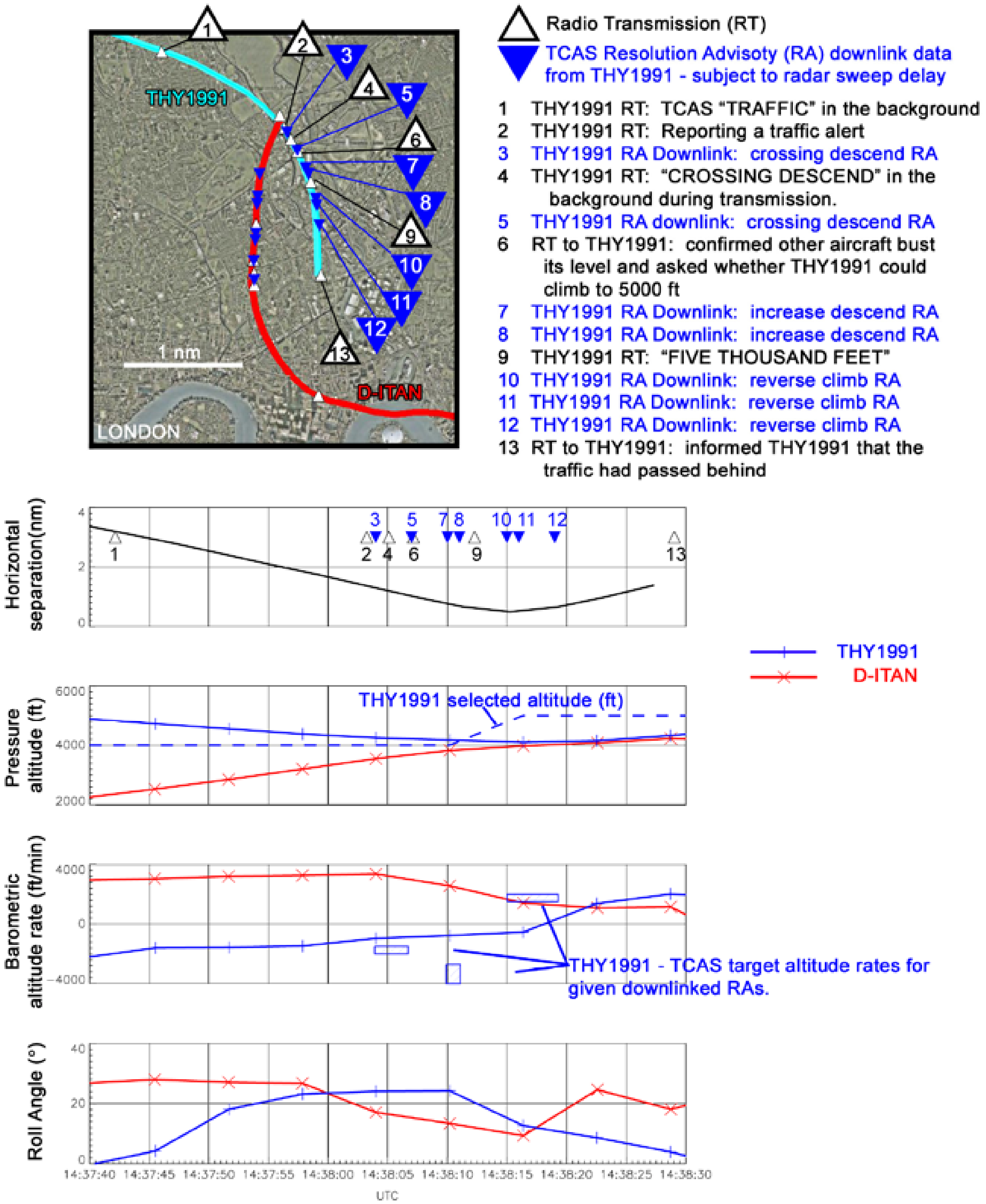


Figure 2

Salient radar data, downlinked data and RT extracts

Thames radar controller

When D-ITAN took off, the Thames radar controller noticed its radar return but he did not recall looking at it again until its pilot reported on his frequency. At that time, he also saw that D-ITAN had triggered the high-level Short Term Conflict Alert (STCA)[3]. It was not unusual for aircraft departing London City Airport to trigger the STCA due to the high rate of climb required when flying the SID. The controller instructed D-ITAN to descend to 3,000ft considering that this was permitted since the pilot had not reported an RA.

Heathrow Final Director

The Heathrow Final Director was alerted to the conflict by the pilot of TC-JJA reporting the TA. The pilot did not report an RA but the controller was expecting there to be one because of the close proximity of the two aircraft on his display. The controller was aware that he should not issue instructions to an aircraft experiencing an RA event and this led him to ask whether TC-JJA was able to climb to 5,000 ft, rather than to issue an instruction to do so.

Airprox report by the crew of D-ITAN

The commander of D-ITAN filed an Airprox report in which he stated that the crew received a clearance from "City Radar" to climb to an altitude of 4,000 ft. He was familiar with the usual departure procedure but interpreted this as a clearance to climb "directly" to 4,000 ft because he had TC-JJA in sight "all the time". Initially, he thought his aircraft would be "well above" TC-JJA as he crossed its track. Subsequently, he realised that the two aircraft would be quite close when they crossed and he recalled changing the aircraft's heading "about 30 degrees to the left" to pass behind TC-JJA. He believed there had been no risk of collision.

Further information from the crews

D-ITAN

The commander of D-ITAN later stated that he interpreted the ATC clearance from London City Airport as a climb to 4,000 ft "non-standard to the published outbound departure route". He believed his TCAS equipment was serviceable and stated that at no time did it display a TA[4].

TC-JJA

The commander of TC-JJA stated that on receiving the TA he adjusted the range scale on his display and tried to acquire the traffic visually. He recalled a "very brief RA to descend" but noticed from the TCAS display that the traffic was passing the three o'clock position and climbing, and he judged that a descent would only increase the risk of collision. The commander reported that, on receipt of the reversal climb RA, he took control, disengaged the autopilot and followed the RA guidance. The only person to see D-ITAN was a pilot occupying the right observer seat who saw it pass west of them at an estimated 100 to 200 ft below.

Flight Data Recorder information

Flight recorders

TC-JJA, callsign THY1991, was fitted with a Cockpit Voice Recorder (CVR), Flight Data Recorder (FDR) and a Quick Access Recorder (QAR). The initial delay in notification of the event to the AAIB and the subsequent delay in communications with the operator meant that data recorded by the FDR and CVR was overwritten.

Footnote

[3] STCA is a ground-based safety net intended to assist the controller in preventing collisions between aircraft by generating an alert of a potential or actual infringement of separation minima.

Footnote

[4] The aircraft was fitted with TCAS I equipment which does not generate RAs.

The QAR should have had sufficient storage not to have been overwritten but the data was lost due to system failure.

D-ITAN was not fitted with, or required to be fitted with, crash-protected recorders or flight data monitoring recorders. Neither TCAS unit fitted to the aircraft involved had capability to record event data.

Primary and secondary radar tracks for both aircraft were recorded by the Debden and Heathrow radar installations. Mode S datalink recordings of both aircraft were also recorded by Debden radar. This provided the following parameters with a refresh rate corresponding to the 6-second rotation rate of the radar antenna:

- Altitude with a 25ft resolution
- Roll angle
- True track angle
- Ground Speed
- True Airspeed
- Heading
- Indicated airspeed
- Mach
- Barometric altitude rate
- Selected altitude (TC-JJA only)

THY1991 also transmitted TCAS-related messages via Mode S. These messages were also subject to a delay due to the rotation rate of the radar antenna but were received by a number of radar heads. The content of the messages indicated that the TCAS fitted to THY1991 had incorrectly identified D-ITAN as not being Mode S equipped, whereas NATS radar had received Mode S data direct from D-ITAN. The cause of this discrepancy was not found but it would have had little effect on the outcome of these particular events.

ATC voice communications were also made available to the investigation.

Figure 2 is an amalgamation of these data sources. The recordings showed that TCAS was fully operational on THY1991. A traffic alert was issued to the crew whilst descending to a selected altitude of 4,000 ft and the crew passed this information to the controller. Shortly after this, TCAS issued a "CROSSING DESCEND" RA. This was evident in the background of a transmission by THY1991, though may not have been noticeable to the controller, and was also downlinked via Mode S but this was not available to the controller. The RA required an increased descent rate; the descent rate was reduced. The controller asked whether THY1991 could climb to 5,000 ft. This was followed by a downlink of an 'increase descent RA', requiring a descent rate of greater than 2,500 ft/min. The crew read back "FIVE THOUSAND FEET". The next RA downlinks indicated a reversal to a climb RA. This was followed by an increase in the selected altitude of the aircraft. The aircraft then passed abeam each other with a lateral separation of 0.5 nm and a vertical separation of 164 ft.

Simulations carried out by NATS and Eurocontrol confirmed that the TCAS of THY1991 provided the expected commands.

Standard Instrument Departures (SIDs)

DVR 4T SID

The DVR 4T SID is a 'step-climb' SID with an initial climb to an altitude of 3,000 ft. The departure is in close proximity to obstacles and requires an initial minimum climb gradient of 7.94%; no maximum gradient is stipulated. The departure track of the SID crosses the tracks of aircraft being vectored for approach to Runways 27L or 27R at Heathrow airport. Traffic inbound to Heathrow Airport is not cleared below an altitude of 4,000 ft in this region to ensure vertical separation from traffic on the SID. A warning on the SID states:

> *'Due to interaction with other routes pilots must ensure strict compliance with the specified climb profile unless cleared by ATC.'*

NATS reported that, since January 2004, there have been 21 occasions when aircraft departing London City Airport have climbed above the step altitude of 3,000 ft published in the SID. A third of the incidents led to a loss of ATC separation. Evidence from London Stansted Airport showed that removing the step-climb element of the CPT/BUZ SIDs led to a reduction in the number of aircraft that climbed through the first cleared altitude after takeoff. There were 12 'level busts' reported on the SIDs in the 24 months before the end of 2005 when the step-climb was removed. There were 5 level busts in the following three years and seven months.

It was standard practice when issuing DVR 4T departure clearances for controllers to instruct crews to maintain 3,000 ft after takeoff. Since the incident, the instruction to maintain 3,000 ft is given separately from the remainder of the clearance and requires a separate readback from the crew. Operators flying from the airport have also been asked to reiterate to their crews the importance of levelling off at 3,000 ft.

SID procedures and phraseology

A change to '*International Civil Aviation Organisation (ICAO) Doc 4444 (PANS-ATM)'* in November 2007 introduced revised procedures and phraseology associated with climb instructions issued to aircraft following a SID. The document stated that:

> *'When a departing aircraft on a SID is cleared to climb to a level higher than the initially cleared level or the level(s) specified in a SID, the aircraft shall follow the published vertical profile of a SID, unless such restrictions are explicitly cancelled by ATC.'*

An example of the phraseology is: 'climb to FL120 level restrictions (*SID designator*) cancelled'.

As a result of concerns raised by member States and industry, ICAO acknowledged that States had encountered difficulties implementing the new procedures and undertook to consult further. The UK did not implement the revised procedures and phraseology for reasons explained in the CAA's '*Flight Operations Division Communication (FODCOM)* 16/2009'. In the UK, for all stages of flight, an instruction to climb or descend cancels any previous restrictions unless they are reiterated as part of that instruction. For aircraft on a SID, the word 'now' is added to climb clearances above the SID profile eg 'climb now FL120' is an instruction for an aircraft to climb directly to FL120 ignoring the vertical profile of the SID.

The CAA issued a Supplementary Instruction (SI) to '*CAP 493 Manual of Air Traffic Services (MATS) Part 1'* on 24 April 2009. The SI clarified UK SID procedures and phraseology and gave guidance to controllers on the recent developments. It stated:

> *'Controllers must remain alert to the potential for incorrect or unexpected interpretation of ATC instructions by non-UK aircraft operators and take appropriate action to ensure any required separation.'*

Germany, the State of Registry of D-ITAN and the State of its operator, implemented the revised ICAO procedures and phraseology on 18 December 2008 through amendment to its '*Manual of Operations Air Traffic Control Services'*.

On 31 March 2010, the CAA issued '*FODCOM 09/2010'*, which referred to the results of the ICAO consultation on the revised procedures. The FODCOM stated:

> *'From the State responses, ICAO has identified that their current provisions have not provided the intended simplicity, efficiency, and global standardisation to ensure flight safety.'*

Consequently, ICAO recommended that States promulgate, as a matter of urgency, any difference from the PANS-ATM SID/STAR provisions in the national AIP. ICAO reported that it would work expeditiously to determine the optimum solution to the current situation.

Airborne Collision Avoidance System (ACAS)

Rules for the carriage of ACAS

ACAS is a set of standards for aircraft-based equipment. ACAS I issues TAs, which alert crews to the presence of potential threat aircraft. ACAS II also issues RAs, which instruct crews to manoeuvre the aircraft in the vertical plane in order to resolve a conflict. The only equipment currently able to meet the requirements of ACAS II is TCAS II. Turbine jet aircraft flying in the UK are required to carry ACAS II if they have a maximum takeoff weight exceeding 5,700 kg, or a maximum approved passenger seating configuration of more than 19. The Boeing 777 was fitted with TCAS II. The Cessna Citation 525 was not required to carry ACAS although it was fitted with TCAS I.

ACAS II RAs

The procedures to be followed by pilots in the event of an RA are detailed in '*ICAO PANS-OPS (Doc 8168)'*. When an ACAS II RA is generated, pilots are expected to:

> *'Respond immediately by following the RA as indicated, unless doing so would jeopardize the safety of the aeroplane.'*

For RAs requiring a change in vertical speed, the pilot is expected to respond correctly within five seconds of the RA being displayed. Compliance with the RA will generally require a vertical speed of approximately 1,500 ft/min, corresponding to an initial vertical acceleration of 0.25g, but this may vary according to the event. The RAs of two TCAS II equipped aircraft will generate a miss distance in the vertical sense that is coordinated through a Mode S data link. An RA can be generated by TCAS II against a threat aircraft not fitted with TCAS II, providing such an aircraft is equipped with an altitude-reporting transponder. The safety benefit will be reduced, however, because there will be no coordination between the aircraft and the threat aircraft will be incapable of generating its own RA. During a TCAS alert, the RA may require an increase or decrease in vertical speed or may reverse its sense. In such cases a response is required from the pilot within two and a half seconds. Doc 8168 notes that:

> *'Visually acquired traffic may not be the same traffic causing an RA. Visual perception of an encounter may be misleading, particularly at night.'*

Consequently, pilots are discouraged from making their own judgements about resolving a conflict once an RA has been triggered. Apart from possibly considering the wrong threat aircraft, their action might invalidate any coordination that is taking place, thereby making the situation worse. The document also notes that:

> *'The ability of ACAS to fulfil its role of assisting pilots in the avoidance of potential collisions is dependent on the correct and timely response by pilots to ACAS indications. Operational experience has shown that correct response by pilots is dependent on the effectiveness of the initial and recurrent training in ACAS procedures.'*

The effect of TCAS II on ATC operations

'CAP 493 MATS Part 1' includes instructions for ATC controllers on dealing with aircraft responding to TCAS RAs. When a pilot reports an RA:

> *'Controllers shall not attempt to modify the aircraft flight path until the pilot reports "clear of conflict".'*

Once an aircraft departs from an ATC clearance in compliance with an RA, or a pilot reports an RA, the controller ceases to be responsible for providing separation between that aircraft and any other aircraft affected by the manoeuvre induced by the RA. The controller resumes responsibility for providing separation when the aircraft has resumed the current clearance, or the crew reports they are resuming the current clearance and the controller issues an alternative clearance.

ACAS phraseology

Specific ACAS phraseology, contained in '*ICAO PANS-ATM (Doc 4444)',* has been adopted to provide the means to ensure that pilots and controllers have a clear understanding of the progression of an RA manoeuvre, and the means to delineate the point at which responsibility for the separation of aircraft transfers from controller to pilot and back to controller. The crew should notify the appropriate ATC unit as soon as possible, as permitted by workload, of any RA which requires a deviation from the current ATC clearance by transmitting:

"TCAS RA".

After the RA response is completed and a return to the ATC clearance is initiated, the pilot should transmit:

"CLEAR OF CONFLICT RETURNING TO (assigned clearance)".

When the ATC clearance has been resumed, the pilot should transmit:

"CLEAR OF CONFLICT (ASSIGNED CLEARANCE) RESUMED".

Automatic notification of TCAS RAs

Eurocontrol estimates that 25% of RAs are never reported to the controller and 25% are notified '*very late'*. Pilot reports (when they happen) are often '*lengthy, unstructured, incorrect or incomplete, requiring repetition or clarification from the controller'*. If controllers do not know that the aircraft is responding to an RA, they might issue an instruction in an attempt to resolve the conflict and that instruction could contradict the RA.

Automatic notification of RAs to controllers' screens (RA downlink) has been contemplated for some time. Eurocontrol carried out a 'Feasibility of ACAS RA Downlink' Study (FARADS project), which found that currently an en-route controller would on average be aware of an RA 30 seconds after it was presented to the pilot. Controllers would be aware of RAs within 10 seconds in 95% of cases where aircraft were using Mode S transponders to downlink the RA information. The potential benefits of RA downlink would be: the reduced likelihood of contradictory clearances;

improved situational awareness; more up-to-date traffic information, especially to other aircraft in the vicinity; and better post-conflict traffic planning.

The International Federation of Air Traffic Controllers Associations (IFATCA) is opposed to RA downlink. However, should it be implemented, IFATCA is concerned that there must be clear and unambiguous legal responsibilities for controllers with no delay in the downlink (for example due to antenna rotation) and nuisance and false alerts being kept to a minimum. The International Federation of Airline Pilots' Associations (IFALPA) supports the concept in principle but requires the data update rate to be not less that one report per second.[5]

Increasing the update rate of information within the system is technically feasible although not yet implemented. However, the functionality to display RAs to the controller using Mode S transponders already exists in commercial ATC systems; some states have implemented the functionality and some others are considering doing so. Eurocontrol is concerned that a Europe-wide concept of operations should be developed to avoid a proliferation of national concepts.

NATS investigation report

An assessment of the performance of TCAS was provided by NATS's ACAS 'Interactive Collision Avoidance Simulator' (InCAS) team. The pilot of D-ITAN reported that his TCAS equipment did not generate any TAs, which was unexpected given the alerts known to have been generated in TC-JJA. No technical explanation for this was established due to a lack of recorded data. TC-JJA did not treat D-ITAN as being Mode-S equipped.

The pilot was aware that a clearance to climb to 4,000 ft was non-standard but did not query the clearance. Radar data indicated that D-ITAN complied with the rate of climb stipulated in the SID but the high rate of climb reduced the time available for the error to be detected. There was no downlink from D-ITAN of the flight level selected on the autopilot and so the level-bust could not be anticipated by the controller. D-ITAN did not report on the Thames radar frequency until so close to the point of minimum separation that the controller did not have time to take effective action to resolve the situation. The report concluded that the event was not resolved by ATC.

The pilot of TC-JJA did not use the correct phraseology to inform the Heathrow Final Director that he had received an RA. The aircraft flightpath did not appear to change in compliance with the first two RAs to descend. The flightpath did change after the climb RA was triggered but this was not apparent from the radar data until after the two aircraft were passing each other. The report concluded that the event was not resolved by TCAS.

Both aircraft were in VMC but D-ITAN was not seen by either operating pilot in TC-JJA and so no action was taken on this aircraft to resolve the situation. The crew of D-ITAN reported that they were in visual contact with TC-JJA and adjusted their aircraft's flightpath in order to avoid it. The report concluded that the conflict was resolved by the crew of D-ITAN.

The report noted that departures from London City Airport require crews to make full power takeoffs before levelling off less than one minute after leaving the ground, which is unusual. It is critical that aircraft comply with the level-off because there is a high probability that the departing traffic will cross the track

Footnote

5 Report on the Eurocontrol 'RA Downlink Workshop' dated 20 November 2009.

of an aircraft inbound to Heathrow Airport, which might be only 1,000 ft above.

The NATS investigation report recommended that:

1) all SIDs from London City Airport should terminate at an altitude of 3,000 ft, and
2) lateral interaction should be eliminated between the SIDs and the base leg turn for aircraft positioning to land at Heathrow Airport.

Subsequent comments by NATS

Following further assessment, managers within NATS concluded that the recommendation (2, above) regarding the London City Airport SID track could not be accepted. The track could not be moved effectively as the interaction with aircraft positioning to land at Heathrow Airport occurs almost immediately after departure. Moving the Heathrow Airport arrival track significantly to the west would result in aircraft joining the approach from above the glideslope, which would increase the risk of aircraft making unstable approaches. Descending aircraft early, so that they joined the approach from beneath the glideslope, would increase noise and fuel burn. NATS also reported that there would be increased difficulty in applying wake turbulence procedures. However, NATS stated that new procedures had been trialled that would mitigate the risk resulting from a level bust in the area concerned.

