SERIOUS INCIDENT

Aircraft Type and Registration:	Raytheon 390 Premier I, G-FRYL
No & Type of Engines:	2 Williams International FJ44-2A turbofan engines
Year of Manufacture:	2004
Date & Time (UTC):	7 August 2008 at 1800 hrs
Location:	En route Copenhagen, Denmark to Farnborough, UK
Type of Flight:	Commercial Air Transport (Non-Revenue)
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	None
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	60 years
Commander's Flying Experience:	11,830 hours (of which 1,850 were on type) Last 90 days - 140 hours Last 28 days - 30 hours
Information Source:	AAIB Field Investigation

Synopsis

During descent the crew reported experiencing the loss of airspeed information followed by the loss of all three electronic flight instrument system (EFIS) displays. The investigation concluded that the loss of air data information was due to a blockage in the right pitot system caused by moisture ingress which subsequently froze. However, despite exhaustive testing, it was not possible to determine the cause of the loss of all three EFIS displays.

One Safety Recommendation is made.

History of the flight

The aircraft was returning to Farnborough having delivered a passenger to Copenhagen. The outbound flight had been uneventful except for the presence of three large thunderstorms south of the aircraft's route, around which there had been some short duration turbulence, characterised by the commander as "light to moderate". Engine anti-ice was selected ON during the descent into Copenhagen.

The aircraft was on the ground at Copenhagen for approximately one hour, during which it was refuelled. The crew remarked that passenger baggage, unloaded from the rear hold, felt damp and cold, whereas in their experience it usually felt only cold.

The commander was the pilot flying from Copenhagen to Farnborough. Approximately 20 mins after takeoff, whilst cruising at FL400 with an indicated outside air temperature (OAT) of -62°C, the aircraft encountered "significant" turbulence for about 10 mins. The commander estimated that the aircraft was 25 nm downwind of a thunderstorm in a layer of cloud that he did not consider to be cumulonimbus. Although he did not consider the Premier to have a specific turbulence penetration speed, he reduced thrust in an attempt to decelerate and achieve a more comfortable ride. Having done so, he was surprised at the high rate at which the indicated airspeed decreased. The airspeed indicated on his Primary Flight Display (PFD1) dropped quickly from 220 kt to 180 kt, which he considered excessive for the selected thrust reduction. He commented that the aircraft "felt different" but that there was no visible ice accretion on the airframe. The crew requested and were cleared to climb to FL410, where the aircraft was clear of cloud and turbulence and the OAT was -59°C. The commander noted that, when normal thrust was reselected, the speed increased "very slowly", estimating that acceleration to 220 kt took more than 10 minutes.

Cumulonimbus clouds were now visible across the route and the crew requested several heading changes to fly between the larger ones whose tops were at a similar level to the aircraft. During this time the commander was demonstrating to the co-pilot several functions of the Multi Function Display (MFD), including how to access fuel, navigation and diversionary information.

Shortly before commencing a planned descent, an amber IAS comparator message appeared on both PFDs, indicating a disagreement in IAS between the left and right air data systems of greater than 10 kt. The co-pilot's Primary Flight Display (PFD2) and the standby airspeed indicator (ASI) both indicated a steady 220 kt, which the commander interpreted as confirmation that PFD2 was indicating correctly. A lower and reducing airspeed was indicated on PFD1.

The commander recalled saying to the co-pilot that this indicated an Air Data Computer (ADC) failure. He therefore placed the ADC reversion switch in position '2' so that both PFDs would display information derived from ADC2. When so selected, IAS on PFD1 "jumped up" and PFD1, PFD2 and the standby ASI indicated the same airspeed.

Shortly afterwards the aircraft was cleared to descend to FL370. Immediately the descent commenced, both pilots noticed that the PFDs and the standby ASI indicated a reduction in airspeed. The commander also noticed that the rate of reduction of IAS varied with the rate of descent, "as if the ASI was acting like an altimeter"[1]. All three altimeters indicated the same altitude and he did not recall any discrepancy with geometric altitude derived from GPS data.

Before reaching the initial cleared level the aircraft was cleared for further descent and consequently did not level off. The crew advised ATC that they were experiencing "some airspeed difficulties". As IAS continued to reduce, the commander reselected the ADC switch to the normal position, whereupon PFD1 indicated an overspeed. However, the aural warning normally associated with an overspeed did not sound and, having retarded the thrust levers and hearing no increase in wind noise, the crew were content that airspeed was not excessive. Nevertheless the commander reverted to ADC2 and the IAS indication reduced once more.

Footnote

1 If an airspeed indicator behaves like an altimeter it indicates that the associated pitot source may be blocked.

As IAS continued to fall, the commander opened the right STALL WARN circuit breaker (CB) to disarm the stick pusher[2]. IAS continued to reduce without activation of the stick shaker or aerodynamic buffet. The commander recalled that at approximately 60 kt IAS he heard a "click" from the vicinity of the instrument panel, reminiscent of a relay operating. Most of the information normally presented on the PFDs disappeared and the red IAS, HDG and ALT fail messages illuminated. The standby ASI indicated zero but the standby altimeter, attitude and heading indicators appeared to function normally. The commander used his experience of the aircraft to set thrust lever position and aircraft attitude appropriate to the phase of flight.

The central Multifunction Display (MFD) was now completely blank. The commander tried without success to restore the MFD presentation by selecting the DISPLAY/NORM reversion switch, first to PFD and then to MFD, then reselected the NORM position of this switch. He also selected each of the display reversion modes in turn without effect.

