INCIDENT

Aircraft Type and Registration:	Embraer EMB-145EP, G-RJXA
No & Type of Engines:	2 Rolls-Royce AE 3007A turbofan engines
Year of Manufacture:	1999
Date & Time (UTC):	10 May 2007 at 1215 hrs
Location:	In the climb, 20 nm south-west of Aberdeen Airport
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 4 Passengers - 16
Injuries:	Crew - None Passengers - None
Nature of Damage:	No 1 IC-600 computer unserviceable
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	36 years
Commander's Flying Experience:	5,000 hours (of which 3,000 were on type) Last 90 days - 112 hours Last 28 days - 39 hours
Information Source:	AAIB Field Investigation

Synopsis

Approximately four and a half minutes after takeoff from Aberdeen (Dyce) Airport, while in the climb passing FL116, the Engine Indicating and Crew Alerting System (EICAS) caution and the 'AUTOPILOT DISCONNECT' warnings sounded. At the same time the commander's Primary Flight Display, Multi Function Display and EICAS went blank and smoke appeared from the left side of his seat. After the crew declared an emergency and completed limited cockpit drills, G-RJXA returned to Aberdeen, where it landed within 15 minutes without further incident. The aircraft's No 1 Integrated Avionics Computer (IC-600) had failed.

History of the flight

G-RJXA was on a scheduled flight from Aberdeen (Dyce) Airport to Manchester Airport. This was the operating crew's fourth and final sector of the day. The co-pilot was PF for this sector.

The start up, takeoff and initial climb proceeded without event. Approximately four and a half minutes after takeoff, while in the climb passing FL116, the Engine Indicating and Crew Alerting System (EICAS) caution and the 'Autopilot (AP) disconnect' warnings sounded. At the same time the commander's Primary Flight Display (PFD), Multi Function Display (MFD) and EICAS went blank and smoke appeared from the left side of his seat. The flight deck crew described this as a "smoky haze" and they smelt an "acrid burning smell". After the PFD,

MFD and EICAS went blank a red 'X' was displayed on the screens. The Radio Management Unit (RMU) had also changed to an Engine display. The commander declared an in-flight emergency to ATC, and a return to Aberdeen was initiated. At the time the aircraft was in IMC and the co-pilot flew the aircraft manually.

Soon after the descent was initiated, the commander said to the co-pilot that he was selecting the AUTO/MAN switch, on the pressurisation control panel at the rear of the centre pedestal, to MAN (MANUAL) he then rotated the manual controller to the 1 o'clock position. He did this without referring to the Quick Reference Handbook (QRH).

Three minutes after the start of the incident the commander gave the senior member of the cabin crew a NITS[1] brief, using the interphone, and enquired whether there was any smoke in the cabin. She replied that there was a strong smell at the front of the passenger cabin. The commander then said that they expected to land in approximately 10 minutes and asked her to try and find the source, if she had time. The commander then said to the co-pilot "FORGET ALL THE CHECKS THERE'S NO TIME". He added there was only a little smell of smoke and "I'M HAPPY TO CONTINUE WITHOUT MASKS ARE YOU?". The co-pilot agreed. Approximately 30 seconds later the commander said "IT STINKS IN HERE" adding they had to land as soon as possible.

Two minutes later the cabin crew contacted the commander and said that there was only a smell of smoke and a "smoky haze" at the front of the passenger cabin. The commander informed them that he had turned the No 1 air conditioning pack OFF. During this exchange the commander had to interrupt the cabin crew in order to acknowledge and action instructions from ATC.

Radar vectors from ATC put the aircraft on a closing heading for a position 5 nm out on the runway centreline and it broke cloud at approximately 1,500 ft amsl. Once below cloud the commander quickly became visual with Runway 34, but as the co-pilot could not see it; the commander took control. After the Landing checklist was completed, the commander asked the co-pilot to try to contact the cabin crew, at approximately 300 ft aal, in order to see how the smoke was in the cabin; they did not respond.

The aircraft landed on Runway 34, 15 minutes after the incident started, with the red 'X' still on the commander's PFD, MFD and EICAS. The aircraft vacated Runway 34 onto Runway 32, where it was brought to a stop and an evacuation initiated with the AFRS in attendance. All passengers and crew vacated the aircraft without incident.

At no time during the incident did the crew put on their oxygen masks, instruct the cabin crew to put on their oxygen masks, deploy the passenger oxygen masks or refer to the QRH. Throughout the approach, to Aberdeen, the commander handled all the communication with ATC and the cabin crew.

Quick Reference Handbook (QRH)

Smoke checklists

There are three checklists associated with smoke, in the QRH, for this operator's EMB 145 aircraft. They are 'Air Conditioning Smoke', 'Electrical System Fire Or Smoke' and 'Cabin Fire Or Smoke'.

Footnote

[1] A 'NITS' brief is given to the senior member of the cabin crew, by the operating crew, in the event of an incident or emergency. NITS stands for Nature [of emergency], Intentions, Time [available before landing] and Special instructions e.g. whether there will be a need to evacuate upon landing.

After the description of the condition, for the use of the checklist, the following four actions are common to all three drills. They are boxed to indicate that they are Immediate Actions (IA), that is, items to be done from memory:

Crew Oxygen Masks.....DON, 100%
Smoke Goggles.....DON
Crew Communication.....ESTABLISH
Recirculation Fan.....PUSH OUT

The following checklist is to be done to remove smoke once the source has been isolated (Figures 1a and 1b):

SMOKE EVACUATION

Condition: Smoke or odor inside the cabin and/or cockpit requiring removal.