Analysis

Communication

The initial event in this incident was the miscommunication between the crew of D-ITAN and the aerodrome controller. The delay in their reply suggested the crew were probably not expecting to receive their departure clearance when they called for start clearance, and this might have contributed to them writing down the incorrect altitude. Subsequently, although they were aware that a climb to 4,000 ft was unusual, they did not query the clearance. The controller missed the incorrect readback of the cleared altitude, which meant that the crew took off prepared to climb through the step altitude on the SID. The new communication procedures implemented at London City Airport since this incident are designed to ensure that crews understand and comply with the requirement to level off at 3,000 ft.

The commander of TC-JJA notified ATC that his aircraft had generated a TA, which he was not required to do. His transmission and the subsequent reply from ATC were made at the same time as the first two RAs, which might have made the warnings more difficult to hear than otherwise. The commander took control from the co-pilot to respond to the reversal climb RA and it was unclear whether or not responsibility for communication had moved to the co-pilot. The "TCAS RA" call to ATC was omitted, which resulted in the controller being unsure whether a TCAS event had occurred. The "CLEAR OF CONFLICT" transmission was also omitted and the phraseology used subsequently to inform ATC about the RA was incorrect.

Airspace management

On the DVR 4T SID, although the departure track crosses the base leg turn of traffic inbound to Heathrow Airport, aircraft in the same position laterally should still be separated vertically by a minimum of 1,000 ft. Because of the overlapping tracks, one third of aircraft which climb through their cleared altitude are likely to cause a loss of ATC separation but it is not practicable to remove the lateral interaction. NATS has trialled new procedures which, it believes, will mitigate the risk resulting from a level bust in this area. Therefore:

Safety Recommendation 2010-056

It is recommended that NATS demonstrates to the Civil Aviation Authority (CAA) that appropriate mitigation has been put in place to reduce significantly the risk of an accident resulting from a level bust by an aircraft departing London City Airport or on the base leg turn positioning to land at Heathrow Airport.

Prior to the incident, the DVR 4T SID was issued along with an instruction to maintain 3,000 ft but, despite this, some aircraft still failed to level off at the step altitude. The high rate of climb associated with the SID, while necessary to provide clearance from nearby obstacles, reduces the time for corrective action should an aircraft climb through the step altitude. Evidence from Stansted Airport suggests that removing the step-climb from the SID, and terminating the SID at 3,000 ft, is likely to result in fewer incidents of aircraft climbing through 3,000 ft. However, it would probably be unwise to have one SID terminating at 3,000 ft while the others terminated at 4,000 ft. Therefore this AAIB investigation endorses the NATS investigation, and makes the following two Safety Recommendations:

Safety Recommendation 2010-057

It is recommended that London City Airport amends all Standard Instrument Departures (SIDs) so that they terminate at an altitude of 3,000 ft.

Safety Recommendation 2010-058

It is recommended that London City Airport removes Step Climb procedures from its Standard Instrument Departures (SIDs).

TCAS

Because there was no Mode S downlink of D-ITAN's selected flight level, there was no opportunity for the radar controllers to anticipate the conflict and take appropriate action. D-ITAN did not generate any TAs, which was unexpected given the geometry of the encounter. The lack of a TA could not be explained because no recorded data from either aircraft was available to the investigation, and the serviceability of D-ITAN's TCAS equipment could not be confirmed after the flight.

TC-JJA's flightpath during the two descent RAs was consistent with it levelling off at the cleared altitude of 4,000 ft rather than it following the RAs. The aircraft then climbed towards 5,000 ft, which was consistent both with the climb RA and the controller's suggestion that a climb would be appropriate. The commander faced a rapidly changing TCAS encounter with two RAs generated within six seconds and three in less than 10 seconds. Pilots are expected to react to a first RA within five seconds and it is likely that the second, increase descent, RA was generated because of a lack of response to the first RA. The commander was only briefly aware of the requirement to descend but judged that a climb would be better. In this case, his judgement was based on the correct threat aircraft and was in the same sense as, and coincident with, the climb RA.

The Heathrow Final Director was unsure whether an RA had been triggered within TC-JJA because of the use of incorrect and late TCAS phraseology by its crew. The controller asked whether TC-JJA was able to climb, a transmission which, although not an instruction, was in the opposite sense to the 'increase descent' RA that was generated at the same time.

It was 45 seconds from the first RA, and 35 seconds from the last, before the controller was told that there had been an RA event. ATC systems utilising RA downlink based on Mode S would be expected to reduce this delay to within 10 seconds. Had the delay been 10 seconds in this incident, the controller would still not have known there was an RA event until just after the 'climb RA' was generated and so the sequence of events was unlikely to have changed substantially. Both IFATCA and IFALPA require delays that are significantly shorter than 10 seconds before they will support the concept in practice. Eurocontrol is therefore attempting to develop a European concept of operations in the knowledge that RA downlink systems are already being implemented, even though the professional bodies of the system operators have reservations about their use. The arguments for and against implementation are not clear cut and, as Euroctontrol is already considering the issue, no recommendations are made in this regard.

During this incident, the crew of D-ITAN saw TC-JJA in time to take effective avoiding action. Had the aircraft been in IMC, this would not have been the case and TCAS would have been the only barrier to a potential mid-air collision. The incident was not resolved by TCAS for two reasons, the first being that the crew of TC-JJA did not respond to the RAs in time to affect the geometry of the incident. It has been shown that correct crew response to ACAS is dependent on the effectiveness of initial and recurrent training and therefore:

Safety Recommendation 2010-059

It is recommended that the Directorate General of Civil Aviation of Turkey ensures Turkish Airlines TCAS training complies with the Airborne Collision Avoidance System Training Guidelines contained in '*ICAO PANS-OPS (Doc 8168)*'.

The second reason that TCAS did not resolve this incident was that D-ITAN did not have TCAS II, which meant that the increased safety benefit of coordinated RAs was not available. The new procedures already implemented at London City Airport, and the recommendations regarding SIDs made in this report, should reduce the risk of a level bust occurring in the future. Should a level bust recur despite these changes, the procedures trialled by NATS should mitigate the risk of an accident. However, the consequences of a midair collision in this part of the London TMA would be particularly serious because of the population density below, and further mitigation of the risk could be achieved by mandating the carriage of TCAS II. An assessment of whether such action would be proportionate to the residual risk of loss of separation is beyond the scope of this report and therefore:

Safety Recommendation 2010-060

It is recommended that the Civil Aviation Authority considers whether the carriage of TCAS II should be mandated for aircraft operating in those parts of the London TMA where London City Airport SIDs interact with traffic positioning to land at Heathrow Airport.

ICAO procedures

The note on the SID required strict compliance with the climb profile unless cleared otherwise by ATC. At the time of the incident, the crew of D-ITAN believed their ATC clearance was to climb directly to 4,000 ft without levelling off at the intermediate SID altitude of 3,000 ft. Contrary to the commander's recollection, there was no reiteration of the clearance to 4,000 ft from any ATC agency prior to the point where D-ITAN passed TC-JJA. The clearance to climb to 4,000 ft was issued by Thames Radar after D-ITAN had climbed above, and been instructed to descend back to, 3,000 ft. The intention to climb directly to 4,000 ft was, therefore, based solely on the crew's (incorrect) understanding of their ATC clearance. Had the revised ICAO procedures been adopted by the UK, it is likely that this incident would have been prevented because D-ITAN would have levelled off at 3,000 ft regardless of its cleared altitude.

The arguments for and against implementation of the revised procedures are beyond the scope of this report and, since ICAO is already working to resolve the situation, no recommendations are made on this topic, as a result of this incident, beyond endorsing the need for urgency in reaching a resolution.

INCIDENT

Aircraft Type and Registration:	Mystere Falcon 50, G-KPTN
No & Type of Engines:	3 Allied Signal TFE731-40-1C turbofan engines
Year of Manufacture:	2004
Date & Time (UTC):	21 January 2010 at 1617 hrs
Location:	Approximately 4 nm south-west of London City Airport
Type of Flight:	Private
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	61 years
Commander's Flying Experience:	12,000 hours (of which 7,000 were on type) Last 90 days - 23 hours Last 28 days - 12 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and subsequent enquiries made by the AAIB

Synopsis

The aircraft was on a short positioning flight to London City Airport when it descended below its cleared level of 2,000 ft amsl. The commander believed the aircraft was on final approach for Runway 27 when in fact it was downwind for Runway 09. Following an ATC instruction the aircraft climbed to its cleared level and landed on Runway 09 without further incident. The operator took safety action aimed at preventing a recurrence.

History of the flight

The aircraft was on a positioning flight from Biggin Hill Airport to London City Airport (LCY), a distance of about 10 nm. The pilots were operating in a freelance capacity for the aircraft operator and were normally based overseas. They were both instructors with considerable experience on type and both were qualified to act as commander on the aircraft. Only one of them had previously landed at LCY and he was nominated as the commander for the flight. It was intended that he should use the opportunity to familiarise the co-pilot (the handling pilot for the flight) with the airport and its required steep approach. The commander occupied the right hand seat.

Prior to departure the commander briefed the co-pilot on the intended flight. The weather at Biggin Hill was good with a light southerly wind, good visibility, few cloud at

1,000 ft and scattered cloud at 2,000 ft. Sunset that day was at 1630 hrs.

The aircraft departed from Biggin Hill's Runway 21 at 1608 hrs and was then handed over by Biggin Hill ATC to Thames Radar. Thames Radar instructed the aircraft to climb to 3,000 feet and advised that its range was approximately 32 nm from touchdown on Runway 09 at London City. Thames Radar subsequently instructed the crew to contact City Radar, as follows:

Thames Radar:	"GOLF TANGO NOVEMBER MAINTAIN ONE NINER ZERO KNOTS CONTACT ERR CITY RADAR ONE TWO EIGHT DECIMAL ZERO TWO FIVE"
G-KPTN:	"WE MAINTAIN ERR ONE NINER ZERO ONE TWO EIGHT ZERO TWO FIVE AH GOLF TANGO NOVEMBER"
G-KPTN:	"ERR SAY AGAIN ERR TOWER CITY FREQUENCY PLEASE TANGO NOVEMBER"
Thames Radar:	"GOLF TANGO NOVEMBER CITY RADAR ONE TWO EIGHT DECIMAL ZERO TWO FIVE"
G-KPTN:	"ZERO TWO FIVE SORRY SIR"

The use of City Radar is not routine and often aircraft are passed directly from Thames Radar to City Tower. The commander stated that he attempted to select the frequency for City Tower (as opposed to Radar) but mis-selected it, getting no response to his initial call. As a result he called Thames Radar again to obtain the frequency, this time establishing contact with City Radar as initially instructed.

On contacting London City Radar the pilots were instructed to descend to 2,000 ft and take up a heading of 275º. The steep approach procedure was normally flown without the use of the autopilot which was disengaged before the aircraft descended. Flap 20 was then set. The APPROACH mode of the flight director was armed during the descent and entered the APPROACH CAPTURE mode shortly afterwards.

The commander was visual with the ground and could see two bright lights ahead, which he believed were the touchdown zone lights for Runway 27 at LCY. The DME indicated that the aircraft was about 4 nm from the airport. At about this time another aircraft on the frequency was instructed to adjust its heading slightly to establish on the localizer and subsequently to descend with the glideslope. Shortly afterwards G-KPTN was given a further slight heading change.

The commander mistakenly believed that the aircraft was landing on Runway 27 and that it was nearing the final approach point, although he couldn't discern the runway itself. He was concerned that it was becoming too high to conduct an approach and therefore instructed the co-pilot to commence a descent.

The spoilers and full flap were both deployed. A steady descent rate of approximately 2,200 ft/min was established until, on passing 1,100 ft amsl (approximately 900 ft agl), ATC instructed the aircraft to climb. The descent rate was reduced quickly, the aircraft descending approximately 250 ft before achieving a climb. The aircraft was now approximately 4 nm south-west of the runway on a downwind leg.

The radio transcript covering this period is reproduced below:

London City Radar:	"CLIMB CLIMB ALTITUDE TWO THOUSAND FEET INDICATING ONE THOUSAND ONE HUNDRED"
G-KPTN:	"COPY CLIMBING"
G-KPTN:	"WE GO AROUND CONFIRM"
London City Radar:	"CLIMB TWO THOUSAND FEET NOW"
G-KPTN:	"CLIMBING NOW TWO THOUSAND FEET"

During the climb back to the cleared altitude Flap 20 was reset but the spoilers and landing gear remained deployed, contrary to the published go-around procedure. The aircraft regained the cleared altitude and landed on Runway 09 without further incident at 1624 hrs.

Recorded data

The aircraft was fitted with a Flight Data Recorder (FDR) and a Cockpit Voice Recorder (CVR). Power to the CVR was not isolated on landing after the incident and the recording of the event was subsequently overwritten. Data was successfully retrieved from the FDR. Recordings of radar tracks were obtained together with the relevant down linked Mode S parameter recordings. These were combined with recorded ATC transmissions to produce Figures 1 and 2.

London City Airport

The airport is situated in the built-up heart of London, adjacent to the River Thames. The runway is aligned 095º/275º and both Runway 09 and Runway 27 are equipped with an ILS/DME. They share the common frequency 111.15 MHz and both have a glidepath of 5.5º. The identification code for the Runway 09 ILS is I-LSR and for the Runway 27 ILS is I-LST.

Enhanced Ground Proximity Warning System (EGPWS)

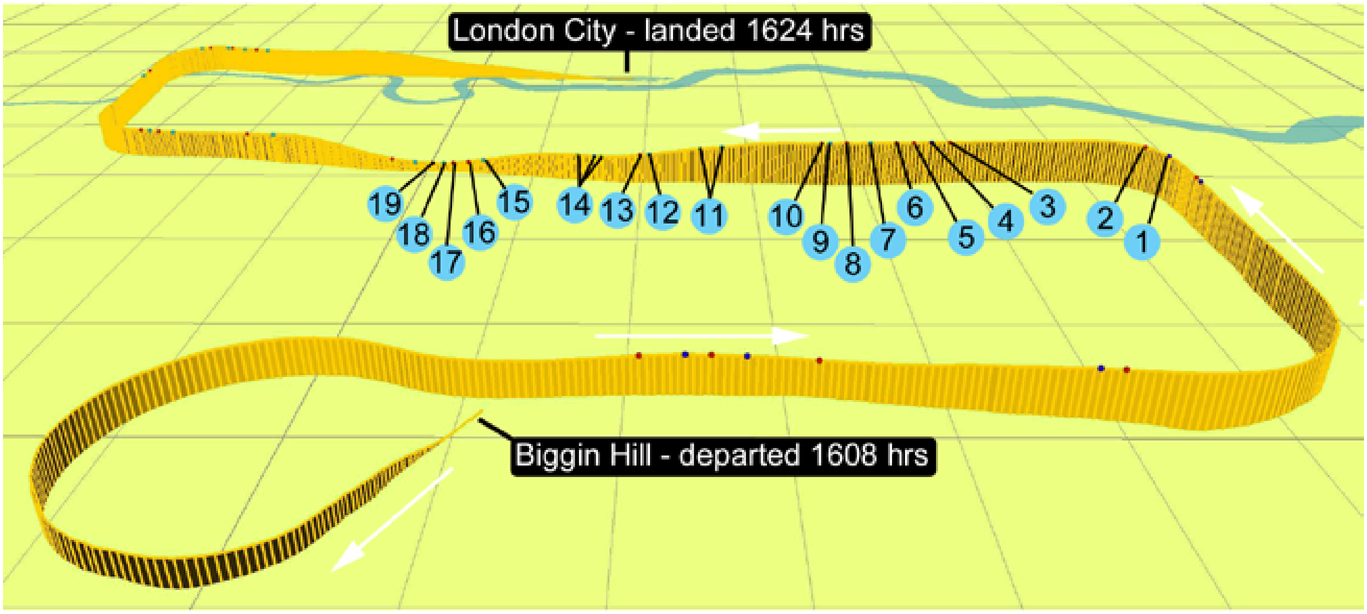
The EGPWS was removed, downloaded and tested. It was found to be fully operational during the event. No crew warnings were generated during the incident but testing and analysis has shown that this was in accordance with its design.

Manufacturer simulations showed that, had the aircraft carried on descending at 2,200 ft/min, "SINK RATE" followed by "PULL UP" aural warnings would have been initiated on passing through a radio height of 422 ft. The crew would then have had 3.4 seconds after hearing the "PULL UP" to successfully initiate the recovery, assuming a similar recovery profile to that flown.

Analysis

It is apparent from the information provided by the commander that he believed the aircraft was intended to land on Runway 27 at LCY and that he had mistaken their position on the downwind leg for Runway 09 as being on final approach for Runway 27. There are several factors that may have influenced this belief.

- The aircraft had departed from Runway 21 at Biggin Hill and therefore a landing in a westerly direction might be expected at London City, only 10 nm away.
- The aircraft was flying into a slight headwind component when on a westerly track.



PERTINENT EXTRACTS FROM ATC RECORDINGS (Call signs omitted for clarity)
AC = AIRCRAFT
TR = THAMES RADAR
CR = CITY RADAR

1 TR: "...CONTACT CITY RADAR ONE TWO EIGHT DECIMAL ZERO TWO FIVE"
2 AC: "...ONE TWO EIGHT ZERO TWO FIVE.." — Correctly read back frequency
3 AC: "ER SAY AGAIN THE THE TOWER CITY FREQUENCY PLEASE..." — Did not tune the read back frequency. Expected City Tower frequency
4 TR: "...CITY RADAR ONE TWO EIGHT DECIMAL ZERO TWO FIVE"
5 AC: "ZERO TWO FIVE SORRY SIR"
6 AC: "CITY GOOD AFTERNOON..."
7 CR: "...DESCEND NOW ALTITUDE TWO THOUSAND FEET TURN RIGHT FIVE DEGREES REPORT THAT HEADING"
8 AC: "TO THE RIGHT FIVE DEGREES ER TWO SEVEN FIVE CONFIRM DESCENT TWO THOUSAND"
9 CR: "THAT IS CORRECT ..."
10 AC: "DESCENDING TWO THOUSAND..." — Correctly read back the last cleared altitude of 2,000 ft
11 City Radar gave another aircraft a heading change to establish on the localizer and instructions to descend with the glidepath when established. This was acknowledged by that aircraft.
12 CR: "...TURN RIGHT HEADING TWO EIGHT ZERO DEGREES"
13 AC: "TWO EIGHT ZERO..."
14 The other aircraft reported established on the glideslope. The aircraft was instructed to descend with the glidesope and contact City Tower.
15 CR: "...CLIMB CLIMB ALTITUDE TWO THOUSAND FEET INDICATING ONE THOUSAND ONE HUNDRED"
16 AC: "COPY CLIMBING..."
17 AC: "...WE GO AROUND. CONFIRM" — Approach / landing terminology
18 CR: "...CLIMB TWO THOUSAND FEET NOW"
19 AC: "CLIMBING NOW TWO THOUSAND FEET..."