The co-pilot declared an emergency and stated that the crew intended to land at Manston, which they could see clearly. ATC advised that Manston was closed and that Ostend was available. As the aircraft descended below FL150, a combined PFD and MFD presentation appeared on the MFD[3]. The commander recalled that FL150 may have been the freezing level. The co-pilot then cancelled the 'MAYDAY', maintained the distress transponder code of 7770 and advised ATC that the crew now intended to leave controlled airspace and fly visually to Farnborough.

During the visual flight to Farnborough the commander reselected the ADC switch to the NORM position and returned the DISPLAY/NORM selector to NORM. The presentation of information on the two PFDs and the MFD was now normal in every respect and the remainder of the flight was uneventful, except that after landing the flight management system (FMS) showed an airborne time of 37 minutes, whereas the aircraft had been airborne for over 2 hours.

The following morning, after more rain, water was found in the front baggage bay and both pitot heads were damp when the pitot covers were removed.

Co-pilot's statement

The co-pilot's recollection of events broadly confirmed but differed in some detailed respects from that of the commander. Whereas the commander recalled that all three screens had immediately become blank except for the three red fail messages, the co-pilot recalled that the compass rose presentation and artificial horizon had remained visible on her PFD (PFD2) at first. She also stated that during the event the autopilot became disconnected and that the PITCH TRIM FAIL annunciator on the master warning panel was illuminated. She commented that the crew did not conduct any of the procedures contained in the abnormal and emergency sections of the pilot checklist because there were "no relevant annunciations."

While preparing the aircraft for the outbound sector the co-pilot noticed that although there had been heavy rain overnight and on the morning of the flight the aircraft did not appear particularly wet.

Footnote

2 The stick shaker is disabled by opening both stall warning CBs.

3 A combined presentation is shown on the MFD when the DISPLAY/NORM selector is in the MFD position, PFD1 is blanked.

Meteorological information

The Met Office provided a comprehensive report on the meteorological conditions prevailing along the route.

Synopsis

A complex region of surface low pressure prevailed along the flight path from Denmark to the United Kingdom, with several shallow but distinct low pressure centres over Denmark, Norway and southeast England. The flight mostly took place within a warm sector, later encountering a cold front as it approached the Kent coast.

Temperature

Before crossing the cold front, the coldest air temperature that the aircraft would have encountered was approximately -61° C at an altitude of 38,000 ft. The coldest air temperature over the southern North Sea was approximately -54° C.

Turbulence

AMDAR[4] reports from other aircraft indicated short range wind speed changes consistent with moderate or severe turbulence. A jetstream over the southern North Sea at the time was expected to generate moderate turbulence, possibly with areas of severe turbulence. It is also possible that turbulence was transported into the area from upstream thunderstorms over northeast France and the Netherlands.

Icing

The aftercast indicated that during most of the flight across the southern North Sea the aircraft would have been in clear air. However, cumulonimbus anvils, in which icing may have been significant, were moving northwards on the southerly upper winds. At temperatures below approximately -40° C, flight in cirrus cloud is normally considered to pose a negligible icing hazard, except if that cirrus cloud contains a cumulonimbus anvil. Cold soak of the airframe might intensify such effects.

Emergency and abnormal procedures

A *Pilot Checklist* handbook available in the cockpit included normal, emergency and abnormal procedures, shown in Table 1.

System description

Avionics system

The Premier 1 Model 390 is fitted with a Rockwell Collins Proline 21 fully integrated avionics system. It includes an Integrated Avionics Processor System (IAPS) which is designed to interconnect and manage the aircraft's various avionics sub-systems. There are eight sub-systems: an Electronic Flight Instrument System (EFIS), an Engine Indicating System (EIS), an Air Data System (ADS), an Attitude Heading Reference System (AHRS), a Flight Guidance System (FGS), a Flight Management System (FMS), a Radio Sensor System (RSS) and a Weather Radar System (WXR). The IAPS also contains a Maintenance Diagnostic Computer (MDC) module which monitors the sub-systems and stores diagnostic data in non-volatile memory.

The EFIS consists of three large colour displays, two Primary Flight Displays (PFD1 and PFD2) and a Multifunction Display (MFD), and two display control panels, one for each pilot's display (see Figure 1). The PFDs show attitude, navigation/compass, flight control, air data (altitude, airspeed and vertical speed), and TCAS advisory functions. Air data information is supplied

Footnote

4 The Aircraft Meteorological Relay (AMDAR) program collects temperature and static pressure data from commercial aircraft via a VHF downlink.

'AIRSPEED (IAS) COMPARATOR ILLUMINATED

Illumination of the Airspeed (IAS) comparator message indicates a disagreement between the left and right air data systems of greater than 10 KIAS.

If unable to determine reliable indication:

1. *At Higher Airspeeds .... USE HIGHER INDICATION*
2. *At Lower Airspeeds, Approach and Landing......................... USE LOWER INDICATION'*

'ELECTRONIC FLIGHT DISPLAY FAILURE

1. *Display Reversion Switch ....SELECT OPERABLE DISPLAY*

If all displays fail:

2. *Use copilot's (two display) or standby (three display) instruments'*

'SINGLE AIR DATA COMPUTER FAILURE

1. *ADC Reversion Switch .... SELECT OPERATING ADC*
2. *STALL WARN Circuit Breaker (Affected Side) .... PULL*

WARNING

The stick pusher is inoperative any time one or both STALL FAIL annunciators are illuminated.

NOTE

Failure of one ADC will render the following equipment inoperative: Autopilot; Flight Director; Pitch Trim (refer to PITCH TRIM FAIL) procedure in the Emergency Procedures section); Yaw Damp (refer to YAW DAMP FAILURE procedure in this section); Rudder Boost (refer to RUDDER BOOST FAILURE procedure in this section).

If the No.2 ADC has failed, also refer to the PRESSURIZATION CONTROLLER FAILURE procedure in this section.'

'DUAL AIR DATA COMPUTER FAILURE

1. *Use Copilot's (two display) or Standby (three display) Instruments.*

WARNING

The stick pusher is inoperative any time one or both STALL WARN[1] FAIL annunciator are illuminated.

NOTE

Failure of one ADC will render the following equipment inoperative: Autopilot; Flight Director; Pitch Trim (refer to PITCH TRIM FAIL) procedure in the Emergency Procedures section); Yaw Damp (refer to YAW DAMP FAILURE procedure in this section); Rudder Boost (refer to RUDDER BOOST FAILURE procedure in this section); Automatic Pressurization Controller (refer to the PRESSURIZATION CONTROLLER FAILURE procedure in this section).'

[1] (sic) The correct name for this annunciator is 'STALL FAIL' as in the procedure for single air data computer failure.

Table 1

by two identical Air Data Computers (ADCs) and the aircraft attitude and heading information is supplied by two Attitude Heading Computers (AHCs).

The MFD provides engine indicating displays, navigation/compass information, weather radar, Enhanced Ground Proximity Warning System (EGPWS) display, flight management, checklist, and diagnostic information. Engine information is supplied by the Engine Indicating System (EIS). The MFD also receives the same information as PFD1 and can act as a reversionary PFD. When reverted, a composite display showing combined information, normally presented on PFD1 and MFD, is shown on the selected PFD1 or MFD screen, and the other screen is blanked.

Display reversion

A series of display reversion/selection switches are located to the left of PFD1, in the pilot audio panel. These switches enable the pilot to select alternate display configurations or sources.

The 'display/norm' switch selects reversionary display on the PFD or MFD. When selected to NORM, PFD1 and the MFD display their own information, when selected to PFD, PFD1 displays the composite information and MFD is blanked, and when selected to MFD, the MFD displays the composite information and PFD1 is blanked. PFD2 is unaffected by the switch selection and displays its own information.

The AHRS switch selects attitude and heading source for the PFD and MFD displays. When selected to NORM, PFD1 displays AHC1 information and PFD2 AHC2 information. By selecting 1, both PFD1 and 2 use AHC1 information and AHC1 caption is displayed; selecting 2, both PFD1 and 2 use AHC2 information and an AHC2 caption is displayed.

Similarly, the ADC switch selects the air data source for the PFD and MFD displays. When selected to NORM, PFD1 displays ADC1 information and PFD2 ADC2 information. Selecting 1, both PFD1 and 2 use ADC1 information and 'ADC1' caption is displayed; selecting 2, both PFD1 and 2 use ADC2 information and an ADC2 caption is displayed.

Figure 1

Air Data System

The ADS includes two identical ADCs which output processed air data from pneumatic and temperature sensor inputs. The pitot/static system has two probes, one each side of the front fuselage, which connect via various tubes, connections and unions to the two ADCs and to the standby instruments. (See Figure 2). The left probe pitot connection supplies the left (No 1) ADC only and the right probe pitot connection feeds the right (No 2) ADC and the standby ASI. The left and right probe static lines are cross-connected and supply static pressure to the ADCs. The standby ASI and altimeter use the same static feed as ADC2.