Figure 1

Overview of the flight

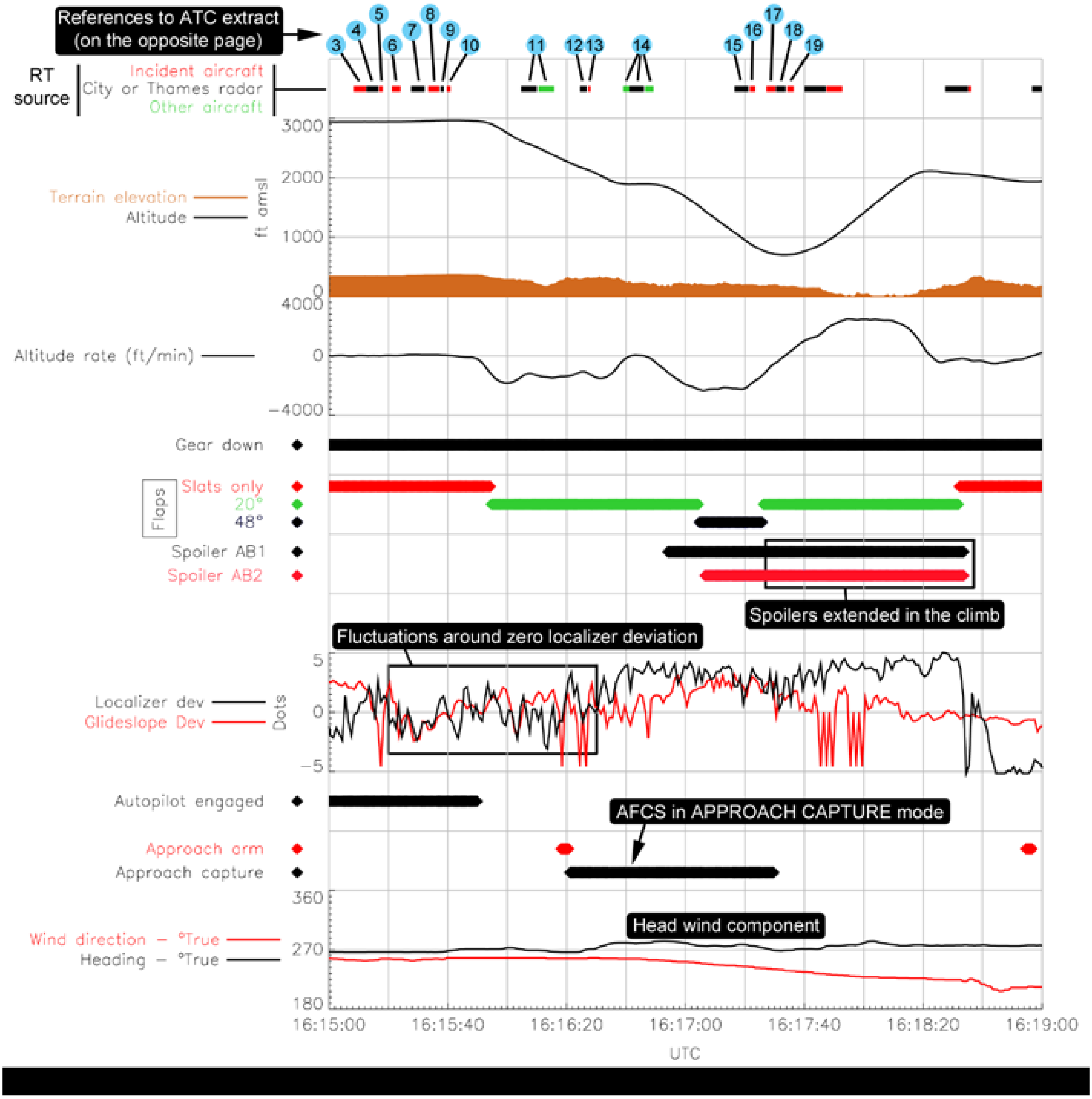


Figure 2

Descent below cleared altitude

- The flight director had entered APPROACH CAPTURE mode whilst on a westerly track.

- The runway at London City is difficult to differentiate from the backdrop of high rise office and residential buildings. This might have been made more difficult by the prevailing lighting conditions, with the aircraft flying in a westerly direction just before sunset. The commander had convinced himself that he could see the runway touchdown lights.

- The ILS/DME frequency required to be selected by the pilots was the same for both runways. The identifier codes, although not the same, are very similar.

- The requirement to fly the steep approach with the autopilot disengaged increased the crew workload on an already busy flight.

- Another aircraft was given a heading change and clearance for the approach, just before the commander was also given a heading change on the same frequency.

- The commander had thought he had been passed to City Tower, rather than City Radar. By not reading back ATC instructions in full the opportunity to pick up this mistake was lost. He associated being passed to City Tower with being on the latter stages of the approach.

The crew's confusion was evident when ATC instructed the aircraft to climb back to its cleared altitude, the spoilers and landing gear remaining deployed as the crew queried the instruction and sought confirmation that a go-around should be initiated.

Subsequent actions

The commander co-operated fully with the operator during the subsequent internal investigation and later attended additional simulator training before returning to flying duties.

As a result of their investigation the operator has made changes to the composition requirements of crews operating into LCY. They have also changed training procedures to minimise the risk of a repetition and published information to crews highlighting the incident and the lessons learned.

SERIOUS INCIDENT

Aircraft Type and Registration:	Aero AT-3 R100, G-TGUN
No & Type of Engines:	1 Rotax 912-S2 piston engine
Year of Manufacture:	2008
Date & Time (UTC):	12 June 2009 at 1640 hrs
Location:	Old Sarum Airfield, Wiltshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Damage:	Damage to propeller, right wing and engine gearbox
Commander's Licence:	Private Pilot's Licence
Commander's Age:	60 years
Commander's Flying Experience:	192 hours (of which 7 were on type) Last 90 days - 5 hours Last 28 days - 2 hours
Information Source:	AAIB Field Investigation

Synopsis

After engine start the aircraft moved forward and to the left and struck a fuel bowser, despite the pilot applying pressure to the toe brakes. It is probable that the parking brake lever had inadvertently been moved to the ON position, when the pilot exited the aircraft to refuel it, without hydraulic pressure being applied to the brakes at the time. This rendered the toe brakes inoperative, and prevented the pilot from being able to stop the aircraft. The AAIB makes three Safety Recommendations addressing the parking brake system design and information provided to the pilot about its limitations.

History of the flight

The Aero AT-3 is a low-wing two-seat aircraft certificated in the Very Light Aeroplane (VLA) category (Figure 1). After an uneventful local flight the pilot taxied the aircraft to the fuel bowser and parked alongside it. He shut down the engine and electrics and left the parking brake lever set to OFF. After uplifting 10 litres of fuel the pilot and his passenger climbed back into the aircraft and closed the canopy. After turning the battery and generator on, the pilot applied pressure to the toe brakes, set the throttle lever to ¼", called "clear prop" and turned the ignition key to START. The engine started, the aircraft moved forward and then turned sharply to the left. The pilot continued to apply pressure to the toe brakes but the brakes did not appear to work and after the aircraft had turned left through approximately

160° the propeller struck the fuel bowser, followed by the right wing. The engine stopped as a result of the propeller strike and the aircraft came to rest. The passenger vacated the aircraft first, followed by the pilot after he had turned off the switches. It was later determined that the parking brake lever had been upright, in the ON position.

Figure 1

Photograph of the incident aircraft, G-TGUN
(photograph courtesy Simon Palmer)

Description of the braking system

The Aero AT-3 has a hydraulic braking system that operates a disk brake on each main wheel using toe pressure on the rudder pedals. A parking brake lever is fitted to some aircraft, including G-TGUN, and is located on the right side of the pilot's footwell, as shown in Figure 2. The parking brake lever is off when it is in the horizontal position and on when it is in the vertical position. In order to set the parking brake the pilot needs to apply toe brake pressure before moving the lever to ON, because the lever works by trapping hydraulic pressure in the brake lines. The aircraft maintenance manual depicts two different versions of the braking system: Versions 1 and 2 as shown in Figure 3. Version 1 was fitted to early models of AT-3, while Version 2 was fitted to G-TGUN. In Version 1 there is one set of callipers per brake disk, and the left-seat and right-seat pedals operate the same pair of callipers. The brake pedals from both seats are routed

Figure 2

Parking brake lever in the horizontal OFF position; right side of left-seat footwell

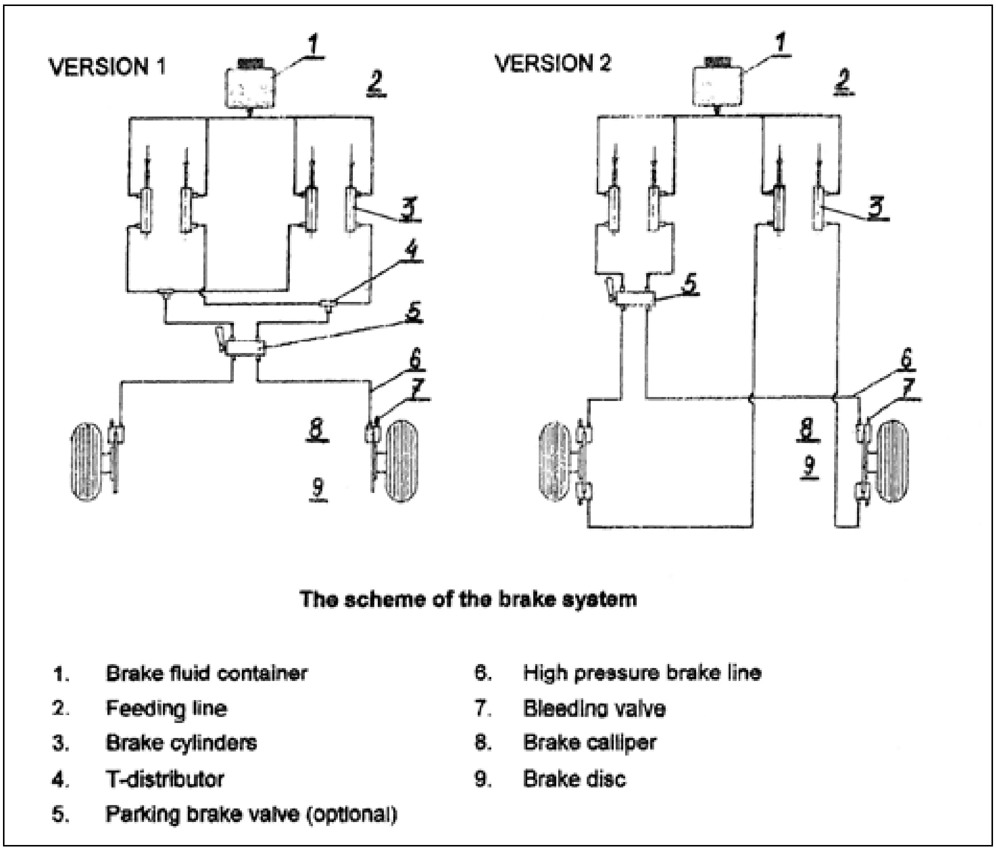


Figure 3

Brake system diagram extracted from Aero AT-3 Maintenance Manual
(G-TGUN brake system was as 'Version 2' above with optional parking brake valve)

through the parking brake valve, so either set of pedals can be used to apply the parking brake. In Version 2 there are two sets of callipers per brake disk, and the front callipers are operated by the left-seat pedals while the rear callipers are operated by the right-seat pedals. Only the left-seat pedals are routed through the parking brake lever, so only the left-seat pilot can apply pressure to operate the parking brake.

The parking brake lever can be moved to the 'ON' position and will stay in the 'ON' position even if no hydraulic pressure is applied to the brake pedals prior to moving the lever. In this situation the parking brake is off despite the parking brake lever indicating ON. Early versions of the parking brake valve incorporated a bypass valve, to enable the toe brakes to apply hydraulic pressure even when the parking brake lever was in the ON position. This particular type of valve suffered from leaks, so the aircraft manufacturer changed the valve to a new type that did not incorporate a bypass valve. The parking brake valve fitted to G-TGUN did not contain a bypass valve. Therefore, on G-TGUN if the parking brake lever was in the ON position, the toe brakes had no effect on braking.

Evaluation of the braking system by a CAA test pilot

Following the G-TGUN incident a test pilot from the Civil Aviation Authority performed a ground test of G-TGUN to evaluate its braking system. He determined that the parking brake operated satisfactorily when the parking brake lever was moved to the ON position while applying foot pressure to the toe brakes. When the parking brake lever was moved to ON without applying foot pressure, the parking brake was not applied. He also determined that it was possible inadvertently to select the parking brake lever to the ON position. His report stated that:

> *'This was possible with both foot contact, or clothing contact, especially when exiting from the aircraft. Such contact could easily select the lever to the up (ON) position thereby trapping zero foot-motor pressure, the result would be to indicate a Parking Brake "ON" condition without any pressure at the brake which is UNACCEPTABLE.'*

In the test pilot's opinion this condition did not meet the intention of the EASA Certification Specification (CS) 1301 for VLA. CS-VLA 1301 states the following:

> ***'CS-VLA 1301 Function and installation***
>
> *Each item of installed equipment must –*
>
> *(a) Be of a kind and design appropriate to its intended function;*
>
> *(b) Be labelled as to its identification, function, or operating limitations, or any applicable combination of these factors;*
>
> *(c) Be installed according to limitations specified for that equipment; and*
>
> *(d) Function properly when installed.'*

Further, the test pilot considered that pilots may reasonably expect that toe brakes will be available at all times. His report stated that:

> *'Using "trapped" pedal pressure to achieve a Parking Brake is a sensible design desire; however, rendering the foot brakes inoperative in the process is UNACCEPTABLE. It is recommended that the system be re-designed to function safely and provide continuous pressure at the foot brakes.'*

Regulations

CS-VLA 1309 on '*Equipment, systems and installations*' further states that:

> *'The equipment, systems, and installations must be designed to minimise hazards to the aeroplane in the event of a probable malfunction or failure.'*

There is no specific requirement in CS-VLA for an aircraft to be fitted with a parking brake. However, CS-VLA 735 states that *'brakes must be provided'*.

and it is logical that these brakes should be available at all times. In relation to the parking brake lever fitted to the AT-3, CS-VLA 777 on 'Cockpit controls' states that:

> *'Each cockpit control must be located to provide convenient operation, and to prevent confusion and inadvertent operation.'*

EASA Regulation Part 21, which is concerned with the certification of all aircraft types, states under section 21A.3B that the agency shall issue an airworthiness directive when:

> *'an unsafe condition has been determined by the Agency to exist in an aircraft…'*

Under the 'acceptable means of compliance' (AMC 21A.3B) section for unsafe conditions, it states that an unsafe condition exists, among other things, if there is an unacceptable risk of serious or fatal injury to persons other than occupants. Furthermore, an unsafe condition may exist even though the airworthiness requirements are complied with. Under the guidance material for this section (GM 21A.3B), it states:

> *'When an accident/incident does not involve any component malfunction or failure but when a crew human factor has been a contributing factor, this should be assessed from a man-machine interface standpoint to determine whether the design is adequate or not.'*

It further states that when establishing an unsafe condition on the basis of human factors aspects, the assessment should include:

> *'Characteristics of the design that allow or facilitate incorrect operation.'*

Flight Manual and checklists

The Flight Manual for G-TGUN (version from September 2004) contained a brief description of the braking system in the main body of the manual and a brief description of the parking brake in a supplement at the end of the manual. The accompanying diagram in both sections was for the 'Version 1' system, even though G-TGUN was fitted with the 'Version 2' system. This diagram gives the reader the incorrect impression that the parking brake could be applied from the right-seat pedals when that was not the case. The Flight Manual's description of the parking brake system did not include the information that the toe brakes would be rendered inoperative when the parking brake lever was in the ON position.

The checklist in the Flight Manual for G-TGUN did not contain references to the parking brake. The checklist called for wheel chocks to be positioned and brakes to be applied before starting the engine. The lack of reference to the parking brake could be due to the parking brake being optional on early models of aircraft.

The UK supplier of Aero AT-3s had provided the flying school, which operated G-TGUN and other AT-3s, with a modified checklist for the aircraft in September 2008. This checklist called for the parking brake to be set on before the walk-around checks, and for the parking brake to be selected off and toe brakes applied before engine start. The flying school did not adopt this practice but instead created a checklist that called for the parking brake to be on before engine start. This led to an incident where an AT-3 veered left immediately after engine start, because some of the trapped pressure in the parking brake valve had leaked out. Following this incident the flying school revised their checklist and training so that pilots started the engine with the parking brake off and toe brake pressure applied. The revised checklist included a check that the parking brake lever was off prior to the walk-around checks, and the 'Starting Engine' section was revised to include '*Toe Brakes – Hold On*'. The pilot of G-TGUN was using this checklist.

Following the G-TGUN incident the flying school added a second '*Parking Brake – Horizontal (Off)*' check at the beginning of the 'Starting Engine' section.

Aero AT-3 Service Letters

A few days after the G-TGUN incident, but unrelated to it, the aircraft manufacturer published Service Letter ATB3.10.L entitled '*Parking Brake Usage*' (Issue 1, 22/06/09). This Service Letter warned that it was not recommended to leave the aircraft for a period longer than a few hours with the parking brake engaged, because the braking force may drop due to internal leakage of the brake valve or a change in ambient temperature. It recommended that, for longer parking periods, the aircraft was either chocked or tied down. The Service Letter warned that:

> *'Parking brake must be disengaged and toe brakes applied prior to starting the engine!'*

It also recommended installing placards near the throttle levers which stated: 'BEFORE ENGINE START: - RELEASE PARKING BRAKE - APPLY TOE BRAKES.'

This letter was issued in response to incidents resulting from pilots starting the engine with the parking brake applied, and the aircraft suddenly moving or turning unexpectedly due to uneven parking brake pressure distribution to the wheels; the letter was not in response to the potential problem of starting the engine with no brake pressure in the parking brake system and inoperative toe brakes. The Service Letter did not include the information that on some models of AT-3 the toe brakes would be rendered inoperative when the parking brake lever was in the ON position. A revised Service Letter (Issue 2, 27/08/09) also did not explain the lack of a bypass valve or why the toe brakes would be rendered inoperative when the parking brake lever was in the ON position.

Updated AERO AT-3 Flight Manual

In October 2009 the aircraft manufacturer published an updated Flight Manual for the AERO AT-3. In the checklist section of the manual the words '*Parking brake (if installed) – OFF*' were added to the 'Before starting engine' checks. The braking system section of the manual was also amended to include diagrams of both the 'Version 1' and 'Version 2' braking systems. A note in bold typeface was also added stating that toe brake pressure must be applied before moving the parking brake lever to ON, and that the parking brake should not be used over a prolonged period of time due to a possible decrease in pressure in the brake lines.[1] However, the amended Flight Manual did not include the information that the toe brakes would be rendered inoperative when the parking brake lever was in the ON position.

Analysis

The pilot had intended to start the engine with the parking brake off, and was holding the toe brakes to prevent the aircraft from moving forwards after start. This was in accordance with the flying school's procedures and its checklist. The fact that the aircraft moved forwards after engine start, and did not respond to toe brake application, indicates that the parking brake lever was probably in the ON position and had been moved to the ON position without toe brake pressure applied. Based on the observations by the CAA test pilot, it is likely that the parking brake lever had been inadvertently moved to the ON position while the pilot was exiting the aircraft in order to refuel it – his right leg or clothing could have brushed against the lever and moved it.

Footnote

[1] These changes to the Aero AT-3 Flight Manual were incorporated in the 'August 2008' amendment, but this amendment was not published until October 2009.

If the pilot had checked the position of the parking brake lever prior to engine start the incident would probably have been avoided. However, his checklist did not include a parking brake lever check in the 'Starting Engine' section and, more importantly, the pilot was not aware that an inadvertent selection of the parking brake lever would render the toe brakes inoperative, because the Flight Manual did not explain this and there was no warning placard in the cockpit. The Flight Manual's description of the braking system was not adequate, and also incorrect in that it contained the wrong diagram for the type. An amended AT-3 Flight Manual, published in October 2009, incorporated the correct diagram, but still did not explain that selection of the parking brake lever would render the toe brakes inoperative.

It could be argued that when the aircraft started to roll forwards the pilot should have closed the throttle, but when an aircraft rolls forward unexpectedly a pilot tends to react instinctively, and the initial instinct is usually to apply, or press down harder on, the brakes. Therefore, the root of this serious incident was the parking brake system design. For safe manoeuvring of light aircraft on the ground, it is fundamental that the manual braking system should be available at all times. Therefore:

Safety Recommendation 2010-053

It is recommended that the European Aviation Safety Agency (EASA) require that the Aero AT-3 brake system be modified such that the toe brakes remain functional regardless of whether the parking brake is off or on.

In the interim, it is important both that the Flight Manual accurately reflect the design and function of the brake system installed and that this be reinforced by the provision of warning placards. Therefore, as an interim measure until the brake system is redesigned, the following two Safety Recommendations are made:

Safety Recommendation 2010-054

It is recommended that the European Aviation Safety Agency (EASA) require Aero Sp to update the Flight Manual for the Aero AT-3 to explain the operation of the braking system clearly and to include a warning that the toe brakes become inoperative when the parking brake lever is selected on.

Safety Recommendation 2010-055

It is recommended that the European Aviation Safety Agency (EASA) require Aero Sp to provide warning placards, to be installed in all affected Aero AT-3 aircraft, which state that the toe brakes become inoperative when the parking brake lever is selected on.

Safety Action

Following this investigation, the aircraft manufacturer stated that they intend to provide warning placards for all affected aircraft which state 'LEFT SEAT TOE BRAKES ARE INOPERATIVE WHEN PARKING BRAKE LEVER IS "ON"'. They also intend to amend the Flight Manual to include the same warning and additional information explaining the operation of the braking system.

ACCIDENT

Aircraft Type and Registration:	Bellanca 7GCBC Citabria, G-HUNI
No & Type of Engines:	1 Lycoming O-320-A2B piston engine
Year of Manufacture:	1973
Date & Time (UTC):	31 May 2010 at 1330 hrs
Location:	Henstridge Airfield, Somerset
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Landing gear, underside of fuselage, propeller and right wingtip damaged
Commander's Licence:	Private Pilot's Licence
Commander's Age:	46 years
Commander's Flying Experience:	284 hours (of which 10 were on type) Last 90 days - 6 hours Last 28 days - 1 hour
Information Source:	Aircraft Accident Report Form submitted by the pilot

Whilst landing on Runway 07 at Henstridge, the right main landing gear leg failed and detached from the aircraft, causing the underside of the fuselage and the right wingtip to contact the runway. The aircraft veered to the right and came to rest beside the runway, facing in the opposite direction. Both occupants were uninjured and able to vacate the aircraft unaided.

The pilot reported that the weather conditions were good, with a surface wind from 060° at 5 kt, and that the approach and touchdown were normal. He had satisfactorily completed a proficiency check with an instructor immediately prior to this flight.

The detached section of the steel landing gear leg was returned to the AAIB for examination. Inspection of the fracture surfaces revealed evidence of an approximately 15 mm deep pre-existing crack propagating from the rear edge of the gear leg. The crack surfaces in this region were heavily corroded (Figure 1), indicating that the crack had been present for some time prior to the failure.

Figure 1

Fracture surface of landing gear leg showing location of pre-existing crack (circled)

ACCIDENT

Aircraft Type and Registration:	Bucker BU133 Jungmeister, G-BVXJ
No & Type of Engines:	1 Siemens-Bramo SH14A-4 radial piston engine
Year of Manufacture:	1953
Date & Time (UTC):	7 March 2010 at 1630 hrs
Location:	Breighton Airfield, Yorkshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A Others - 1 (Serious)
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	54 years
Commander's Flying Experience:	22,000 hours (of which 2 were on type) Last 90 days - 180 hours Last 28 days - 60 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and further enquiries by the AAIB

Synopsis

When the owner 'hand swung' the propeller to start the engine, the engine started unexpectedly on the first attempt. The propeller struck the owner's left hand and severed two of his fingers.

History of the flight

The Bucker BU133 Jungmeister is a single-seat vintage biplane powered by a Siemens-Bramo SH14A-4 radial piston engine (Figure 1). The engine is not fitted with an electric starter and is therefore started by hand swinging the propeller. The aircraft had completed three flights earlier in the day and prior to each flight the engine had been difficult to start, requiring several

Figure 1

Bucker BU133 Jungmeister, G-BVXJ
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swings of the propeller. For the final flight of the day the aircraft was positioned on an area of level tarmac and the brakes applied. The pilot was in the cockpit and the aircraft's owner stood in front of the aircraft to swing the propeller.

The owner, an experienced pilot with 30 hours on type and 900 hours on Tiger Moths, judged that the engine was still slightly warm from its flight 30 minutes previously, and decided that only a small amount of priming was necessary, without 'sucking in'. After priming, and having confirmed that the magnetos were off with standard calls and hand signals, he moved the propeller through one or two compressions to put the blades in the optimum position for starting. He then called "THROTTLE SET, SWITCHES ON", after which the pilot set the throttle for start, turned on the magnetos and replied "THROTTLE SET, CONTACT" while giving a 'thumbs up' signal. As the owner swung the propeller the engine started immediately. The pilot heard the engine fire and almost simultaneously heard a heavy 'thud', and saw the owner fall backwards, away from the propeller.

The pilot realised that the owner was probably injured so he shut down the engine and went to help. As he exited the aircraft he saw a flying club member, who was also a doctor, already attending to the owner. The propeller had severed two fingers from the owner's left hand. Other members of the flying club assisted the doctor by providing a first aid kit and blankets. The pilot dialled '999' and called for an ambulance.

Pilot's comments

The pilot commented that his and the owner's expectation that the engine would be difficult to start, and would need several swings, probably contributed to the incident. They were both taken by surprise when the engine suddenly started on the first attempt.

Owner's comments

The owner commented that it was very unusual for the engine to start on the first swing. His technique was to swing the propeller downwards using just his left hand, standing legs apart about 30° 'right shoulder out' from the plane of the propeller (the propeller rotates anti-clockwise when viewed from the front of the aircraft). He would then stride backwards as soon as he had completed the swing. In this event he believes the engine fired on the first stroke, and while he was still following through with his left hand, the other blade came down and struck it.

Safety Action

The CAA does not currently have published advice on how to swing the propeller during a hand start. However, following this accident the CAA has stated that they will consider publishing such advice.

ACCIDENT

Aircraft Type and Registration:	Cessna 120, G-AJJS
No & Type of Engines:	1 Continental Motors Corp O-200-A piston engine
Year of Manufacture:	1947
Date & Time (UTC):	9 May 2010 at 1245 hrs
Location:	Near Bicester Airfield, Oxfordshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Damage to landing gear, one wing, fuselage and engine cowlings
Commander's Licence:	Private Pilot's Licence
Commander's Age:	48 years
Commander's Flying Experience:	428 hours (of which 5 were on type) Last 90 days - 5 hours Last 28 days - 5 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and subsequent enquiries by the AAIB

Synopsis

The aircraft suffered a power loss of unknown cause whilst in the cruise. The subsequent forced landing resulted in significant damage to the aircraft.

History of the flight

The aircraft took off from Sywell (Northampton) Airfield at 1310 hrs for a flight to Popham Airfield with the pilot and a passenger on board. The aircraft used Mogas and both wing tanks were completely filled before departure.

The pilot reported that while cruising at 1,800 ft he applied carburettor heat several times as a precaution. After the aircraft had been airborne for about 30 minutes, the engine suddenly lost power so he applied carburettor heat again and turned the aircraft towards Bicester Airfield, which was nearby. Engine power was temporarily restored, but reduced again shortly afterwards. The pilot confirmed there was still fuel indicated in the selected tank, but did not switch to the other tank. He also confirmed that both magnetos were selected ON and that the mixture was rich.

Unable to maintain altitude, the pilot continued to fly towards Bicester in order to make a forced landing there, but when the engine stopped completely at about 200 ft he landed the aircraft at the edge of an adjacent field. During the landing the aircraft suffered severe damage but both the pilot and his passenger were uninjured and able to leave the aircraft unaided.

Possible cause

The use of Mogas has been associated with vapour lock, a condition where vapour forming in the fuel system prevents fuel getting to the engine. It is less likely to occur in high-wing aircraft and under the prevailing conditions described by the pilot is considered unlikely in this case.

An aftercast of weather covering the route indicates that, at the level flown, the temperature was approximately 5°C and the dew point approximately 2.0°C. This would have placed the aircraft at risk of severe carburettor icing at any power setting. Despite the pilot's statement that he had used carburettor heat periodically during the flight and again when the engine lost power it is possible that this was insufficient to prevent the build-up of ice in the carburettor or to remove it once the engine's loss of power became significant.

It is possible that debris in the fuel system restricted fuel flow. Had this been the case it might have been possible to restore power by selecting the other fuel tank.

The aircraft was probably damaged beyond economic repair and the owner has, at the time of writing, not carried out any further inspection. It therefore remains possible that the power loss was caused by an additional, still unidentified, problem with the engine or fuel system.

ACCIDENT

Aircraft Type and Registration:	1) Cessna 150M, G-BPAX 2) Diamond DA 40 D Diamond Star, G-CDEK
No & Type of Engines:	1) 1 Continental Motors Corp O-200-A piston engine 2) 1 Thielert TAE 125-02-99 piston engine
Year of Manufacture:	1) 1975 2) 2004
Date & Time (UTC):	6 June 2010 at 1100 hrs
Location:	Shoreham Airport, West Sussex
Type of Flight:	1) Private 2) N/A
Persons on Board:	1) Crew - 1 Passengers - None 2) Crew - None Passengers - None
Injuries:	1) Crew - None Passengers - N/A 2) Crew - N/A Passengers - N/A
Nature of Damage:	1) Propeller and nose cone bent, rear tiedown torn off, right wing leading edge punctured, fuselage creased near wing root 2) Tail section severed
Commander's Licence:	1) Private Pilot's Licence 2) N/A
Commander's Age:	1) 64 years 2) N/A
Commander's Flying Experience:	1) 325 hours (of which 291 were on type) Last 90 days - 1 hour Last 28 days - 1 hour 2) N/A
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The pilot of G-BPAX reported that when starting the engine with the throttle set near to its idle position, it increased speed rapidly to its maximum of about 2,500 rpm. The aircraft then travelled forward and the pilot was unable to stop it using the brakes or control its direction. After travelling approximately 90 ft, G-BPAX collided with G-CDEK, which was parked. The pilot of G-BPAX was uninjured and vacated the aircraft. The pilot was unsure of the reason for the accident. The braking system was subsequently confirmed by an engineer as being serviceable.

History of the flight

G-BPAX was parked on a grass area adjacent to the main terminal building at Shoreham Airport. Positioned ahead of G-BPAX and on an adjacent hardstanding area to its left were a number of parked aircraft, which included G-CDEK. The pilot of G-BPAX had planned to make a local flight and, having completed the external pre-flight inspection, entered the cockpit to continue his checks. He recalled setting the engine mixture to fully rich and the throttle to just above the idle position. The pilot stated that upon start-up the engine speed immediately increased to its maximum of about 2,500 rpm. The aircraft then moved forward and veered to the left with the nosewheel lifting from the ground. The pilot attempted to stop the aircraft using the brakes and steer away from the other aircraft, but was unable to prevent it from colliding with G-CDEK. G-BPAX had travelled about 90 ft from its parking position. On impact, the engine stalled and the aircraft came to a stop. The pilot, who was uninjured, vacated the aircraft through the cockpit door with the AFRS in attendance. During the collision, the tail section of G-CDEK had been severed and G-BPAX had sustained damage to its propeller, spinner and right wing root and leading edge. The rear tiedown of G-BPAX had also been torn from the aircraft. The pilot stated that he had removed the tiedown ropes during the pre-flight inspection and that the damage to the rear of the aircraft had been a result of the aircraft tail striking the ground. The pilot was unsure as to the reason for the accident. Following the accident, an engineer inspected the braking system and confirmed that it was serviceable.

ACCIDENT

Aircraft Type and Registration:	Cessna 152, G-CEYI
No & Type of Engines:	1 Lycoming O-235-L2C piston engine
Year of Manufacture:	1979
Date & Time (UTC):	18 June 2010 at 1006 hrs
Location:	RAF Henlow, Bedfordshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to the nose landing gear, propeller, engine cowling, engine, engine bay, firewall and lower fuselage
Commander's Licence:	Private Pilot's Licence
Commander's Age:	78 years
Commander's Flying Experience:	24,350 hours (of which 30 were on type) Last 90 days - 4 hours Last 28 days - 1 hour
Information Source:	Aircraft Accident Report Form submitted by the pilot

The pilot reported that the purpose of the flight was to update his currency. The cloud was overcast at about 1,500 ft, so he elected to fly circuits at the airfield. Grass Runway 02 was in use, the wind was light from the north-east and the visibility was good. The first circuit was described as normal, as was the second until the aircraft bounced on touchdown. The subsequent landing was flat and firm and, after rolling a few metres, the nose landing gear collapsed. The propeller blades struck the surface and the aircraft came to a halt on the runway with the engine stopped. The pilot turned off the fuel, the magnetos and the master switch and vacated the aircraft normally, uninjured. There was no fire.

In an open and honest report the experienced pilot considered that the accident occurred because, having bounced, he did not go-around or, alternatively, maintain the correct landing attitude. Thus, during the subsequent firm landing the nose landing gear was overloaded and collapsed. He also considered that his lack of recent experience in light aircraft may have been a factor.

ACCIDENT

Aircraft Type and Registration:	Cessna FRA150L Aerobat, G-BCFR
No & Type of Engines:	1 Continental Motors Corp O-240-A piston engine
Year of Manufacture:	1974
Date & Time (UTC):	21 April 2010 at 1200 hrs
Location:	Old Buckenham Airfield, Norfolk
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Nosewheel, propeller, engine frame and bulkhead
Commander's Licence:	National Private Pilot's Licence
Commander's Age:	71 years
Commander's Flying Experience:	389 hours (of which 356 were on type) Last 90 days - 8 hours Last 28 days - 7 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The aircraft took off from Earls Colne Airfield in Essex with the intention of flying to Old Buckenham. On the day of the accident, Old Buckenham was unlicensed and as such, no air-ground radio service was available. Despite this, during the approach, the pilot made attempts to contact the airfield to retrieve the airfield information. As no reply was received, two circuits were flown with a view to ascertain the wind direction which was judged to be variable.

The aircraft landed on Runway 25, a down-sloping runway with a dry asphalt surface and a landing distance available of 640 m. The pilot considered that the landing was normal and stated that the aircraft touched down approximately one quarter length along the runway. After touchdown, braking was applied and the aircraft began to decelerate. However, the aircraft continued beyond the end of the runway, ran through an area of rough grass and came to rest in a field. Both the pilot and passenger were wearing full harnesses and were uninjured.

The pilot considered that a gusting tailwind increased the landing distance, leading to the aircraft departing the end of the runway.

ACCIDENT

Aircraft Type and Registration:	Diamond DA 42 Twin Star, G-OCCX
No & Type of Engines:	2 Thielert TAE 125-01 piston engines
Year of Manufacture:	2006
Date & Time (UTC):	26 March 2009 at 0952 hrs
Location:	Runway 21, Cranfield Airport, Bedfordshire
Type of Flight:	Training
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Left main landing gear, left propeller, left engine and the left wing
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	66 years
Commander's Flying Experience:	8,920 hours (of which 290 were on type) Last 90 days - 19 hours Last 28 days - 18 hours
Information Source:	AAIB Field Investigation

Synopsis

The aircraft suffered a left main landing gear failure while landing. A defect was identified which had not been detected during a previous special inspection of the failed area. No other instances of a defect remaining undetected following such an inspection were identified.

History of the flight

The student was carrying out a practice asymmetric approach in a 7 kt crosswind from the right. The instructor judged that the landing was normal except that the crabbed approach was not straightened. The aircraft touched down on the left main wheel, drifting to the left, before the instructor could intervene. Almost immediately the left main landing gear collapsed and the aircraft veered off the runway to the left, coming to rest on the grass about 8 m from the runway edge.

The instructor shut down both engines and the aircraft electrics, after alerting ATC. Both occupants, who were uninjured, vacated the aircraft in the normal manner by raising the cockpit canopy.

Examination of the failed landing gear revealed that the attachment of its side brace to the primary structure had failed.

Landing gear

The aircraft type has a primary structure fabricated largely from Carbon Fibre Reinforced Plastic (CFRP). Each main landing gear side brace attachment to its wing takes the form of a steel pivot pin, orientated fore and aft, with its forward end being bonded and encapsulated into a sandwich Glass Reinforced Plastic (GRP) assembly. The assembly has a dished profile, with flanges at its vertical edges and its lower horizontal edge, bonded to the aft face of the main-spar. The upper edge of the assembly forms a flange in a plane orientated parallel with, and bonded onto, the lower surface of the wing upper skin. The lower, side and upper flanges form a continuous bond line between the sandwich assembly and the wing CFRP primary structure.

Examination of failure

Complete separation of the GRP assembly had taken place at the bond line. Examination of the failed bond area between the upper flange of the assembly and the underside of the wing skin revealed a large void ie a localised absence of bonding paste material. The void occupied approximately one third of the surface area of the joint between the GRP assembly and the wing skin.

Mandatory Service Bulletin

The presence of voids in the bond between the sandwich assembly and the wing skin had previously been identified as a defective feature in some DA 42 aircraft before this accident. A Mandatory Service Bulletin (MSB), MSB 42-031, had been issued detailing an inspection procedure intended to identify this defect.

The MSB calls for extensive dismantling steps to be carried out to gain access to the critical area on each side of the aircraft. Thereafter, it requires three holes to be drilled through each upper flange of the sandwich assembly at selected locations. The process of drilling and subsequent examination of the holes forms the procedure for assessing the presence, or otherwise, of bonding. If a bond defect is found, a repair/reinforcement procedure is specified.

The repair involves bonding in new specially manufactured sections which incorporate steps or joggles which permit them to fit over the outside of the GRP sandwich assembly. The sections are bonded to the sandwich assembly whilst their edge flanges are bonded directly to the under-surface of the wing skin and the aft face of the wing spar. In all cases the inspection holes are subsequently filled with resin.

The requirements of this MSB had been carried out on G-OCCX before the accident. Examination of the separated assembly from the aircraft revealed that two of the three holes had been drilled into a bonded area whilst the other had entered a void. The repair/reinforcement procedure, required if an area of no bond is found, had not been implemented.

Inspection process

Once dismantling has been carried out to gain access, the MSB specifies a 4 mm diameter drill to be used for each hole. During drilling it is required to assess the changing drill torque or resistance behaviour. Initially the resistance is expected to be high, since the drill is cutting through the GRP laminate of the brace attachment assembly. It then decreases as the drill passes through the bonding paste. It then either increases significantly due to the CFRP laminate of the upper shell of the centre wing section being encountered or it decreases significantly before the drill hits the hard surface of the upper shell. In each case drilling must stop as soon as the upper shell is encountered, or before. In the first case the operative is required to stop drilling immediately as the resistance increases. Alternatively, the resistance decreases significantly as the drill encounters the bonding paste void, then the drill hits the upper shell of the centre wing section. In this instance the operative is required to stop drilling as the resistance decreases ie before the upper shell is encountered.

The drill is then required to be removed and the hole inspected. If the bottom of the hole is the same colour as the bonding paste (light grey) then it is assumed that a correct bond exists. If, however, only black glossy surfaces are visible it is assumed that no bond material is present and no structural bond exists. In such a case, a repair/reinforcement is called for.

Other incidents

The manufacturer stated that they had had good success with the MSB and were aware of only one other case of a landing gear failure following the application of the repair scheme. In that instance, they reported that the repair "ribs" had been poorly bonded during the reinforcement procedure.

Development of the inspection procedure

The manufacturer stated that when they developed the inspection procedure they wanted to make it as simple as possible, using standard tools, because more sophisticated methods, such as ultrasonic inspections, required experienced personnel to interpret the results correctly. The concern was that trained personnel with those skills would be scarce in general aviation. The inspection procedure as detailed in the MSB was satisfactorily tested on their production and maintenance staff.

The manufacturer considered requiring all DA 42 aircraft to be equipped with the additional "ribs" but investigation revealed that there was a significant number of unaffected aircraft and to do so would impose a weight, time and cost burden on the owners.

Discussion

The presence of voids in the bond between the sandwich assembly on the main landing gear side brace attachment and the wing skin had previously been identified as a defective feature in some DA 42 aircraft. A Mandatory Service Bulletin (MSB), MSB 42-031, had been issued detailing an inspection procedure intended to identify this defect.

MSB 42-031 had been carried out on G-OCCX. A void in the bond existed in the attachment for the left main landing gear side brace but the repair/reinforcement procedure had not been completed. Subsequently the main landing gear failed during the landing on the accident flight.

No other instances of a defect remaining undetected following the MSB procedure were identified. However, the manufacturer was aware of one case of reinforcement ribs being poorly bonded during the application of the MSB repair procedure on one aircraft and the landing gear subsequently failing.

The manufacturer had considered more sophisticated examination techniques when developing the MSB but concluded that this procedure, using standard tools, was the most appropriate.

Conclusions

The left main landing gear collapsed during a practice asymmetric landing as a result of the failure of the bond between the sandwich assembly on the main landing gear side brace attachment and the wing skin. This was attributed to a void in the bond for which the repair/

reinforcement, detailed in MSB 42-031, had not been completed, although the MSB had been carried out on the aircraft. The MSB had been developed to identify this defect.

The manufacturer was aware of one other case of a landing gear failure following the application of this repair scheme. In that instance, it was reported that the repair "ribs" had been poorly bonded during the reinforcement procedure.

ACCIDENT

Aircraft Type and Registration:	Jodel D117, G-ATIZ
No & Type of Engines:	1 Continental Motors Corp C90-14F piston engine
Year of Manufacture:	1957
Date & Time (UTC):	29 April 2009 at 0900 hrs
Location:	Tower Farm, Wollaston, Northamptonshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Propeller, tailwheel and leading edges of both wings
Commander's Licence:	Private Pilot's Licence
Commander's Age:	49 years
Commander's Flying Experience:	247 hours (of which 63 were on type) Last 90 days - 1 hour Last 28 days - None
Information Source:	Aircraft Accident Report Form submitted by the pilot

Having removed the aircraft from its hangar, the pilot carried out the external pre-flight inspection before entering the cockpit to continue his checks. The aircraft was not equipped with a parking brake and was not chocked. Having turned the fuel ON, set the magnetos ON, the mixture to fully rich and the throttle to just above the idle position, he recalled that he had omitted to turn the propeller through a number of turns, as was his usual practice, prior to starting the engine. He disembarked from the aircraft and proceeded to turn the propeller. On the third turn of the propeller the engine started and the aircraft started to move. The pilot attempted to restrain the aircraft by pushing against the leading edge of the left wing, but the aircraft turned to the left before setting off towards a hedge. The pilot attempted to enter the cockpit to stop the aircraft, but was unsuccessful. The aircraft struck the hedge and the engine stalled. The propeller, tailwheel and both wing leading edges were damaged but the pilot was uninjured. He considered that the accident had been a result of his haste to fly and failure to follow his checklist.