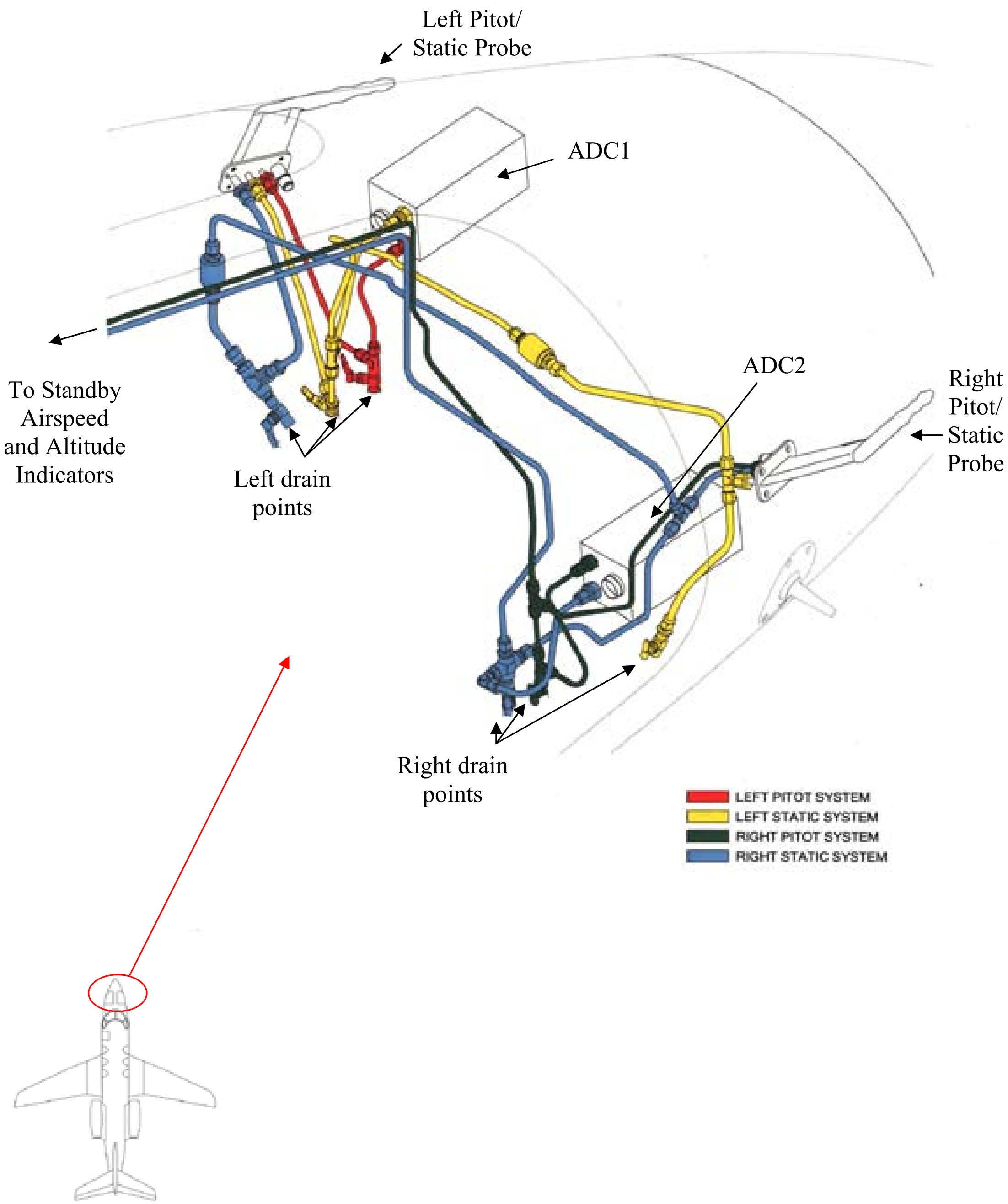

Figure 2

Pitot/static connections

Both left and right pitot/static systems have drain traps, located at the lowest point in the lines to collect any moisture, which can be drained by operating a spring loaded lever on the drain traps. The pitot/static probes are electrically heated.

G-FRYL was fitted with standby airspeed, altitude and attitude instruments, located above the central warning display in the centre of the instrument panel.

PFD warning and captions

Aircraft attitude and heading parameters are provided to the PFDs and MFD by the AHCs. A red HDG flag is displayed at the top of the compass presentation on the PFD if the heading sensor input fails.

When the difference between the ADC1 and ADC2 airspeed exceeds 10 kt, an airspeed comparator warning flag is displayed on PFD1 and PFD2 by means of a yellow boxed IAS caption adjacent to the airspeed tape. The caption flashes continuously until the master caution is reset.

If the air data information becomes invalid, red boxed IAS, ALT and VS captions appear instead of the airspeed, altitude or vertical speed tape on the PFD of the side affected. With these flags in view, all air data information is removed (see Figure 3),

Autoflight

The Flight Guidance System (FGS) provides an integrated Flight Director (FD), Autopilot, Yaw Damper and Automatic Pitch Trim system. If Automatic pitch trim is disabled a red boxed TRIM caption appears on the PFDs.

Figure 3

PFD display with air data information invalid

Electrical power

In flight, electrical power is provided by a DC electrical generation system consisting of two engine-driven starter/generators, two generator control units, a power distribution system, a main battery and a standby battery. Electrical power is distributed from the main 'power box' to the electrical services via relays and a busbar arrangement which is divided into the following buses: left main bus, right main bus, essential bus, non-essential bus, hot battery bus and standby bus. The right bus is normally supplied by the right generator and the left bus, normally supplied from the left generator, provides power to the essential bus and the standby bus. The bus connectors are located in the 'power box' which is in the right rear fuselage, behind the pressure bulkhead.

In normal operation, the left generator would supply power to the MFD, PFD1, AHRS1, and the CVR while the right generator would supply PFD2 and AHRS2.

Equipment location

Most of the Proline avionic system units, which were the subject of this investigation, are located in the right avionics bay in the nose of the aircraft. These include the IAPS, both AHS and ADC2. ADC1 is located in the left avionics bay.

The aircraft manufacturer reported that from certification test flying experience, temperatures within the forward avionics bay can drop below freezing and any moisture in the pitot/static tubes can freeze at altitude. Some avionics units will remain warm from internal heat generated, but others can become cold. The IAPS has an internal heater which will automatically operate if the temperature falls below -41 ºC and will only switch off again if the temperature rises above -35 ºC.

Pitot/static drain operation

The Aircraft Maintenance Manual (AMM) requires the operation of the pitot and static drains every 200 hours in order to remove moisture which may have entered the system. The process requires the removal of the blanking caps on the bottom of the drains and the turning of a red spring-loaded lever on each of the drain traps for the two independent (left and right) static and pitot systems (see Figure 2). This should allow any moisture to drain. The system must be leak-checked following the procedure. Figure 4 shows the location for the right system drains in the right avionics bay.

The AMM also details a separate procedure for purging the pitot and static systems to remove any foreign matter by attaching an external source of dry air to the pitot or static system. In order to purge the system, all the equipment, such as computers and instruments, must be disconnected. Each pitot/static system must be purged separately.

Recorded information

The aircraft was fitted with a 30-minute Cockpit Voice Recorder (CVR) which covered the period of the recovery of the aircraft to Farnborough. It had been replayed by the operator. However, when the incident was reported to AAIB, the recording of the incident flight had been overwritten during the ground testing. No flight data recorder was fitted to the aircraft and none was required.

The EGPWS memory was replayed and confirmed the failure messages which were logged on the Maintenance Diagnostic Computer (MDC) and were also downloaded. The relevant failure messages are shown in Table 2.