ACCIDENT

Aircraft Type and Registration:	Maule M5-235C Lunar Rocket, G-BVFT
No & Type of Engines:	1 Lycoming O-540-J1A5D piston engine
Year of Manufacture:	1978
Date & Time (UTC):	24 April 2010 at 0955 hrs
Location:	Glanusk Park, Crickhowell, Powys
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Left wing, propeller, lower engine cowl, engine, rear fuselage and tail wheel
Commander's Licence:	Private Pilot's Licence
Commander's Age:	38 years
Commander's Flying Experience:	193 hours (of which 138 were on type) Last 90 days - 1 hour Last 28 days - None
Information Source:	Aircraft Accident Report Form submitted by the pilot

The pilot reported that en route to his destination he listened to the ATIS for Gloucestershire Airport, 37 nm to the east, which reported a surface wind from 190° at 5 kt. The landing strip at Glanusk Park is grass, orientated approximately 110/290°. The pilot flew an approach in the north-westerly direction; the approach was slightly high, and he side-slipped the aircraft to lose height. He reported that the approach had felt "fast" and that the landing was "long and fast". As the aircraft approached the fence at the end of the strip the pilot retracted flap and applied power to go around. There was insufficient time to complete the correct short-field takeoff procedure and, despite a final attempt to lift off, the aircraft struck the fence and then a tree trunk, against which it came to a halt.

The pilot attributed the accident to lack of recent flying experience, poor judgement of the wind (which locally was a strong tailwind), and a late decision to go around.

ACCIDENT

Aircraft Type and Registration:	Piper PA-28R-201 Cherokee Arrow III, G-WAMS
No & Type of Engines:	1 Lycoming IO-360-C1C6 piston engine
Year of Manufacture:	2001
Date & Time (UTC):	29 June 2010 at 1613 hrs
Location:	Stapleford Airfield, Essex
Type of Flight:	Training
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to underside of fuselage and propeller, engine shock loaded
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	68 years
Commander's Flying Experience:	11,748 hours (of which 6,636 were on type) Last 90 days - 45 hours Last 28 days - 21 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot.

The examiner and the candidate were carrying out a skills test with the candidate occupying the left seat and the examiner the right. During the upper air work, while carrying out a stall recovery with the aircraft in a clean configuration and the landing gear retracted, the landing gear audio warning was heard to function normally when the throttle was closed.

The final element of the test was for the candidate to demonstrate a flapless landing on Runway 22L. The weather was good, with a light southwesterly surface wind and CAVOK. The aircraft joined left base and the Fuel, Radio, Engine, Direction Indicator (DI) and Altimeter (FREDA) checks were performed. A slightly steeper than normal approach was made, with a low power setting and an IAS of 80 kt. The aircraft was flared at the normal height and sank onto the runway with the landing gear in the retracted position. Neither pilot heard the landing gear audio warning. A post-accident function check of the warning system showed it to be working normally. The examiner concluded that the normal checks of the landing gear during the initial and final approach phases had not been performed.

ACCIDENT

Aircraft Type and Registration:	Sukhoi SU-29, HA-YAO
No & Type of Engines:	1 Vedeneyev M14P piston engine
Year of Manufacture:	1998
Date & Time (UTC):	13 June 2010 at 1154 hrs
Location:	North Weald Airfield, Essex
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Damage to the underside of the right wing and right aileron
Commander's Licence:	Private Pilot's Licence
Commander's Age:	67 years
Commander's Flying Experience:	1,235 hours (of which 200 were on type) Last 90 days - 25 hours Last 28 days - 15 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The aircraft, which is fitted with a tailwheel, landed on Runway 31 at North Weald Airfield. During the landing roll it drifted to the right and the right wing struck a runway signboard. Runway 31 is an asphalt runway of 650 m length and 45 m width. The surface wind was from 240° at 10 kt. The pilot remarked that he lost his visual references during the landing.

ACCIDENT

Aircraft Type and Registration:	Taylor Titch, G-MISS
No & Type of Engines:	1 Walter Minor 4-3 piston engine
Year of Manufacture:	2009
Date & Time (UTC):	8 November 2009 at 1508 hrs
Location:	Eldernell Lane, Coates, Whittlesey, Cambridgeshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 (Fatal) Passengers - N/A
Nature of Damage:	Aircraft destroyed
Commander's Licence:	National Private Pilots Licence (Aeroplanes)
Commander's Age:	70
Commander's Flying Experience:	856 hours (of which 0 were on type) Last 90 days - 14 hours Last 28 days - 4 hours
Information Source:	AAIB Field Investigation

Synopsis

The aircraft had been built from plans and was flying on a Permit to Fly. The owner lent the aircraft to a friend who, for his first trip in this type of aircraft, was briefed to fly a few stalling exercises followed by a few circuits back at the airstrip. The weather conditions were good and the aircraft departed from grass Runway 36. It was last seen by the owner at a height of approximately 2,000 ft, several miles to the north of the airstrip in a left turn. Witnesses saw a small aircraft enter a steep spiral dive, complete several revolutions, then crash into a bank on the edge of the River Nene. The investigation found no mechanical cause for the accident. The spin characteristics of the aircraft were assessed by an aerodynamicist, who considered that the aircraft would probably recover from a spin should the pilot make the correct control inputs.

The postmortem revealed that the pilot's cause of death was multiple injuries, although, given his medical history, it was considered possible that he had suffered from an incapacitating cardiac event just prior to the accident.

History of the aircraft

G-MISS was a modified Taylor Titch which had been built from plans by its first owner. Instead of the suggested Volkswagen or Continental horizontally-opposed engines, he had decided to install a Walter inverted in-line four cylinder powerplant. This considerably altered the profile of the aircraft nose. The original builder died before the aircraft was completed. The final stages of build were completed by another enthusiast on behalf of the original builder's widow. The aircraft accrued some 12 hours of flight testing (carried out by another pilot) before being sold to its current owner in 2007. The new owner, a Light Aircraft Association (LAA) inspector, examined the aircraft closely, rectifying a number of defects and making several changes where he felt that there were deficiencies in the original design or build. This took some time and in August 2009, having completed 16 hours 30 minutes of flight testing, the aircraft was granted its Permit to Fly. The flight test report concluded that G-MISS:

> *'performs well and is pleasant and easy to fly'.*

History of the flight

The aircraft had flown just over 14 hours since the issue of its Permit to Fly, when the owner noticed that fuel was weeping from the fuel tank. He removed the tank, had it rebuilt and during the morning of 8 November 2009 refitted the fuel tank into the aircraft. A duplicate check of the work carried out was performed by the owner's friend, a pilot who lived nearby. Once the tank was properly installed the owner refuelled his aircraft to full using Avgas 80/87 from a barrel; this gave the aircraft around 150 minutes endurance. At approximately 1410 hrs he took off for a 25 minute local check flight. As he was taxiing out, his friend, who had gone home after the tank fitting, returned to the airfield in his own aircraft, an Isaacs Fury biplane. The owner's friend decided to follow the Taylor Titch in his biplane, to compare the aircraft's climb performance and to observe the flight. During the flight, which included the use of high power settings and stalling, G-MISS performed normally, and as it was returning to the airfield, its owner, using the radio, offered to let his friend fly it. His friend accepted and, after they both landed at White Fen Farm Airstrip and shut down, they conducted a brief.

This would be the owner's friend's first flight in a Taylor Titch, so the owner gave him an extensive brief on the handling characteristics of the aircraft. He briefed him to climb to height in the airfield overhead, carry out some general handling, to include stalling, and then to return to the circuit for a few touch-and-gos. The flight was expected to last approximately 20 minutes.

The aircraft was a little difficult to start, as the engine was still warm from the previous flight, but after starting the pilot carried out his normal checks, including the magneto checks, and taxied out to Runway 36. The departure, at around 1500 hrs, was described by the owner as "a bit messy" as the pilot seemed to have some difficulty in controlling the heading as the aircraft progressed down the runway. This may have been due to the fact that the propeller rotated in the opposite direction on G-MISS to that on the pilot's own Isaacs Fury. After takeoff the aircraft continued climbing to the north, reaching a height that the owner estimated was 2,000 ft. The owner commented that the aircraft's climb angle was not as steep as he was expecting and he wondered whether the pilot had left the carburettor heat selected, as he had taxied out with it on. The owner saw the aircraft turning left, assumed it was returning to the airfield but then he lost sight of it. After 30 minutes, when the aircraft had not returned, the owner became concerned and initiated 'overdue' action.

Witnesses

A witness was walking with her husband along the flood dyke to the south of the River Nene near the village of Eldernell. She described hearing the noise of an aircraft suddenly reduce. This attracted their attention to a small white aircraft which they both estimated was at a normal height for a light aircraft. They then heard the engine noise increase and, shortly afterwards, saw the aircraft enter a descending spiral turn. The spiral turn became very steep after several rotations, the aircraft losing height rapidly, and the witness became concerned that the aircraft would not recover. The aircraft remained in a descending spiral, with no apparent change in its rate of rotation, until it hit the ground approximately 200 m from them, on the bank of the river. This witness called the emergency services at 1509 hrs and her husband went to the accident site. It was immediately apparent that nothing could be done to assist the pilot.

Another witness, who was located to the west of Eldernell, was watching birds to the east of his position, through binoculars, when a small aircraft came into his field of view. The aircraft was in a steep spiral dive, rotating to the right but descending almost vertically. He had previously flown gliders and considered that he was witnessing a spiral dive, not a spin. He initially thought that the aircraft was performing aerobatics but became concerned as the aircraft continued to descend. The aircraft hit the ground about a mile from his position and he heard a noise which he described as a thump. He called the emergency services and proceeded to the aircraft.

Weather

An aftercast provided by the Met Office indicated that a moderate and unstable north-easterly flow covered the Cambridgeshire area, with good visibility and a small amount of convective cloud. In the area of the accident site the 2,000 ft wind was estimated to be from the north-east at 20 kt, reducing to 10 kt from a more northerly direction at the surface. Whilst the aftercast did suggest the possibility of turbulence in the area, the weather was not thought to have been significant in this accident.

Taylor Titch spin characteristics

In 1973, the Ministry of Technology, at the Royal Aircraft Establishment (RAE) Bedford, conducted a flight test on a Taylor Titch fitted with the Continental O-200 engine. The flight test included spinning and the report commented that the aircraft both entered and recovered quickly from the spin.

G-MISS was fitted with a Walter Minor engine and had a slightly longer and narrower engine compartment and a larger tail fin to aid its directional stability see Figure 1). This caused an increase in pitch inertia. No spinning trials had been conducted on such a modified Taylor Titch, and neither standard nor modified aircraft of this type were cleared for spinning.

Examination of the aircraft and accident site

The aircraft had struck very soft mud on the bank of the river and come to rest partially in the water. The front fuselage wooden structure had almost entirely fragmented as far back as the rear of the cockpit: the pilot had been thrown into the water since all the wooden members securing his seat harness had disintegrated. Aft of the cockpit, the fuselage was basically intact with the empennage in situ, although the right tailplane detached during recovery. The left wing had fragmented whilst the right wing, albeit almost detached, was still essentially intact outboard of the flap. A distinct impression of the left wing leading edge was discernible in the river bank, indicating a steep nose-down attitude at impact. This was further reinforced by the angle at which the engine had buried itself in the mud: it was estimated to be in the order of 50° or more nose-down.

Despite the degree of disruption, it was not felt that the aircraft's speed had been particularly high, since metal items such as the fuel tank showed very little longitudinal compression and it had only one, relatively small, split. In the absence of hard evidence, speed estimation becomes subjective, based on experience of damage inflicted following other accidents involving similar structures. Such an assessment suggested that G-MISS had struck the ground at a speed of less than 100 kt.

After recovering the aircraft to the AAIB facility at Farnborough, a detailed inspection was carried out of its structure and flying controls. It was concluded that the aircraft was structurally intact at impact and there had been no pre-impact disconnection or failure of the flying control mechanisms. No foreign objects were recovered which could have caused jamming of the flying controls.

The engine, which was remarkably intact due to the relatively slow impact speed and extremely soft ground, was partially dismantled and all the internal components were found to be in good condition. The wooden propeller had largely fragmented and was considered to have been rotating at medium to high speed.

Empirical analysis of the spin characteristics of G-MISS

The LAA conducted an analysis of the spin characteristics of G-MISS using the methods of NACA (National Advisory Committee for Aeronautics) report TN (Technical Note) 1329 and TN D (Technical Note Design) 6575. The results predict that the aircraft would have been able to recover from a spin.

The AAIB investigation also commissioned a report by an aerodynamicist to identify how the spin characteristics of G-MISS differed from those of the standard Taylor Titch. The aerodynamicist used the method stipulated in the Defence Standard 00-970 Leaflet 18, *Spinning and spin criteria for spin resistance and recovery*, published by the UK Ministry of Defence in 1999. His report concluded that G-MISS would have been no more prone to enter a spin than a standard Taylor Titch. He also concluded that G-MISS would probably have recovered from a fully developed spin following the application of the normal spin recovery control

Figure 1

Comparison of the profile of a 'standard' Taylor Titch aircraft (green) with G-MISS (red), overlap region in yellow inputs. However, the aerodynamicist noted that, due to the increase in pitch inertia, if the ailerons had been applied against the spin, this may have delayed or even prevented G-MISS from recovering from a spin.

Medical and pathology

The pilot had a medical condition, known as atrial fibrillation, which had necessitated admission to hospital in 2008. He was treated with a variety of drugs including the anticoagulant warfarin, which is acceptable for NPPL Medical certification. At the time of the accident the pilot was flying on a valid NPPL medical declaration, countersigned by his general practitioner.

A postmortem examination revealed that the pilot had suffered multiple severe injuries, which were consistent with being caused by the aircraft striking the ground. The toxicology tests revealed no evidence of alcohol or drugs in the pilot. A specialist aviation pathologist reviewed the pilot's medical history and the postmortem results, and considered that it was possible that the pilot had suffered an incapacitating cardiac event just prior to the accident. The cause of death was given as multiple injuries.

Analysis

Witnesses observed the aircraft in a manoeuvre, which they described as a spiral dive, which did not seem to change significantly during its descent. The investigation considered reasons why the aircraft might follow the flight path observed.

The pilot had briefed that he would be carrying out stalling exercises but he was not familiar with the aircraft, so the investigation considered the possibility that the aircraft had unintentionally entered a spin from which the pilot could not recover. To some witnesses a spin might appear similar to a spiral and a theoretical evaluation of G-MISS's spin characteristics was carried out. The investigation concluded that G-MISS was no more prone to enter a spin than the standard Taylor Titch and should have recovered from an inadvertent spin with the application of normal spin recovery controls.

The aircraft could have entered a spiral manoeuvre if it had suffered from a control restriction or failure. However, the engineering investigation concluded that the aircraft was structurally intact at impact and that there had been no pre-impact disconnection or failure of the flying control mechanisms. No foreign objects were recovered which could have caused jamming of the flying controls. Consequently, the aircraft ought to have been recoverable from either a spin or a spiral dive if the correct control inputs had been made.

Another reason for a spiral dive, or spin, could have been pilot incapacitation. The investigation noted that the cause of death given by the pathologist was multiple injuries but that it was possible that the pilot had suffered an incapacitating cardiac event just prior to the accident.

In summary, there was insufficient evidence to determine the cause of the accident. However, given the pilot's medical history and that no attempt appears to have been made to recover a flyable aircraft from a spin or spiral dive, it was possible that the pilot became incapacitated in the final stages of the flight.

ACCIDENT

Aircraft Type and Registration:	Zivko Aeronautics Inc Edge 540, N540BW
No & Type of Engines:	1 Lycoming AEIO-540 piston engine
Year of Manufacture:	1998
Date & Time (UTC):	22 August 2009 at 1057 hrs
Location:	Silverstone Circuit, Towcester, Northamptonshire
Type of Flight:	Competition
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 (Fatal) Passengers -N/A
Nature of Damage:	Aircraft destoyed
Commander's Licence:	FAA Commercial Pilot's Licence
Commander's Age:	41 years
Commander's Flying Experience:	2,500 hours (of which 1,400 were on type) Last 90 days - 50 hours Last 28 days - 11 hours
Information Source:	AAIB Field Investigation

Synopsis

The aircraft was being flown in an aerobatic competition during which it failed to recover from a downwards snap roll manoeuvre, initiated at about 2,300 ft agl. The aircraft continued to rotate until it struck the ground, fatally injuring the pilot. The investigation discovered a mechanism whereby rudder pedal extensions used by the pilot could have contributed to a rudder control restriction, but pilot incapacitation was also considered a possible contributory factor.

Background to the flight

The pilot was a competitor in the 25th World Aerobatics Championship, being held at Silverstone racing circuit over a 10 day period in August 2009. She was a member of the US aerobatic team and had arrived in the UK several days before the competition was due to start.

N540BW was based in the UK and the pilot had arranged with its owner to use the aircraft in the competition. On 12 August 2009 she ferried the aircraft from Old Sarum Airfield, near Salisbury, to Dunkeswell Airfield in Devon, where the US team were conducting their final practice flights. Competition flying started at Silverstone on 21 August, beginning with qualifying flights. The pilot was drawn approximately halfway down the list of competitors, so her first flight in the competition was on 22 August.

Each pilot had a 10 minute slot in which to complete a set sequence of nine aerobatic manoeuvres. The length of the slot normally allowed a short practice session before commencing the sequence proper – indicated to the judges on the ground by a wing waggle (radios were fitted but silent procedures were in use).

The aerobatic sequence was to take part within an area of sky known as the 'box', with penalties for aircraft going outside the box during the sequence. The box had a ground footprint of one square kilometre, marked on the ground by orange panels. The lower vertical limit was 120 m (394 ft) agl and it extended upwards to 1,000 m (3,280 ft) agl. The box was aligned with the runway at Silverstone, and set approximately 50 m to the south-east. Judging positions were established a short distance outside the box, on its main axes. A plan of the site, showing the box area and accident site, is at Figure 1 (courtesy Google Earth ™ mapping service/ Tele Atlas, Infoterra Ltd & Bluesky).

History of the flight

On 22 August 2009 flying started at 0800 hrs with a weather check flight. This was followed by the first competition aircraft at 0818 hrs. Low cloud then interrupted the programme, with competition flying resuming at about 1000 hrs. N540BW, which had been kept in a hangar since its arrival at Silverstone, was the fifth aircraft to fly, taking off at 1048 hrs.

On this occasion, the pilot initially flew the first five manoeuvres as a practice before signalling to the judges that she was starting the sequence proper. After one manoeuvre, the pilot signalled that she was interrupting

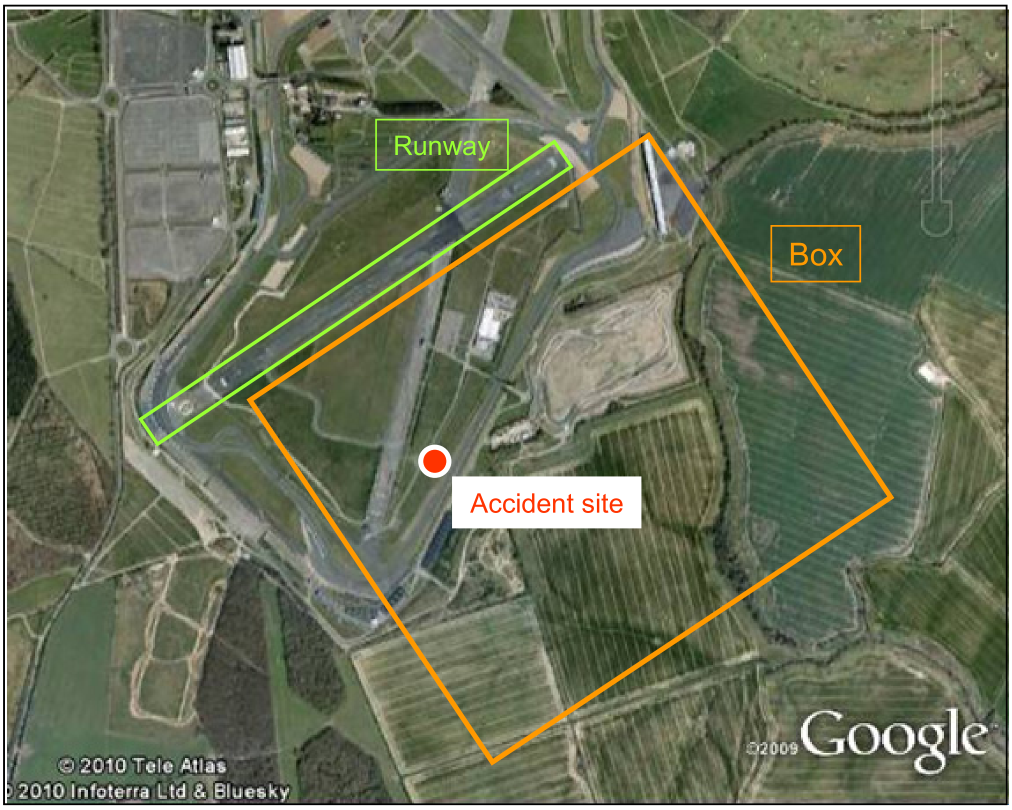

Figure 1

Part of Silverstone circuit showing runway, aerobatic box and accident site the sequence, which was allowed under the rules. About a minute later, the pilot restarted the sequence at manoeuvre two.