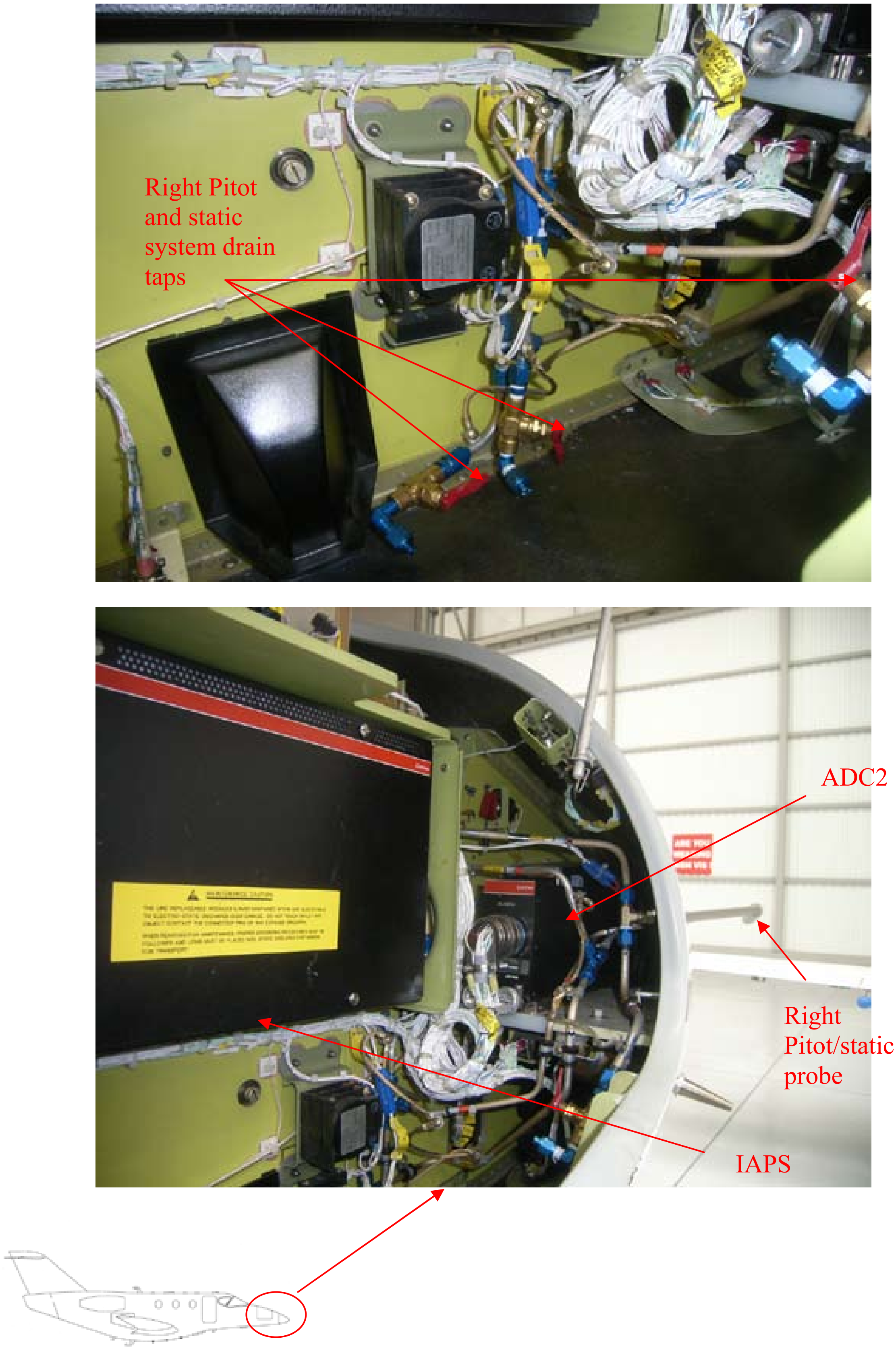

Figure 4

Right Avionics Bay

Time	LRU	Failure Message Code	Cause
18:03	FCG1	FCS CODE=AP DIS FCS CODE=YD DIS	AP disconnected due to roll equalization problem. YD disconnected due to a yaw equalisation problem
18:04	FCG2	FCS CODE=REPAIR	FCG2 repair code due to a pitch roll or yaw cutout
18:05	ADC2	VAR CIRCUITRY	ADC2 had an error bit set which indicates that the pitot pressure was less than or equal to static pressure. Manufacturer's experience is that often this fault is associated with the pitot tube becoming blocked. The ADC was operating as intended
18:05	TCAS	RA 1 DSPLY INVAL	Indicated a variety of faults, since the Vertical Speed Indicator would have been flagged following the ADC2 fault, the PFD would not be able to display Radar Advisories (RAs) from TCAS
18:09 18:10	PFD1 MFD1	NO OUTPUT NO OUTPUT	Both PFD1 and MFD1 are switched off. This could have been due to operation of the reversion switches
18:41	FCG1	FCS CODE=REPAIR	Pitch, roll or yaw equalization error. These errors occur when there are significant differences in the cross comparison of the autopilot command loop. This can be generated by a mis-compare between air data and/or altitude sources

Table 2

The Mode S radar recording data from Debden covered most of the flight from Copenhagen and included airspeed and altitude data in addition to positional information (see Figure 5).

The aircraft was cruising at FL410 before beginning a descent at about 1757 hrs. The Mode S IAS, which had been stable at 220 kt, then began to reduce. However, both the Mode S and radar groundspeeds, which had been around 390 kt, began to increase. Mode S IAS continued to reduce until 1804:30 hrs when, passing through approximately 33,000 ft, having decelerated to 50 kt, the recording suddenly reduced to zero. At the same time, the recorded groundspeed was about 430 kt. Approximately 30 seconds later, with the aircraft passing through 31,000 ft, the altitude indication also suddenly reduced to zero. The recorded groundspeed was 450 kt which then subsequently reduced to approximately 350 kt. About two minutes later the Mode S IAS and altitude information returned showing the aircraft passing 20,000 ft at 270 kt IAS. The airspeed and altitude information appeared normal for the remainder of the flight.

Heading and roll information from the Mode S recording indicated that the AHRS was operating correctly throughout.

Recent maintenance history

The last scheduled maintenance inspection was a 1,200 hour check carried out on 2 June 2008. Prior to the flight on 7 August 2008 the standby battery had been replaced.

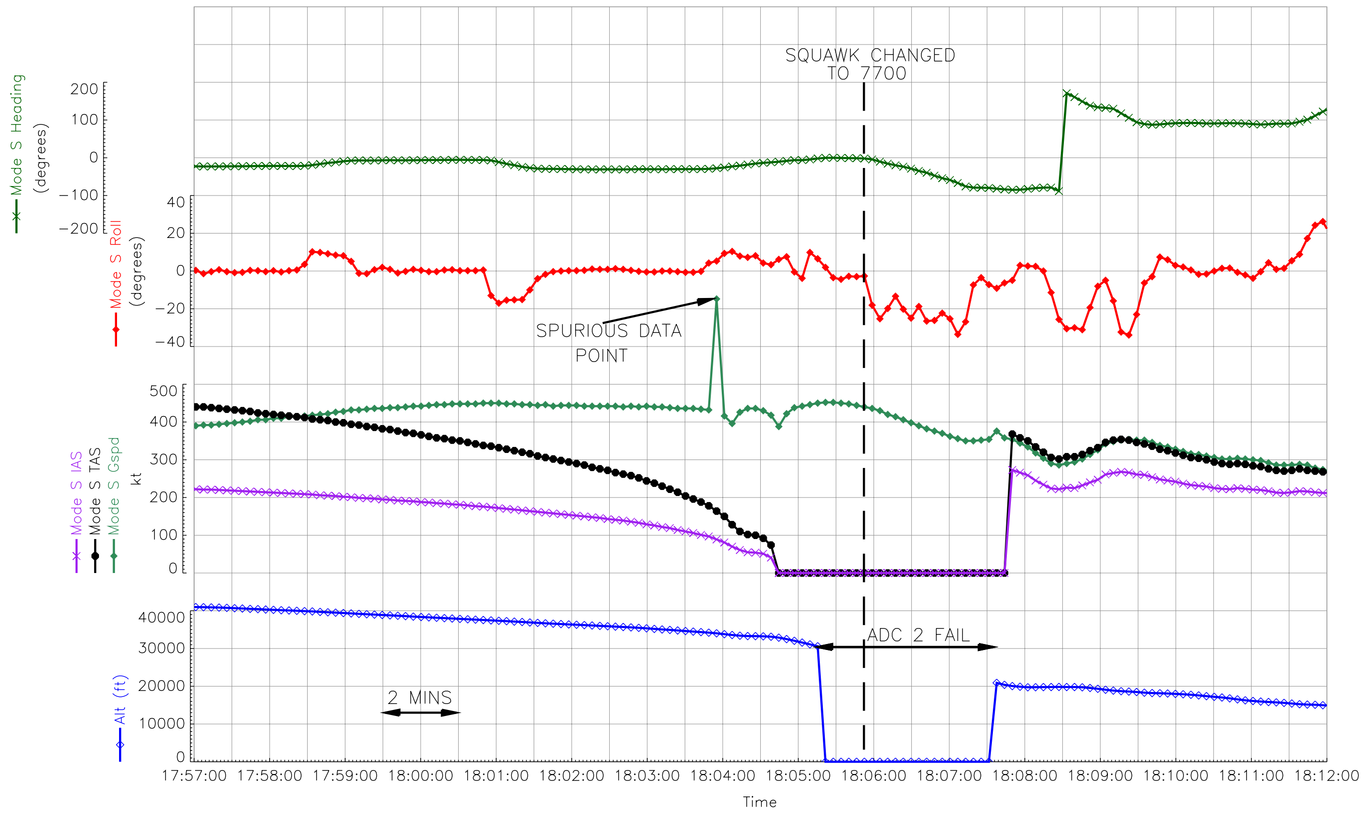

Figure 5

Modes S information

G-FRYL's operator's aircraft are mostly parked outside while on the ground. The aircraft last flew on the evening of 31 July and since then had been parked outside, facing south. Consequently its right hand side was more exposed to the prevailing westerly wind.

The standard pitot probe cover is a vinyl/fabric construction although the operator had been trialling a woven Kevlar pitot probe cover which is claimed to be water repellent. Prior to the incident flight one of the alternative Kevlar pitot covers had been fitted on the right pitot probe, while the left probe retained one of the standard covers (see Figure 6)

Aircraft examination and testing

When the AAIB was informed of this serious incident, extensive trouble-shooting by the maintenance organisation and multiple component removals had already taken place.

There had been three separate checks of the pitot/static drains. Firstly, the drain caps were removed and the drain cocks operated; no water came out. Subsequently, the maintenance organisation carried out a one-way purge of both systems with nitrogen; only one small drop of water came out. The system was then purged both ways with nitrogen and approximately one tablespoon of water (15 ml) was removed. The maintenance organisation also reported that when the pitot/static tubing was dismantled there was a small amount of water around some of the joints, described as "similar to condensation".