The accident occurred during the fifth manoeuvre of the sequence, which was the last manoeuvre the pilot had practised minutes beforehand. The manoeuvre called for a pull up to the vertical, followed by half of an eight point roll (rolling through 180°). The aircraft was then to be 'pushed over' the top of the manoeuvre until it was pointing vertically nose down, before carrying out a positive snap roll[1] to the left through 1¼ turns and pulling out to the horizontal.

The aircraft appeared to perform the initial stages of the manoeuvre normally but it did not recover from the downwards 1¼ snap roll. Instead, the aircraft continued to rotate in a nose-low attitude until it struck the ground.

Airfield staff immediately alerted the circuit race control (motor vehicles were using the race track at the time) and the emergency services. The circuit's own emergency response plan was activated and joined by local police, fire and ambulance services. The pilot was found within the wreckage having suffered fatal injuries.

Wreckage

The wreckage was located within the race track (Figure 1). The wing tips and the engine had struck the ground at an angle of approximately 45°, with the aircraft in a nose down attitude and the left wing being more damaged than the right. The aft fuselage and attached empennage had separated from the wings and forward fuselage, and these two major items of wreckage were located 10 m apart. Smaller items of wreckage were spread over an area approximately 80 m x 30 m, with the majority of the items located beneath the aircraft's final flight path. It was concluded that the aircraft had struck the ground in a nose-down, left wing-low attitude with significant rotation, and that, when the aft fuselage broke from the forward fuselage, parts of wreckage were thrown back along the flight path. All the major items of the aircraft were accounted for and there was no evidence of an in-flight break-up.

There were chordwise witness marks on the propeller blades, the lower blade of which had dug into the ground with a helical motion. It was concluded that the propeller was rotating under power when the aircraft struck the ground.

The air speed indicator had been damaged, with the needle and the face distorted. The needle was pointing at 130 kt.

Aircraft information

The Zivko Edge 540 is a high-performance single-seat aerobatic aircraft, see Figure 2. The wings and empennage on N540BW were made of composite

Figure 2

Photograph of N540BW
(photograph courtesy of Stuart Carr)

Footnote

[1] Also called a flick roll.

material, and the fuselage was constructed from tubular steel covered in a mixture of fabric and composite material.

Figure 3
Cockpit layout

Figure 3 is a photograph of the cockpit layout. The control column was connected to the ailerons and elevators by a series of conventional pushrods and bell cranks. The rudder pedals were mounted on light alloy footplates which were attached to horizontal tubular steel fuselage cross-members. On the outer side of each pedal was a connection to a cable that ran rearwards to the respective rudder control horn. Also connected to the side of each pedal was a light spring that ran forwards and was attached to the fuselage structure. These springs prevented the rudder pedals from falling rearwards when no foot pressure was applied. The rudder pedals were operated with the pilot's heels on the foot plates and the balls of their feet pushing against horizontal tubes on each pedal. The aircraft was fitted with adjustable foot straps which passed through these horizontal tubes. When used, they ensure that the pilot's feet remain in contact with the rudder pedals; they also allow the opposing foot to pull at the same time as the other foot pushes. The range of movement of the rudder cables was ±45 mm, producing rudder deflections of ±30°.

Rudder pedals

The pilot was the owner of another Edge 540 which was based in California. She was 5' 2" / 1.57 m tall and flew her Edge 540 with extensions fitted to the rudder pedals. Prior to her first flight in N540BW, she had a set of her own pedal extensions fitted to the aircraft (see Figure 4). Each extension had been secured at its lower attachment around the pedal pivot tube by a pip-pin. The upper attachment consisted of two tie-wraps fitted diagonally around the horizontal tubes against which the balls of the feet would normally be placed. The pilot did not use the adjustable foot straps, which remained with the rudder pedals.

The pilot had experienced a problem whilst carrying out a snap roll during practice. During the manoeuvre

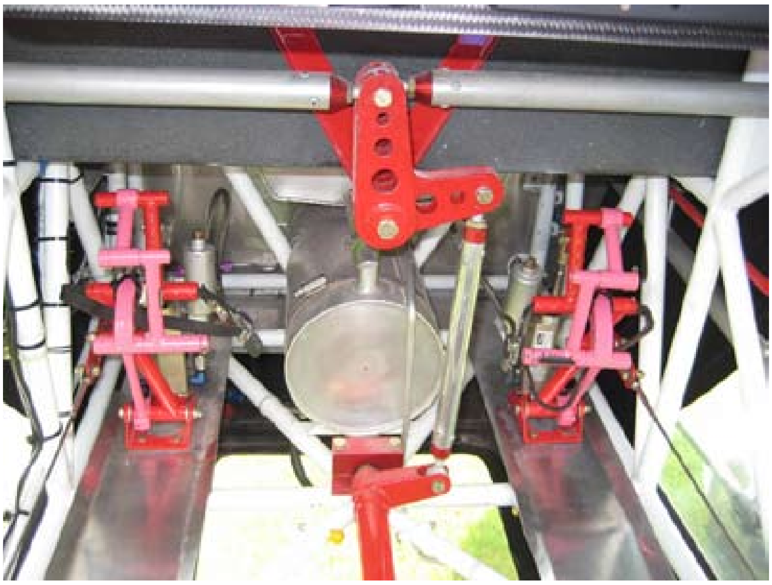

Figure 4
Rudder pedals with pedal extensions (pink) fitted

her right foot had bent the right foot plate downwards, deforming it. The footplate was straightened after the flight. The team engineer prepared a pair of longer, stiffer footplates but these had not been fitted at the time of the accident.

According to information posted by the pilot on her internet site, another pilot had also bent the footplate, whilst getting into the aircraft, and had bent it back. The photograph at Figure 4 shows the right footplate with evidence of the deformation. It is not known if this was taken after the ground or the airborne incident.

Aircraft certification

The aircraft was registered in the USA and had been issued with a FAA *Special Airworthiness Certificate*. It was classified as *Experimental – Exhibition* and the CAA had issued an exemption form for its use in the UK. This category of aircraft is not required to conform to any FAA approved type design and FAA approval was not required for the rudder pedal extensions. The FAA does not consider that pedal extensions are a modification to a primary flying control.

Wreckage examination

The wreckage was recovered to the AAIB for further examination. The elevator and aileron systems were checked for continuity as well as for full and free movement; nothing significant was revealed. The rudder surface operated with full and free movement, but the left and right cables were found to have failed in overload.

Detailed examination of rudder pedal assemblies

Both rudder pedal assemblies (see Figures 5 and 6) were taken to a forensic laboratory for detailed examination.

The following observations were made:

a) The lower attachment of the rudder pedal extensions could be moved in a spanwise direction along the rudder pedal pivot tubes (see Figure 7).

b) In the case of the non-extended rudder pedals, the force applied by a foot acts directly above the point at which the vertical element of

Figure 5

Right rudder pedal with extension

Figure 6

Left rudder pedal with extension

the pedal meets the pivot tube. This is due to the Z shape of the pedal. However, with the pedal extensions, the force applied by a foot acts inboard of the point where the vertical extension element meets the lower attachment, potentially creating a moment that can push the lower attachment outwards along the pivot tubes.

c) There was wear damage on both the left and right pivot tubes consistent with the lower attachment of the rudder extensions moving laterally.

d) There were witness marks on both pivot tubes. The evidence indicated that these were made by the pip-pins, which were positioned approximately 10 mm from the outboard vertical flange on the pedal base plate (Figure 7). These witness marks were probably made when the aircraft struck the ground, and might be indicative of the position of the lower attachments in the later stages of the flight.

e) Using a microscope, red traces were found on the tip of the pip-pin on the left pedal extension. However, there was insufficient material to carry out any detailed chemical analysis of the red traces.

f) There were several witness marks on the base plate of the left rudder pedal. These were approximately 10 mm from the outboard vertical flange on the pedal base plate (see Figures 8 and 9). The two most significant witness marks were made by an object approximately 2.5 mm in radius which is similar to the radius of the pip-pin. There was plastic deformation of the paint on both of these witness marks, consistent with the pip-pin gouging the paint as the rudder moved from a deflection to the left towards the neutral position.

It was concluded that a rudder control restriction could occur if the lower attachment of the rudder pedal extension had moved outboard and the pedal in question, having been pushed forward, was subsequently moved

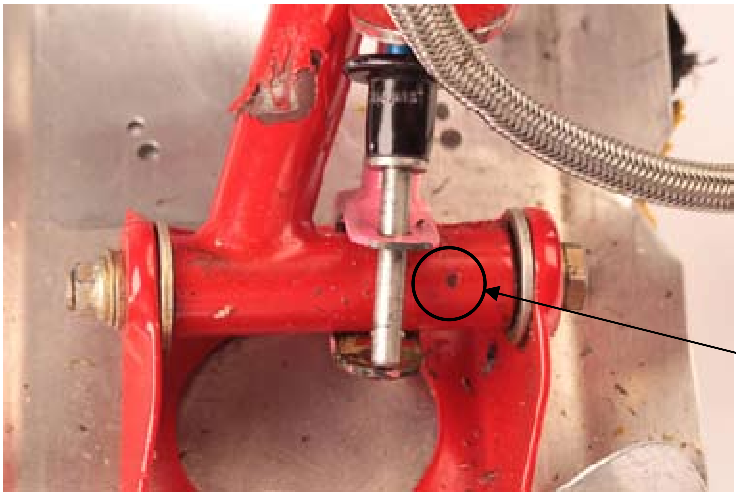
Note the witness mark on the pivot tube probably made by the pip-pin.

Figure 7

Front (and above) view of the left rudder pedal pivot tube
(Note that the lower attachment for the pedal extension, painted pink, can move relatively freely from left to right)

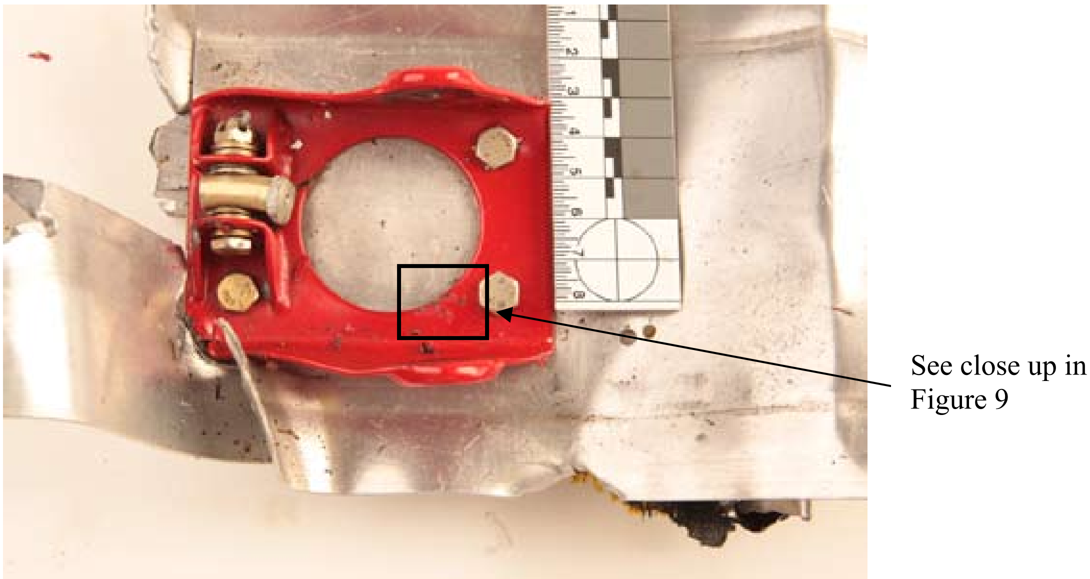

Figure 8

Base plate for left rudder pedal

Figure 9

Close up of Figure 8 showing witness marks probably made by the end of the pip-pin

aft towards the neutral position. The range of rudder positions in which a restriction could occur on the left pedal assembly, with the extension fitted, was estimated to be between 6° and 23° left rudder deflection. Similar values were estimated for a restriction on the right rudder assembly. It was concluded that, if such a restriction occurred, it was unlikely that the force a pilot could apply on the pedal extension would be sufficient to overcome the restriction. The way to free the pedals would be to shift the lower extension attachment point inboard.

Pilot information

The pilot was an American citizen and a former US aerobatic champion. She started flying small, high performance aerobatic aircraft soon after gaining a pilot's licence in 1993. She had owned an Edge 540 since about 1999 and was a highly experienced aerobatic pilot, having been a member of the US aerobatic team on three previous occasions.

Medical and pathological information

Postmortem examination

It was determined that the pilot died from multiple injuries consistent with being caused by the ground impact. Although the pilot was wearing a full harness and helmet, the forces involved were outside the range of human tolerance and were not survivable. There was no evidence of significant natural disease which could have caused or contributed either to death or the cause of the accident. Toxicological examination revealed no evidence of drugs or alcohol.

Physiological effects of high G forces

Competition aerobatics expose pilots to high G forces, the most hazardous of which is Gz: the acceleration acting from head to toe (+Gz) or from toe to head (-Gz). If the heart and vascular system cannot keep pace with the rapid onset of +Gz, pilot performance will be degraded and loss of consciousness will follow.[2]

Tolerance to +Gz has been the subject of many studies. Most show that G-induced loss of consciousness (G-LOC) occurs at around +4.5 Gz in an unprotected individual, although many factors can influence an individual's G tolerance. High accelerations can be tolerated for short periods of time, but will lead to loss of consciousness without warning (ie visual symptoms) if allowed to persist. Aerobatic pilots frequently take advantage of this, pulling very high +Gz loads but for only short periods of time.

An important aspect of G tolerance is the effect of rapidly changing from negative to positive Gz[3]. When a pilot is subject to –Gz there is a slowing of the heart, caused by a reflex reaction to increased blood pressure in the head and chest. Changing rapidly to +Gz would lead to a rapid speeding up of the heart as blood pressure in the head and chest dropped. However, the reflex system takes some time to respond to the change, so blood supply to the brain may decrease during the transition period, increasing the risk of G-LOC.

Recorded information

A portable radar tracking system was being used to allow judges to determine accurately when an aircraft strayed outside the competition box. The system, which included a slaved video camera, was located about 1,300 m to the north of the centre of the box. Video footage from the tracking system and a separate handheld camcorder were available for analysis.

Pull up for the accident manoeuvre started from 1,100[4] ft. The push over at the top of the manoeuvre started at 2,600 ft and the maximum height reached was 2,750 ft. The downwards snap roll was initiated at 2,300 ft. From that point, seven and a half turns were recorded before radar and optical contact was lost at an indicated 200 ft, when the aircraft disappeared from view behind trees. The observed height profile was

Footnote

2 Federal Aviation Administration (FAA) publication AM-400-09/4 '*Acceleration in Aviation: G-Force'*.

Footnote

3 FAA Advisory Circular 91-61 *'A hazard in aerobatics: effects of G-Forces on pilots'* (1984).

4 Heights are radar-derived, as indicated on the associated viewing software.

almost identical to the earlier practice manoeuvre. The handheld camcorder captured a further half turn before, again, the aircraft was lost from view behind trees, very shortly before it hit the ground. From initiation of the snap roll to the point of impact was 10.7 seconds.

Snap roll manoeuvre

Figure 10 shows comparative video images from the practice and accident manoeuvres, from a point just after initiation of the snap roll; the aircraft has rolled through about 120° at this point.

Figure 11 again shows images from the practice and accident manoeuvre, advanced nearly a full turn from the previous images, at about the point of recovery. Significant differences can be seen in terms of rudder angle and pilot's head position (the pilot was wearing a white helmet).

Figure 10

Shortly after initiation of the snap roll – the practice manoeuvre is on the left

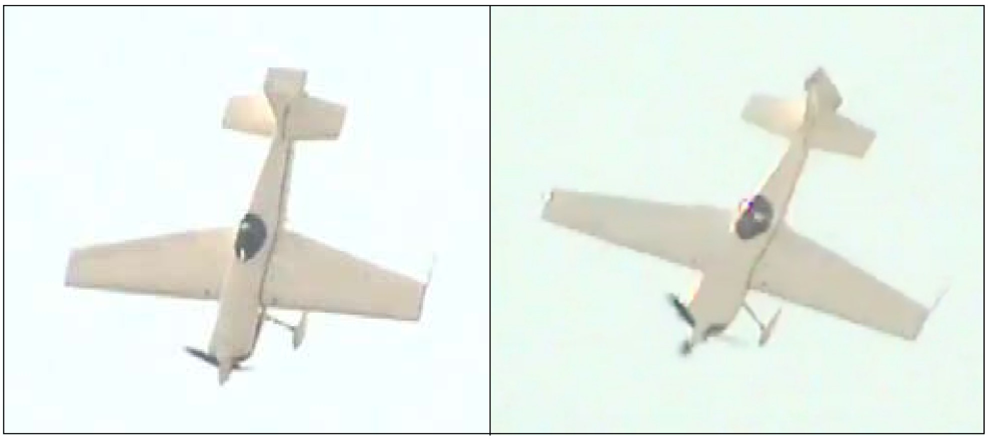

Figure 11

The point of recovery in practice manoeuvre (left) compared to the equivalent point during the accident manoeuvre

Control surface deflections

The radar-slaved video allowed a limited assessment of control surface positions. Figure 12 shows a graphical representation of rudder and aileron positions as the aircraft descended. The data begins at the point of intended recovery (1¼ turns after initiation of the snap roll) and ends when the aircraft descended out of view behind trees. Rudder position could only be accurately assessed when the aircraft presented a plan form to the camera, so the data points are plotted for every half turn. Increased data points are presented for aileron deflections; one per quarter turn. This was possible due to movement of the aileron spades under the wing, which allowed an assessment of their position when viewing the aircraft underside. Also, generally better views of aileron deflection allowed a degree of interpolation when the aircraft's upper plan form was presented to the camera.

Elevator position could not be measured with accuracy, but it was noted that, approaching the point of recovery from the snap roll, the aircraft's body pitch angle was 14° less nose-down than at the equivalent position in the practice manoeuvre (this is visible at Figure 11). For the first two turns after the expected recovery point, the elevator appeared approximately neutral, and the nose-down pitch angle increased to approximately 5° from vertical. During the next three turns there was noticeable 'up' elevator applied, and the nose-down pitch angle reduced to about 18° from vertical. The 'up' elevator remained applied until the aircraft disappeared from view a turn later.

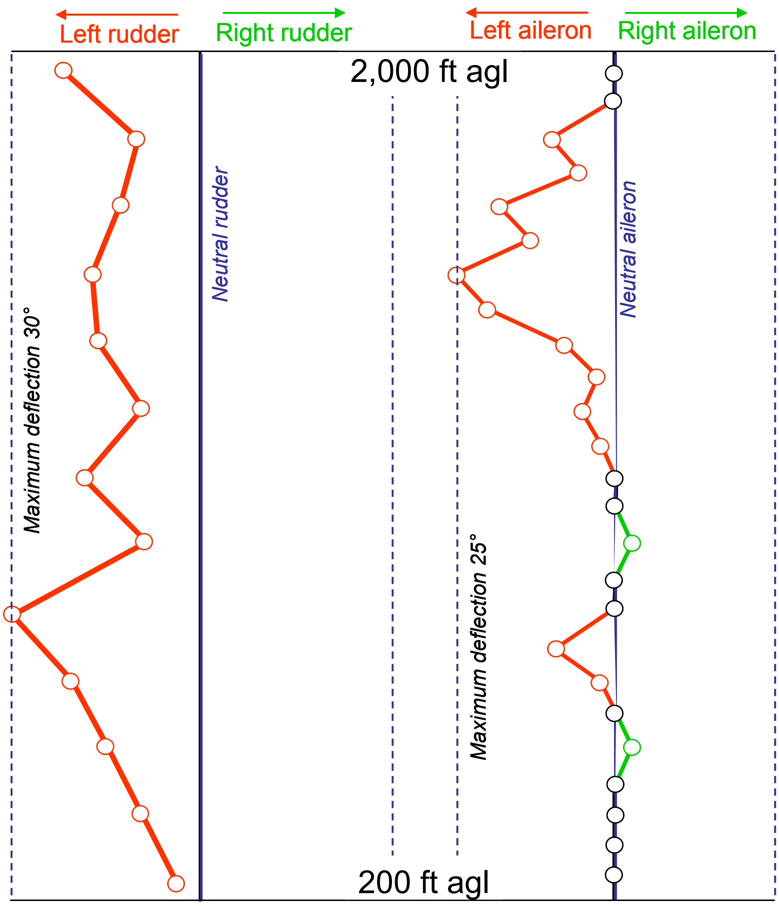

Figure 12

Rudder and aileron deflections

Control surface movement

Figure 13 shows two consecutive images taken during the accident sequence. They are separated by a fraction of a second, at a point about two turns advanced from the images in Figure 11. Despite the very short time interval, significant changes to rudder angle can be seen. The pilot's head position is also still considerably displaced to the left.

Pilot's head position

From the video images it can be seen that the pilot's head position during the early stages of the snap roll was approximately central in the cockpit, and was similar to the equivalent point in practice. However, at the point of expected recovery, the pilot's head is considerably left of centre. The video showed that the pilot's head remained to the left of the cockpit centreline until about half way through the descent, when it returned to approximately centreline and remained so until the video ceased.

Video analysis

The videos of the accident were shown to a number of experts in the field of aerobatics and competition flying, some of whom had also witnessed the accident. Their joint observations are summarised below:

a) At the point of recovery, although a brief application of rudder would have been expected to align the aircraft with the vertical, the observed rudder deflection is unusual.

b) The aircraft is not pitched as far forward on the accident recovery as on the practice, indicating insufficient forward movement of the control column during recovery.

c) The pilot's head would be expected to be central in the cockpit at the point of recovery, to allow the pilot to determine the correct recovery line.

d) Left applied rudder and aileron after the point of expected recovery is unusual: the rotation would have been driven by control deflection - most probably rudder rather than ailerons, as the rotation is not axial.

Figure 13

Two turns after the point of expected recovery, the two images are taken from the accident sequence and only a fraction of a second apart. Note change in rudder position

Previous incident

One of the pilots interviewed reported an incident which occurred while flying a similar snap roll manoeuvre in an Edge 540, in which he was temporarily unable to recover. During the aggressive application of left rudder required to initiate the manoeuvre, his foot came off the right rudder pedal. With the almost simultaneous application of positive 'g' his foot moved down and the heel of his shoe became caught in the aircraft tubular structure behind the metal footplates (see Figure 3). The pilot was unaware of this until he attempted to apply right rudder pedal to stop the rotation and realised that he could not.

It was only when the pilot looked down that he realised the nature of the problem, during which time the aircraft continued to rotate. He was able to correct the situation, but not before a number of unintentional rotations had occurred.

Analysis

Video analysis showed three anomalies at the expected point of recovery; the inappropriate rudder position, the unusual aircraft pitch attitude (compared to the practice case) and the pilot's head position, which would be expected to have been central in the cockpit at that point.

As the manoeuvre continued, there were no apparent control inputs made which could be regarded as being part of a positive recovery attempt. Instead, the rudder remained displaced in the direction of roll, driving the rotation. Although aileron deflection did return to near zero for much of the latter part of the descent, it was at times near full deflection in the early stages, again providing a strong driving force for the rotation. There was almost no aileron movement to oppose the rotation. The rudder position is the most significant anomaly. Either the pilot reacted correctly to the situation but was physically prevented from removing the pro-rotation rudder, or her ability to recognise and/or react to the situation had become impaired.

The examination of the rudder pedal assemblies revealed that a restriction could occur with this set of extensions fitted. Moreover, such was the design of the extensions that they could readily move outboard with normal operation (a requirement for a restriction to occur). This is corroborated by the wear marks on the outboard ends of the pivot tubes and the witness marks made by the pip-pins on the pivot tubes. Importantly, the witness marks on the base plate of the left rudder pedal were consistent with having been made by the pip-pin. This physical evidence suggested that a jam had occurred at some stage, with the left rudder pedal forward and moving towards neutral.

It was not possible to say when this may have occurred, but there was no report by the pilot of a rudder problem prior to the accident flight. It was not possible, either to say why the restriction, if it did occur on the accident flight, did not occur during the same and similar manoeuvres earlier in the flight.

Had rudder control been affected in such a way, it would account for the continued application of pro-rotation rudder, and perhaps also for the varying amounts and rate of rudder input as the pilot tried to free the unknown restriction. It could also account for a significant distraction during the recovery phase, leading to insufficient forward control column and hence the relatively high pitch attitude.

There was some evidence to suggest that the pilot may have experienced a problem similar to that experienced by another Edge 540 pilot in which his foot became trapped during a snap roll. The accident pilot was not using foot straps and it is known that she had recently had a problem when her right foot became significantly separated from the rudder pedal during a snap roll recovery. However, given that the other pilot quite quickly recognised and corrected the situation, and considering the accident pilot's extensive aerobatic experience, it would be expected that she would recognise and recover from such a situation before it became critical.

The pilot's head position to the left of cockpit centre was a further anomaly. If it was deliberate, it may have been an attempt to identify a problem with the pedals or her foot. At the point of expected recovery, she should have been looking centrally ahead to identify her roll out feature and ensure she achieved it accurately. As it would have taken a finite time to recognise that there was a problem inside the cockpit, she would not have been expected to look in straight away, yet her head position is well to the left at the point of expected recovery.

The final manoeuvre was not an extreme one for such an experienced aerobatic pilot, nor did it entail prolonged exposure to very high G forces. There was thus no direct evidence that the pilot had been affected by G-LOC. However, it would be expected that the pilot would have attempted all measures to resolve the situation, including vigorous and obvious control inputs to reduce angle of attack and oppose the rolling motion. No faults were identified with the aileron or elevator control systems, yet no such recovery inputs were apparent. The possibility therefore remains that the pilot's ability to recognise or respond to the situation had somehow become impaired, and this must be considered as a possible contributory factor.

Conclusion

The aircraft did not recover from a downwards snap roll. No recovery action was seen to be taken and the aircraft struck the ground after several rotations. Pro-rotation rudder was applied throughout and pro-rotation aileron applied for part of the descent. A mechanism was identified by which the pilot's rudder pedal extensions could have caused a restriction of the left pedal in such a way that left rudder could not be fully removed once it had been applied. The circumstances of the accident suggested that the pilot's ability to recognise or respond to the situation had somehow become impaired, and this must be considered as a possible contributory factor.

ACCIDENT

Aircraft Type and Registration:	Enstrom 280C Shark, G-COLL
No & Type of Engines:	1 Lycoming HIO-360-E1BD piston engine
Year of Manufacture:	1981
Date & Time (UTC):	19 March 2010 at 1405 hrs
Location:	Near Douglas, Isle of Man
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Substantial damage to the skids, forward fuselage, rotor head and main rotor blades
Commander's Licence:	Private Pilot's Licence (Helicopters)
Commander's Age:	68 years
Commander's Flying Experience:	120 hours (of which 114 were on type) Last 90 days - 3 hours Last 28 days - 1 hour
Information Source:	Aircraft Accident Report Form submitted by the pilot and further enquiries by the AAIB

Synopsis

The helicopter took off from a private landing site. At a height of 200 to 300 feet agl the pilot perceived that the engine had stopped and immediately entered autorotation. He turned towards a field on his left, flared to reduce speed and level off, and the helicopter dropped to the ground from a height of about 10 to 12 ft. The damage was substantial but the helicopter remained upright and the pilot escaped uninjured. No conclusive evidence was found to explain the loss of power.

History of the flight

The helicopter had been parked overnight at a private landing site. The weather conditions were fine; the surface wind was from 160° at 9 kt, with clear skies, good visibility and no significant cloud. The pilot intended to fly on a two day tour around the Isle of Man. His initial planned route was north to Laxey and then on to the Point of Ayre.

The pilot carried out his normal pre-flight and pre-takeoff checks and lifted into the hover. It was his usual practice to wind out the mixture control knob to a pre-set position before lifting off and he did this as normal. When in the hover he made a blind transmission radio call to ATC to advise that he was departing and then set the transponder to ON. The takeoff was normal but at approximately

200 feet agl the pilot noticed that "it all went quiet"; later he recalled that the helicopter had yawed to the left as well. He responded by rapidly lowering the collective, and opened the throttle.

The helicopter entered autorotation and the pilot aimed for a field ahead and to his left. He saw that the far edge of the field was approaching and flared to stop the forward motion. The helicopter levelled off and then dropped to the ground from a height that he estimated was about 10 to 12 ft. It dropped nearly vertically, bounced forward about a metre and stopped in an upright position but rolled to the left with the left skid having collapsed. Although the helicopter sustained substantial damage, the pilot was not injured and was able to evacuate the aircraft unassisted. There were a number of people in the area who were on hand to assist and a call was made to alert the emergency services, who attended the scene.

Discussion

After the accident, the pilot noted that the condition of the blades suggested that there had been little energy left in them, although they were damaged beyond economic repair. The next day, he started the engine and let it run it for 12 minutes at 1,500 rpm; no problem was apparent.

The mixture control is a push/pull knob incorporating a vernier adjustment. The pilot can make precise adjustments to the fuel mixture in flight by turning the control. Larger adjustments, for starting and stopping the engine, can be made by pushing the red button and sliding the control in or out. The pilot advised that he always adjusted the mixture control knob out to the same position before takeoff. He identified this by means of an existing wear mark.

This type of helicopter has a mechanical correlator which will maintain rotor rpm if the helicopter is flown smoothly. For correct operation the throttle twist grip must not be allowed to move as the collective pitch is altered. (The manufacturer suggests adjusting the throttle friction tightly enough to ensure there is no movement.) The correlator is not able to compensate for changes in tail rotor pitch or any translational tendency.

The pilot considered that the loss of power he experienced could have been as a result of a fuel supply problem. However, the day after the accident when the engine was restarted it ran normally at 1,500 rpm. Therefore, why there should have been a loss of power in the climb remains unclear.

ACCIDENT

Aircraft Type and Registration:	Robinson R22 Beta, G-OTOY
No & Type of Engines:	1 Lycoming O-320-B2C piston engine
Year of Manufacture:	1988
Date & Time (UTC):	28 April 2008 at 1600 hrs
Location:	Wellesbourne Airfield, Warwickshire
Type of Flight:	Training
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 (Minor) Passengers - N/A
Nature of Damage:	Damaged beyond economic repair
Commander's Licence:	None
Commander's Age:	53 years
Commander's Flying Experience:	41 hours (of which 14 were on type) Last 90 days - n/k hours Last 28 days - n/k hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and further enquiries by the AAIB

Synopsis

While hover taxiing out to the helicopter training area the helicopter descended and bounced twice on grass before touching down for a third time. The helicopter's skids dug in, causing the helicopter to tip over and the rotors to impact the ground. The student vacated the helicopter with a small cut to his head.

History of the flight

At the time of the accident Runway 23 was in use at Wellesbourne Airfield, Warwickshire and the wind was from 210-230° at 8-12 kt. Prior to the accident flight the student pilot had completed an instructional sortie during which the instructor had highlighted and demonstrated the extra power required to taxi and transition downwind. The instructor subsequently briefed the student for solo circuits and hovering practice before he vacated the helicopter with the rotors running.

The instructor then watched the student lift into the hover before taxiing at a slow speed towards the helicopter training area at approximately 6 ft agl. After crossing Runway 23 the instructor saw the helicopter turn downwind and descend. It bounced twice on the grass before touching down for a third time. As it did, the helicopter's skids dug in causing the helicopter to tip over and the rotors to impact the ground. The student vacated the helicopter with a small cut to his head.

The student stated that as he was hover taxiing the nose of the helicopter raised. He overcorrected this with the cyclic and the aircraft turned left downwind. He tried to correct this with right pedal but the helicopter then lost height and dug into the soft ground before tipping over.

The instructor stated that the student offered no explanation as to why the helicopter descended unchecked during the hover taxi.

ACCIDENT

Aircraft Type and Registration:	Robinson R44 Astro, G-PIDG
No & Type of Engines:	1 Lycoming O-540-F1B5 piston engine
Year of Manufacture:	1999
Date & Time (UTC):	26 June 2010 at 1650 hrs
Location:	Devonshire Arms Country House Hotel, Skipton, North Yorkshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Extensive
Commander's Licence:	Private Pilot's Licence (Helicopters)
Commander's Age:	46 years
Commander's Flying Experience:	253 hours (of which 89 were on type) Last 90 days - 27 hours Last 28 days - 10 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and subsequent AAIB enquiries

The pilot followed an associate in another helicopter to a private landing site with two helipads. The weather was fine with light winds. The other helicopter landed on the larger pad, but the pilot of G-PIDG felt uneasy about members of the public near the smaller one, and so positioned to land in an adjacent field. As he approached his aiming point, the low rotor rpm warning activated, and the helicopter landed heavily. The pilot applied collective pitch to lift into a hover, but the helicopter rolled onto its right side (it is possible that one skid had dug into the ground during the landing) and sustained substantial damage. The occupants vacated without injury and there was no fire.

The pilot reported that he had not visited the landing site before, and had felt somewhat unprepared as he made his approach. He added that he had gripped the throttle too tightly prior to touchdown, and had probably overridden the engine governor, causing the reduction in rotor rpm. He stated that he intended to undertake further dual training with his instructor before flying solo again.

ACCIDENT

Aircraft Type and Registration:	Robinson R44 Raven, G-LWAY
No & Type of Engines:	1 Lycoming O-540-F1B5 piston engine
Year of Manufacture:	2002
Date & Time (UTC):	1 June 2010 at 0805 hrs
Location:	Loch Long, near Arrochar, Scotland
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Aircraft damaged beyond economic repair
Commander's Licence:	Private Pilot's Licence (Helicopters)
Commander's Age:	46 years
Commander's Flying Experience:	634 hours (of which 250 were on type) Last 90 days - 7 hours Last 28 days - 3 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The pilot was flying to a private site adjacent to a sea loch. During the approach, at a height of about 50 ft, he focused his attention on an object in the water. This distracted him and the helicopter struck the surface of the water at an airspeed of about 60 kt, approximately 100 m from the shore. The helicopter tumbled forwards, coming to rest inverted with the cockpit submerged and sinking. Although the accident happened in daylight, the pilot was unable to see underwater due to the combination of salt water and fuel. He was disorientated and had difficulty locating the release on his three-point harness.

The pilot was unsure how long he was in the helicopter and believed that he may have exited through the left door; on the opposite side from his seat. When he reached the surface the last part of the aircraft was just disappearing. He was uninjured and able to swim ashore.

The pilot commented that he had had to concentrate hard during his 25 minute flight and that he had relaxed once his destination was in sight. He believed this may have made him more susceptible to the distraction.

INCIDENT

Aircraft Type and Registration:	Cameron Z-375 hot air balloon, G-VBFN
No & Type of Engines:	None
Year of Manufacture:	2008
Date & Time (UTC):	26 April 2010 at 1840 hrs
Location:	Field off Sturt Road, Haslemere, Surrey
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 1 Passengers - 13
Injuries:	Crew - None Passengers - None
Nature of Damage:	None
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	46 years
Commander's Flying Experience:	2,000 hours (of which 500 were on type) Last 90 days - 30 hours Last 28 days - 37 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

During the landing phase of the flight the pilot was concentrating on a single set of cables, which he cleared before landing in his chosen field, towards dusk. On touchdown, and 'ripping out' of the balloon's deflation system, he noticed a second set of cables, probably 11 kV, about 100 ft downwind. The envelope touched these cables but "slithered off", without apparent damage, and the utility company confirmed there was no damage to the cables.

The pilot commented that he now appreciates that sets of cables may be sited close to each other and that, in concentrating on the first set, he had not observed the second until it was too late to take avoiding action.

ACCIDENT

Aircraft Type and Registration:	EV-97 TeamEurostar UK, G-CCTI
No & Type of Engines:	1 Rotax 912-UL piston engine
Year of Manufacture:	2004
Date & Time (UTC):	4 June 2010 at 1615 hrs
Location:	Sywell Airport, Northamptonshire
Type of Flight:	Training
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to nose leg, firewall, engine mount, floor area around rudder pedals
Commander's Licence:	Student
Commander's Age:	69 years
Commander's Flying Experience:	128 hours (of which 54 were on type) Last 90 days - 11 hours Last 28 days - 4 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The pilot had performed a dual instructional flight with his instructor after which he was briefed for some solo circuits, which were not his first. After refuelling, the aircraft took off in benign weather conditions. During the first touch-and-go, the aircraft bounced three times. On the second and third bounces the aircraft struck the ground nosewheel first, with the third bounce being the most severe. The pilot performed a go-around and the instructor, through the tower, requested that he land after his next approach. The pilot subsequently completed what his instructor described as a "perfect landing". The damage to the aircraft was not immediately apparent and was discovered after the aircraft returned to the apron.

The pilot, wearing a full harness, sustained no injuries. He considered that the initial bounce was caused by insufficient pitch-up attitude during the flare.

ACCIDENT

Aircraft Type and Registration:	EV-97 TeamEurostar UK, G-CFVI
No & Type of Engines:	1 Rotax 912-UL piston engine
Year of Manufacture:	2009
Date & Time (UTC):	3 April 2010 at 1245 hrs
Location:	Peterborough Airfield
Type of Flight:	Training
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to propeller, front fuselage and wings
Commander's Licence:	Student
Commander's Age:	53 years
Commander's Flying Experience:	35 hours (of which 35 were on type) Last 90 days - 5 hours Last 28 days - 2 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The student pilot was attempting a takeoff from Runway 28 at Peterborough Airfield. The forecast wind was 190° at 8 kt, the pilot reported that the actual wind speed was higher. During the takeoff roll the aircraft veered left and pilot applied corrective right rudder but without effect. The aircraft departed the runway and was heading towards a fence. The pilot reduced power to abort the takeoff but the aircraft continued and struck the fence before coming to rest. The pilot was uninjured and exited the aircraft without difficulty. He assessed the cause of the accident as his incorrect use of controls in a crosswind.

ACCIDENT

Aircraft Type and Registration:	EV-97 TeamEurostar UK, G-SJES
No & Type of Engines:	1 Rotax 912-UL piston engine
Year of Manufacture:	2007
Date & Time (UTC):	4 May 2010 at 0845 hrs
Location:	Eshott Airfield, Northumberland
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to the nose landing gear, propeller, engine firewall and floor
Commander's Licence:	National Private Pilot's Licence
Commander's Age:	66 years
Commander's Flying Experience:	105 hours (of which 25 were on type) Last 90 days - 22 hours Last 28 days - 7 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The pilot returned to the circuit after a local flight. He carried out an overhead join and was established on final approach at 600 ft agl. The surface wind was westerly at 10 kt and Runway 26 was in use. During the last part of the approach the pilot encountered some turbulence and as the power was reduced in the flare the aircraft dropped to the ground. The aircraft bounced twice and then stalled onto the nose landing gear, which collapsed.

ACCIDENT

Aircraft Type and Registration:	Fournier RF5, G-AZRK	
No & Type of Engines:	1 Limbach 1834 (Modified) piston engine	
Year of Manufacture:	1972	
Date & Time (UTC):	26 June 2010 at 1610 hrs	
Location:	Berrow Airfield, Worcestershire	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Spinner dented, propeller blade split, crankshaft bent, firewall separated, right wing trailing edge fractured, right outrigger separated and tailwheel arm bent	
Commander's Licence:	Private Pilot's Licence	
Commander's Age:	74 years	
Commander's Flying Experience:	934 hours (of which 101 were on type) Last 90 days - 42 hours Last 28 days - 31 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

Synopsis

Whilst landing on an undulating grass runway, the aircraft momentarily became airborne and drifted to the right of the runway centreline. On touching down again the right wingtip struck an area of raised vegetation, causing the aircraft to veer right, leave the runway and run into a ditch. The pilot was uninjured.

History of the flight

Berrow Airfield has a single grass runway. The pilot reported that the runway had two noticeable undulations and a transverse slope to the south. The first of these undulations was positioned about 100 m from the threshold of Runway 24 and at approximately 260 m from the threshold was a ditch, running either side of the runway and at almost right angles to it. At the edge of the runway was standing vegetation of about 3 ft in height.