Left pitot probe and AOA vane below
Standard cover

Right pitot probe and AOA vane below
Kevlar cover

Figure 6

Types of pitot probe cover

All the avionics functioned normally during testing and a calibration was carried out on the ADS which was within limits.

A ground test was performed with separate pressure test sets connected to the left and right pitot probes, to simulate pitot and static pressures and a blockage in the right pitot line. A similar scenario to that on the incident flight was followed; at a stable altitude of 41,000 ft the 'blockage' was applied. The static pressure was then increased, to simulate a continuous descent of around 1,000 ft/min, and, although the pitot pressure from both test sets was not altered, it was noted that from a nominal start value of 220 kt, the airspeed indication from ADC2 and on the standby airspeed indicator began to reduce. As the airspeed indication passed through 50 kt the autopilot disengaged and at about 26,000 ft the ADC red IAS, HDG and ALT fail messages appeared on PFD2. The automatic pitch trim fail caption also illuminated. Similar fault messages to those from the incident flight were noted on the MDC.

It was also demonstrated that with the PFD1 selected to ADC2, the Mode S transponder altitude output is then supplied by ADC2. When ADC2 failed, the altitude information was lost and the FMS timer was reset.

Both ADCs and the right pitot/static probe, which supplies the standby instruments, were removed from G-FRYL for further examination.

The aircraft was returned to service with replacement ADCs, standby ASI and right pitot/static probe and a test flight carried out. During the test flight the stall 'tape' appeared on PFD2 and the stick shaker activated. The right stall system circuit breaker was pulled and the aircraft landed without further problem. During investigation following this incident the replacement ADC1 failed. This unit was replaced and the aircraft again returned to service without further problems.

Previous Occurrences

The commander commented that in the previous two years he had experienced 9 events involving unusual airspeed indications, most of which he believed were associated with ADC2. Some of these he attributed to flight in icing conditions. He noted that the indications he saw on this occasion were similar to those observed during a previous ADC failure on another company aircraft of the same type.

There were two previous instances of altitude indication anomalies on the Premier 1 reported on the CAA MOR database. There was an occurrence involving G-PREI, operated by the same company, which, in March 2007, experienced an altitude comparator warning. During investigation water was found in the pitot/static line. Secondly, also in March 2007, an occurrence on G-FRYL was reported when the No 2 altimeter was 'unstable and out of limits for Reduced Vertical Separation Minima (RVSM)'. Following investigation it was reported that a 'significant amount of water was drained from the right static line'.

As a result of these two MORs, the operator's maintenance organisation checked another four Premier 1 aircraft and found significant amounts of water in the pitot/static systems on each aircraft. It was noted that water could remain in the system after operating the drains and it was found necessary to purge the system with nitrogen for complete removal. The operator also chose to introduce the use of the alternative Kevlar pitot probe cover.

The aircraft manufacturer was aware of an event on another Premier 1, C-GYPV, in May 2006. At FL400, in the cruise, the pilot noted an altitude comparator flag displayed on PFD2 and an airspeed spilt between the No 1 and No 2 systems. He reported that the No 2 airspeed and altitude indications eventually went blank, and that the standby airspeed and altitude needles "quit moving". Shortly after this the No 1 airspeed and altitude information disappeared. The pilot declared an emergency and commenced a descent. Passing through FL040, valid information returned to the No 1 air data system. The aircraft landed safely. Water was removed from both the right and left pitot/static systems. Of significance was that the aircraft had remained on the ramp, prior to departure, in a rainstorm for approximately 2 minutes with the pitot covers removed.

The aircraft manufacturer has been unable to replicate the reported condition of water in the pitot/static system by any means other than directly injecting water into the pitot probe. Flight testing was conducted with pitot heat switched on and off, and in moderate to heavy precipitation. This did not result in any pitot/static anomalies or trapped water being found.

Further testing

Both ADCs from G-FRYL were returned to the manufacturer for examination and testing. A field performance test was performed on both units. This checked the accuracy of each unit's altitude and airspeed outputs and also performed a sensor leak test. No fault messages were recorded. Both units were also inspected internally, nothing abnormal was observed and there was no evidence of moisture ingress.

The right pitot/static probe was also returned to the manufacturer for examination and testing. Visual and X-ray examination showed that the probe was in good condition and no debris was found in the pitot inlet. The probe heater was tested and the heater current was in accordance with the requirements for the production acceptance test procedure; no faults were found.

Safety action

Since the incident the manufacturer has issued Premier I/IA Model Communiqué #23, dated June 2009, which references the manufacturer's Mandatory Service Bulletin (MSB) 34-3972, entitled *NAVIGATION - MODIFICATION OF #2 AIR DATA COMPUTER PLUMBING*. The MSB requires a modification to the right pitot/static system, which removes the plugs on both drain points and introduces cotter pins in both valves to prevent the valves from being locked open unintentionally.

In addition to the MSB, changes to the Airplane Flight Manual (AFM) have been introduced. They include a *LOSS OF ALL AIRSPEED INDICATION (ADC1, ADC2 AND STANDBY AIRSPEED)* procedure in the Section 3 *EMERGENCY PROCEDURES* and a revised *AIRSPEED (IAS) COMPARATOR ILLUMINATED* procedure in the Section 3A *ABNORMAL PROCEDURES*. There is also a *NOTE* in the *PREFLIGHT INSPECTION* in the Section 4 *NORMAL PROCEDURES* which calls for subsequent maintenance action when

> *'the airplane has been parked outside, exposed to visible moisture, and there is any suspicion one or both of the Pitot-Static Tube covers may have been dislodged or missing.'*

The *EXTERIOR INSPECTION* includes a requirement to drain and secure the standby pitot-static drains.