The pilot was making his second landing of the day at Berrow Airfield, having previously dropped off a passenger before returning to Shenington Airfield in Oxford. The reported surface wind was from 270º at between 5 to 10 kt. Positioning for a landing on Runway 24, the pilot reported that the approach had been fairly steep, with the aircraft touching down at about 55 mph and at a position upwind of the first undulation in the runway. The groundspeed had appeared to be higher than normal and on reaching the crest of the undulation the aircraft briefly become airborne, during which it drifted to the right. On touching down again the right wingtip struck the adjacent vegetation, causing the aircraft to veer to the right. Travelling through the vegetation the aircraft then dropped into the ditch and stopped. The pilot, who had been wearing a full harness, was uninjured and vacated the aircraft. The pilot considered that the accident had been a result of allowing the aircraft to drift to the right following the initial touchdown.

ACCIDENT

Aircraft Type and Registration:	Grob G109B, G-UILD
No & Type of Engines:	1 Grob 2500-D1 piston engine
Year of Manufacture:	1986
Date & Time (UTC):	3 April 2010 at 0930 hrs
Location:	Wing Farm, Warminster, Wiltshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Propeller, both wings and hangar damaged
Commander's Licence:	Private Pilot's Licence
Commander's Age:	58 years
Commander's Flying Experience:	680 hours (of which 104 were on type) Last 90 days - 2 hours Last 28 days - 2 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and subsequent enquiries by the AAIB

Synopsis

The aircraft overran the runway and collided with trees and a hangar during an attempted takeoff in conditions in which the aircraft performance was marginal.

History of the flight

The pilot had planned to fly from Wing Farm to nearby Compton Abbas to refuel, before departing on a cross-country flight. Wing Farm has a 500 m long grass runway, oriented 09/27, with a 2.2% downslope on Runway 09. Each runway direction has a 350 m marker and pilots are expected to abort the takeoff if the aircraft is not airborne on reaching the marker. Located just beyond the end of Runway 09 are 20 ft high trees, a hangar and a bungalow.

The pilot inspected the runway on his arrival, noting that the grass was short and damp and that the ground was soft in places. The wind was around 5 kt from the south-east. He elected to carry out a trial run on Runway 09 to assess the aircraft's acceleration. Starting a quarter of the way down Runway 09, he achieved 35 kt at the 350 m marker before reducing power to slow down. He chose this runway as it was into-wind and slightly downhill. He then taxied back to the start of Runway 09 for takeoff.

Prior to takeoff the pilot checked the engine parameters, which appeared normal. He applied carburettor heat, to which the engine responded normally, before reselecting cold air. The takeoff run seemed sluggish at first, although the engine rpm was satisfactory. The pilot considered abandoning the takeoff, but the aircraft reached 40 kt just before the 350 m marker and became airborne at the marker and so he maintained full power. Shortly after that, the aircraft settled back onto the ground and he was forced to abandon the takeoff. He reduced power to idle and applied the brakes, but these were ineffective on the damp grass and he switched off both magnetos to stop the engine. He was unable to prevent the aircraft from overrunning and colliding with the trees and hangar beyond the end of Runway 09. The aircraft was extensively damaged, but the pilot was uninjured.

Prior to the flight the pilot had checked that the weight and balance of the aircraft were within limits. He was aware that even with dry, hard ground conditions the takeoff performance of the Grob 109B from this strip in a light wind is marginal. He commented that having operated the aircraft from the strip for several years, he had become accustomed to the small performance margin and that in retrospect he had become less appreciative of the implications of this with time.

ACCIDENT

Aircraft Type and Registration:	Ikarus C42 FB UK, G-DUGE
No & Type of Engines:	1 Rotax 912 ULS piston engine
Year of Manufacture:	2003
Date & Time (UTC):	12 November 2009 at 1230 hrs
Location:	Plaistows Farm Airfield, St Albans, Hertfordshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to nose landing gear and propeller
Commander's Licence:	National Private Pilot's Licence
Commander's Age:	60 years
Commander's Flying Experience:	284 hours (of which 203 were on type) Last 90 days - 11 hours Last 28 days - 1 hour
Information Source:	Aircraft Accident Report Form submitted by the pilot

The aircraft took off from grass Runway 15 at Plaistows Farm Airfield and at 700 ft agl the pilot started a turn to the left. As he did so he noticed that the starboard door was coming open. He felt this was affecting the handling of the aircraft badly so he decided to make a forced landing in a nearby field.

The aircraft landed heavily in the field and, as a result, the nose landing gear collapsed and the propeller struck the ground. The pilot was not injured in the accident and was able to vacate the aircraft by the door on the left side.

ACCIDENT

Aircraft Type and Registration:	Mainair Blade 912, G-MZKM
No & Type of Engines:	1 Rotax 912-UL piston engine
Year of Manufacture:	1997
Date & Time (UTC):	18 May 2010 at 1640 hrs
Location:	Field near Lambley, Nottingham
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Aircraft destroyed
Commander's Licence:	Private Pilot's Licence
Commander's Age:	69 years
Commander's Flying Experience:	190 hours (of which 190 were on type) Last 90 days - 20 hours Last 28 days - 5 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

Whilst cruising at 2,000 ft the engine lost power. A forced landing was made in a furrowed field and as the aircraft came to a halt a fire broke out. The pilot, who was uninjured, exited the aircraft unaided. The aircraft was subsequently destroyed by the fire.

History of the flight

The pilot was flying at 2,000 ft on a local flight from Oxton airfield when the engine lost power, causing the aircraft to descend. There was a limited choice of fields suitable for a forced landing. The pilot selected a field and landed perpendicularly to the furrows. As the aircraft came to a halt, it caught fire. The pilot was able to exit the aircraft quickly but could do nothing to prevent the fire from spreading. He considered that the landing across the furrows might have caused a fuel pipe to detach, providing a source of fuel for the fire.

Discussion

The aircraft suffered an engine failure, something which pilots of single-engined aircraft are trained to anticipate. Typical advice for pilots for choosing a suitable field for a forced landing includes selecting a field that is well within gliding range, free from obstructions (particularly in the undershoot and overshoot areas) and with a suitable surface. The surface of the chosen landing field was less than ideal, but there was a limited choice of fields available to the pilot. There was insufficient evidence available to determine the cause of the loss of engine power.

ACCIDENT

Aircraft Type and Registration:	Pegasus XL-R, G-MTAX
No & Type of Engines:	1 Rotax 447 piston engine
Year of Manufacture:	1986
Date & Time (UTC):	4 June 2010 at 1035 hrs
Location:	Beverley Airfield, Yorkshire
Type of Flight:	Training
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to nosewheel, propeller and wing
Commander's Licence:	Private Pilot's Licence
Commander's Age:	57 years
Commander's Flying Experience:	312 hours (of which 4 were on type) Last 90 days - 1 hour Last 28 days - 1 hour
Information Source:	Aircraft Accident Report Form submitted by the pilot

The pilot was experienced on light aircraft and had just completed a differences course to convert to flex-wing microlights. Having been cleared to fly solo, the pilot had been continuing his training and was carrying out circuits on Runway 12. The third approach was planned to be a full-stop landing. He reported that the weather conditions were deteriorating, with strong thermals, and a south-easterly wind gusting between 8 and 10 kt. During the flare the aircraft 'ballooned' and then landed heavily on the nosewheel, which collapsed, causing the aircraft to turn over.

ACCIDENT

Aircraft Type and Registration:	Pegasus XL-R, G-MVAT	
No & Type of Engines:	1 Rotax 503 piston engine	
Year of Manufacture:	1988	
Date & Time (UTC):	21 June 2010 at 1706 hrs	
Location:	Sculthorpe Airfield, Norfolk	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - 1
Injuries:	Crew - 1 (Minor)	Passengers - 1 (Minor)
Nature of Damage:	Aircraft damaged beyond economic repair	
Commander's Licence:	National Private Pilot's Licence	
Commander's Age:	58 years	
Commander's Flying Experience:	180 hours (of which 151 were on type) Last 90 days - 29 hours Last 28 days - 17 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot and subsequent AAIB enquiries	

During flight, the pilot perceived that "something wasn't quite right" with the aircraft's engine, and decided to land to check the spark plugs and fuel system. He landed on a runway at Sculthorpe Airfield, which he believed was closed. Having inspected the engine and found nothing amiss, he took off again. At about 50 ft agl during the climb, the engine lost power and the pilot attempted to land straight ahead. During the landing the aircraft impacted on its nose and then fell onto its side, sustaining damage. The cause of the power loss was not determined.

ACCIDENT

Aircraft Type and Registration:	Pegasus Quantum 15, G-MZIU
No & Type of Engines:	1 Rotax 582-48 piston engine
Year of Manufacture:	1997
Date & Time (UTC):	6 August 2009 at 0849 hrs
Location:	Lepton, near Huddersfield, West Yorkshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - 1 (Serious) Passengers - None
Nature of Damage:	One propeller blade detached and damage to the engine
Commander's Licence:	National Private Pilot's Licence
Commander's Age:	49 years
Commander's Flying Experience:	2,414 hours Last 90 days - 45 hours Last 28 days - 11 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

The aircraft was en-route from Rufforth Airfield to Crosland Moor Airfield when a blade of the three-bladed propeller detached near its root. The consequent severe vibration caused an upset from controlled flight and led to components detaching from the engine. When control was regained, the pilot performed a successful forced landing, although he suffered spinal injuries during the event and after exiting the aircraft.

History of the flight

The aircraft had been housed, fully rigged, in a hangar at Rufforth Airfield when the pilot and passenger arrived for a flight to Crosland Moor Airfield, some 30 minutes flying time away. After a normal pre-flight inspection, they departed the tarmac runway at Rufforth. After about 20 minutes, having climbed to 1,800 ft amsl, the pilot descended to 1,100 ft amsl for a scenic view of a canal and, after doing this, he set a 'cruise-climb' power level of 6,200 rpm to reach an altitude of 2,200 ft amsl (1,700 ft agl). He spoke to Leeds Bradford Airport to reset his transponder code and requested a radio frequency change to Crosland Moor Airfield.

As the aircraft was climbing with a bank to the right of about 20°, the pilot reported that there was suddenly, and with no warning, "an incredibly loud banging and violent shaking" and the aircraft rolled to the right to more than 60° and entered a spiral dive. The pilot recalled that he heard a "SINK RATE SINK RATE PULL UP

PULL UP" message from his GPS-based terrain warning equipment, indicating that he had exceeded 1,500 fpm rate of descent in the dive. The engine stopped and he manoeuvred the aircraft using full control inputs to arrest the spiral and slow the aircraft to its minimum rate of sink speed. He had made a 'MAYDAY' call to Leeds Bradford Airport and they replied that they were able to track his position from his transponder code.

Having regained control, the pilot asked the passenger to look behind and report the damage, receiving the reply that "half the propeller is gone, the carburettors and airbox are missing and the engine is 'hanging off'". As the pilot turned his attention back to navigating the aircraft, he heard the GPS equipment call "TERRAIN TERRAIN PULL UP PULL UP" which signified that the aircraft was below 500 ft agl. He selected a large field on a hillside in front of him which, although far from ideal, was the only landing option available to him. A satisfactory forced landing was performed on the 15° upslope, which was sufficiently steep for the aircraft to roll backwards despite the application of full braking. The passenger climbed out and held it from behind until the Air Ambulance helicopter arrived. The pilot commented that its arrival was "very prompt".

The pilot, whose helmet was severely damaged by an impact from the 'A' frame during the initial loss of control, exited the aircraft in a dazed condition. It later transpired that this impact had caused a fracture of his neck vertebrae and disc damage. He was also diagnosed as having damaged vertebrae in his lower back when he had fallen during his evacuation of the aircraft. He subsequently was hospitalised for thirteen days after the accident.

Examination of the aircraft

One complete propeller blade had detached at its root whilst in-flight but the missing portion of the blade was not recovered. The resulting imbalance had caused severe vibration leading to the detachment of the carburettors and exhaust, and damaged the engine mounts. The aircraft did not appear to have been damaged further during the subsequent forced landing.

The piece of propeller blade remaining in the hub was removed and examined. The construction was typical of such propellers inasmuch as it comprised a glass and carbon fibre reinforced outer skin with a white foam core. The blade had fractured close to where the composite material was bonded into a metal blade grip. Visual examination by a specialist organisation did not suggest that there was an obvious reason for the failure, although the owner had reportedly shown the piece to an associate with expertise in composite fractures who had reported that there were signs of a pre-existing crack in the fracture region. Anecdotal evidence has suggested that the aircraft may have previously been involved in a minor accident, and although it is not known whether the propeller sustained any damage during this previous accident, it had not been replaced.

A report was published in AAIB Bulletin 7/2010 of an accident involving an X'Air 582(1) microlight aircraft (G-BZAF) which had an in-flight delamination of a similarly constructed propeller blade, made by a different manufacturer from that fitted to G-MZIU. This propeller blade had not detached completely, but the consequent severe vibration and subsequent forced landing resulted in the aircraft being damaged beyond economic repair. Discussion with the British Microlight Aircraft Association (BMAA) does not suggest that there are any current significant safety issues with composite propeller integrity, although both they and the AAIB are continuing to monitor trends.

ACCIDENT

Aircraft Type and Registration:	1. Pioneer 200-M, G-WEFR 2. Aerotechnik EV-97 Eurostar, G-VORN 3. Aerotechnik EV-97 Eurostar, G-ZZAC
No & Type of Engines:	1. 1 Rotax 912-UL piston engine 2. 1 Rotax 912-UL piston engine 3. 1 Rotax 912-UL piston engine
Year of Manufacture:	1. 2009 2. 2004 3. 2007
Date & Time (UTC):	23 June 2010 at 0645 hrs
Location:	Knockbain Farm Airstrip, Dingwall, Ross-shire
Type of Flight:	Private
Persons on Board:	1. Crew - 1 Passengers - None 2. Crew - None Passengers - None 3. Crew - None Passengers - None
Injuries:	1. Crew - 1 (Serious) Passengers - N/A 2. Crew - N/A Passengers - N/A 3. Crew - N/A Passengers - N/A
Nature of Damage:	1. Left wing, propeller, fuselage 2. Propeller, cowling and left wing 3. Right wing
Commander's Licence:	National Private Pilot's Licence
Commander's Age:	41 years
Commander's Flying Experience:	1. 207 hours (of which 74 were on type) Last 90 days - 62 hours Last 28 days - 27 hours 2. Unknown 3. Unknown
Information Source:	Aircraft Accident Report Form submitted by the pilot

Knockbain Farm Airstrip has a 650 m long, 15 m wide grass runway, orientated 08/26. The weather at the time of the accident was CAVOK with a light southerly wind and the grass surface was wet from previous rain. The pilot decided to land on Runway 26, which has an upslope of 6% for the first 100 m, a level section of about 100 m and then a 3% downslope for the remaining 450 m. The aircraft touched down on the level section before veering off the right side of the runway, about 200 m from the end. There is a slight downslope from the runway to the apron area, which is on the north side about 40 m from the runway centreline. The aircraft struck two parked, unmanned aircraft on the apron, G-VORN and G-ZZAC, at an estimated speed of 15-20 mph, before stopping.

The pilot appeared uninjured and was able to dismantle and store his aircraft. Subsequently he was diagnosed with broken ribs, which is classified as a serious injury. It was reported that all three aircraft were damaged.

The pilot concluded that the loss of control after landing was due to the downslope on the runway and the wet grass conditions.

ACCIDENT

Aircraft Type and Registration:	Rans S6-ES Coyote II, G-MZMS
No & Type of Engines:	1 Rotax 582-48 piston engine
Year of Manufacture:	1998
Date & Time (UTC):	6 April 2010 at 1600 hrs
Location:	Michaelwood Farm, Alkington, Gloucestershire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to nose leg, left main leg and propeller
Commander's Licence:	National Private Pilot's Licence (Microlight)
Commander's Age:	62 years
Commander's Flying Experience:	55 hours (of which 9 were on type) Last 90 days - 8 hours Last 28 days - 2 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

The pilot was carrying out an into-wind landing on a grass farm strip. Following a normal approach, the aircraft bounced after touchdown, and then the nose gear dug into the ground, causing the nosewheel to separate. The propeller hit the ground and the aircraft spun round to the right and came to rest. The pilot did not report the accident to the AAIB until three months after it had occurred and consequently his recall of the event was limited; he stated that he did not know what had caused the accident.

AIRCRAFT ACCIDENT REPORT No 4/2010

This report was published on 2 September 2010 and is available on the AAIB Website www.aaib.gov.uk

REPORT ON THE SERIOUS INCIDENT TO BOEING 777-236, G-VIIR AT ROBERT L BRADSHAW INTERNATIONAL AIRPORT, ST KITTS, WEST INDIES ON 26 SEPTEMBER 2009

Operator:	British Airways
Aircraft Type and Model:	Boeing 777-236
Registration:	G-VIIR
Location:	Robert L Bradshaw International Airport, St Kitts, West Indies
Date and Time:	26 September 2009, 2105 hrs All times in this report are UTC

Synopsis

The crew received the aircraft's takeoff performance figures for a takeoff from Intersection Alpha on Runway 07 at Robert L Bradshaw International Airport, St Kitts, West Indies. Having received taxi clearance to Intersection Alpha, the aircraft taxied to Intersection Bravo from where it subsequently took off; the crew believed they were at Intersection Alpha. Intersection Bravo on Runway 07 is not an authorised takeoff intersection for the Boeing 777. The estimated Take-off Run Available from Intersection Bravo was approximately 1220 m, which was 695 m less than the planned takeoff run from Intersection Alpha.

The AAIB was informed of the incident by the operator on 29 September 2009 who subsequently notified the Eastern Caribbean Civil Aviation Authority (ECCAA)[1]. The investigation was then delegated to the AAIB which represents the State of Registration.

Three Safety Recommendations have been made.

The investigation identified the following contributory factors:

1 The airport authority had not installed any taxiway or holding point signs on the airfield.

2 The crew did not brief the taxi routing.

3 The crew misidentified Taxiway Bravo for Taxiway Alpha and departed from Intersection Bravo.

4 The trainee ATCO did not inform the flight crew that they were at Intersection Bravo.

Footnote

[1] The Eastern Caribbean Civil Aviation Authority, who are based in Antigua, has oversight for Robert L Bradshaw International Airport.

Findings

1 Both the pilot and co-pilot were properly licensed and qualified to operate the aircraft.

2 The aircraft was certified, equipped and maintained in accordance with the existing regulations and approved procedures.

3 The crew had calculated the aircraft performance figures for a TORA of 1,915 m from Intersection Alpha.

4 The TORA from Intersection Bravo was 1,220 m.

5 The crew did not brief the taxi routing.

6 There were no taxiway or holding point signs on the airfield.

7 The crew misidentified Taxiway Bravo for Taxiway Alpha and departed from Intersection Bravo.

8 The ECCAA did not take appropriate action to ensure the findings of the 2006 airfield inspection were acted upon in a timely manner.

9 St Kitts had not filed any differences to Annex 14 with ICAO.

10 The lack of signage was not published in the ECAIP.

11 There was no formal means of incident reporting within ATC.

12 The operator had not conducted a physical survey of the airfield.

Safety Recommendations

The following Safety Recommendations have been made:

Safety Recommendation 2010-047

It is recommended that the Eastern Caribbean Civil Aviation Authority ensure that Robert L Bradshaw International Airport, St Kitts, establishes a Safety Management System for its airfield operations.

Safety Recommendation 2010-048

It is recommended that the Eastern Caribbean Civil Aviation Authority ensures that the infrastructure of Robert L Bradshaw International Airport, St Kitts, complies with ICAO Annex 14 Standards and Recommended Practices or any differences are filed. In the interim a NOTAM of outstanding deficiencies should be published.

Safety Recommendation 2010-049

It is recommended that British Airways review the process by which all new destination airfields are inspected to identify any operational issues.

FORMAL AIRCRAFT ACCIDENT REPORTS ISSUED BY THE AIR ACCIDENTS INVESTIGATION BRANCH

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.

2/2010 Beech 200C Super King Air, VQ-TIU
at 1 nm south-east of North Caicos
Airport, Turks and Caicos Islands,
British West Indies
on 6 February 2007.

Published May 2010.

3/2010 Cessna Citation 500, VP-BGE
2 nm NNE of Biggin Hill Airport
on 30 March 2008.

Published May 2010.

4/2010 Boeing 777-236, G-VIIR
at Robert L Bradshaw Int Airport
St Kitts, West Indies
on 26 September 2009

Published September 2010.

AAIB Reports are available on the Internet
http://www.aaib.gov.uk