Analysis

Loss of airspeed information

The sequence of events during this incident began with the IAS comparator warning, indicating a mismatch in IAS sensed by the two ADCS. The loss of standby airspeed information, for which the only source is the right pitot/static system, indicated a problem with the right pitot system.

Subsequent testing on the aircraft reproduced the events which occurred during the incident. With a blockage introduced in the right pitot line, and the static pressure increased, with no change in pitot pressure, the difference between the static and the pitot pressure, ie the dynamic pressure and thus the indicated airspeed, reduced. The indications on the flight deck were a reduction in indicated airspeed data from ADC2 and the standby ASI. As the static pressure increased to a value greater than the blocked pitot pressure, ADC2 and the standby airspeed indicator would have sensed a negative airspeed. The ADC would identify this as an invalid input and would 'fail' at this point, displaying the three red flags on the EFIS. The faults recorded in the MDC during the test replicated those recorded during the incident.

The return of valid air data information as the aircraft descended supports the theory that the blockage was caused by ice, which then melted as the outside air temperature rose. Subsequent investigations found no faults within either of the ADCs or the right pitot/static probe.

There have been previous incidents on the Premier 1 of moisture ingress leading to loss of air data information, and temperatures in the right avionics bay can be sufficiently low to allow any moisture present to freeze. This operator has reported that the operation of the pitot and static drains is not always sufficient to clear moisture, and that the systems can require purging to ensure that all moisture is removed. This was the case following this incident, where no water was found in the pitot and static lines by operating the drains; however, some water was found by purging.

The manufacturer's Communiqué #23, issued in June 2009, introduced a pre-flight check to operate the standby pitot-static drains. However, operation of the drains is not always sufficient to clear the moisture. Therefore, the following Safety Recommendation is made:

Safety Recommendation 2009-109

It is recommended that the Federal Aviation Administration should require Hawker Beechcraft Corporation to review and modify, if necessary, the design of the pitot and static drainage on the Premier 1 aircraft in order that its pitot/static systems cannot become blocked as a result of trapped moisture.

Loss of EFIS displays

During the testing it was not possible to recreate that part of the sequence of events in which the pilots reported the blanking of all three displays.

At 1803 hrs the Autopilot and Yaw damper disengaged. Analysis of the fault codes recorded by the MDC indicates that this was probably due to the difference in the airspeeds sensed by the two ADCs. The failure of ADC2 at 1805 hrs, which was supplying air data to both PFDs by that time, would have resulted in the three red flags being displayed on both PFDs and the loss of all air data information. The Mode S data indicated that there was no loss of altitude information, which should have continued to be displayed on the PFDs. The co-pilot recalled that, initially, the compass rose presentation and artificial horizon remained visible on both PFDs.

Use of the reversionary display control would have resulted in the momentary blanking of PFD1 and MFD, as the displays were interchanged. This was recorded on the MDC at 1809 hrs as PFD NO OUTPUT and at 1810 hrs as MFD NO OUTPUT. When the displays reappeared, during the descent, the commander reported that the composite PFD/MFD presentation appeared on the MFD, indicating that the DISPLAY/NORM reversion switch was selected to MFD. This would have resulted in a blank screen on PFD1. PFD2, which is unaffected by operation of the display reversion switch, should have been displaying information throughout.

All three displays are supplied from different electrical buses supplied by two electrical generators, a main battery and a standby battery. A single electrical failure could not cause the loss of all three displays and would have resulted in additional warnings being evident to the crew, with related failure messages being recorded on the MDC. The Mode S recording shows that AHC1 was operating normally throughout the incident, thus indicating that there was no power loss on the left electrical bus.

Abnormal procedures

Following the loss of information on all three electronic flight displays the flight crew used the standby instruments to conduct the flight safely until this information was restored, and they did so without the use of the *Pilot Checklist*. The checklist included several relevant procedures. The item entitled *'Airspeed (IAS) Comparator Illuminated'* provided information about the initial amber IAS annunciation on both PFDs. The following procedures are relevant to the subsequent loss of information from both PFDs and the MFD:

1. *'Electronic Flight Display Failure'*
2. *'Single Air Data Computer Failure'* or
3. *'Dual Air Data Computer Failure'*

Procedure (1) refers to failure of the screen itself, where the display is entirely blank. In this event, however, some information, such as failure flags, was presented on each of the screens. Having identified an ADC failure as a possible cause of the airspeed anomaly the crew carried out both actions in (2), namely operating the ADC reversion switch and opening the STALL WARN CB. However, by not consulting the checklist they missed an opportunity to prepare for the associated failures, such as loss of flight control functions and pressurisation. In the event, pressurisation was not lost.

Meteorological considerations

The commander believed that, at all times, the flight remained clear of cumulonimbus cloud. The report from the Met Office suggests, however, that the layer of cloud in which the aircraft flew immediately prior to the event may have contained an embedded cumulonimbus anvil. The Met Office report also highlighted the risk of encountering severe turbulence downwind of cumulonimbus.

Summary

The loss of airspeed information was caused by a blockage in the right pitot system due to an ingress of moisture, which then froze. Similar incidents had been reported previously. The flight crew also reported the loss of all information from the three EFIS displays. It was not possible to recreate this situation during subsequent tests on the aircraft and the loss could not be explained.