Cockpit Door ..... CLOSE
Recirculation Fan..... PUSH OUT
Gasper Fan ..... PUSH OUT
Pressurization Manual Controller ..... 1 O'CLOCK POSITION

..... WAIT 15 SECS
Pressurization Mode Selector ..... PUSH IN (MAN)
Passenger Oxygen ..... AS REQUIRED

CONTINUES ON NEXT PAGE

Figure 1a

EMERGENCY/ABNORMAL PROCEDURES

Smoke

CONTINUED FROM PREVIOUS PAGE

DESIRED EVACUATION RATE?

Fast

Normal

Pressurization Manual Controller .....AS REQUIRED

Turn the controller clockwise towards UP to adjust desired evacuation rate.

END

Pressurization Manual Controller .....UP
Packs 1 and 2.....PUSH OUT
Bleeds (at least one) ....PUSH IN
Altitude .....10'000 FT OR MEA, WHICHEVER IS HIGHER

Recover cabin pressure as soon as smoke has been cleared.

EMERGENCY DESCENT Procedure (NAP-6) ....AS REQUIRED

END

Figure 1b

Display and IC failures

The following is the Display Failure checklist, for the symptoms the commander experienced (Figure 2):

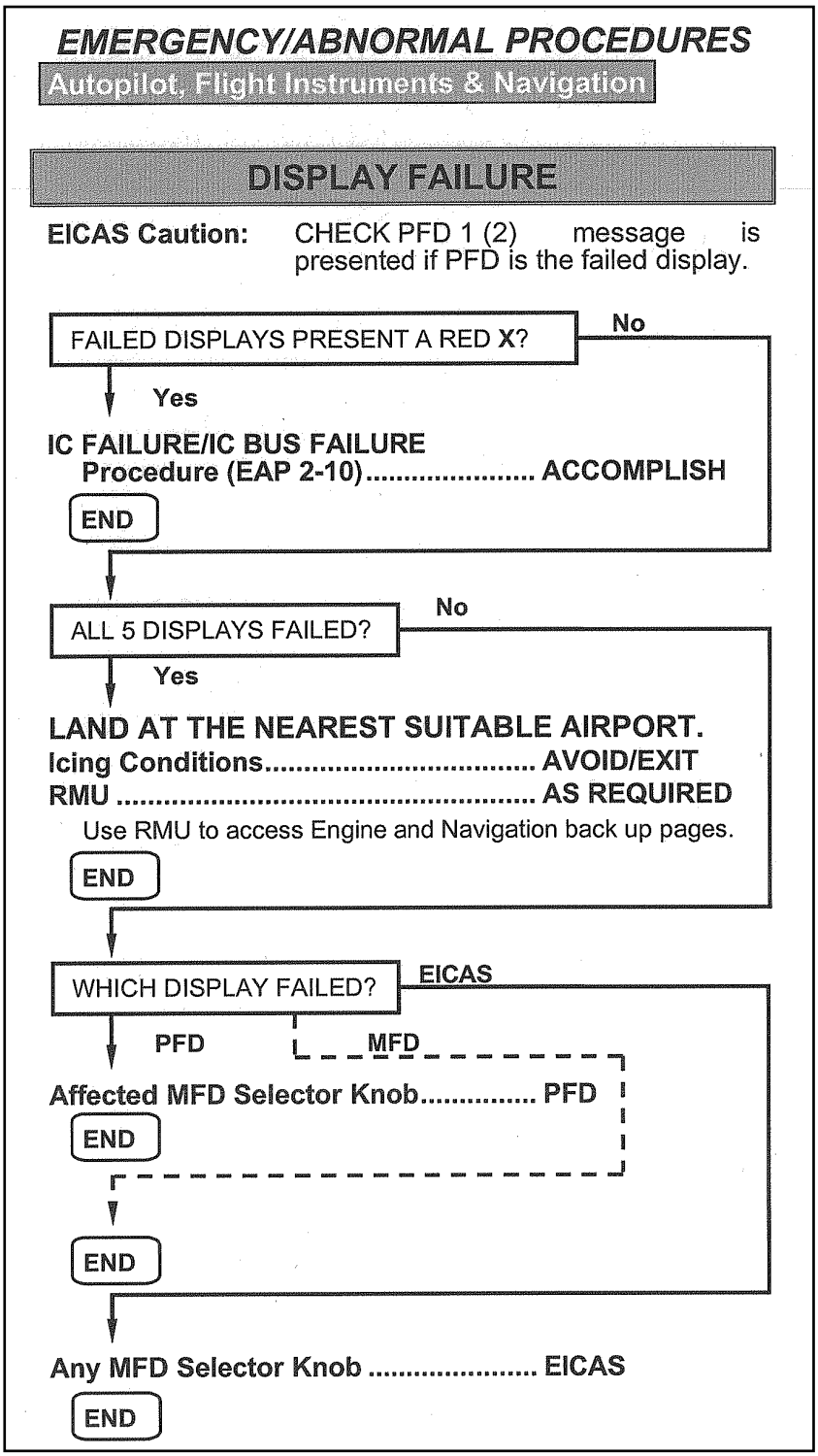

Figure 2

The following is the 'IC Failure' drill to which the 'Display Failure' checklist directs the crew (Figure 3):

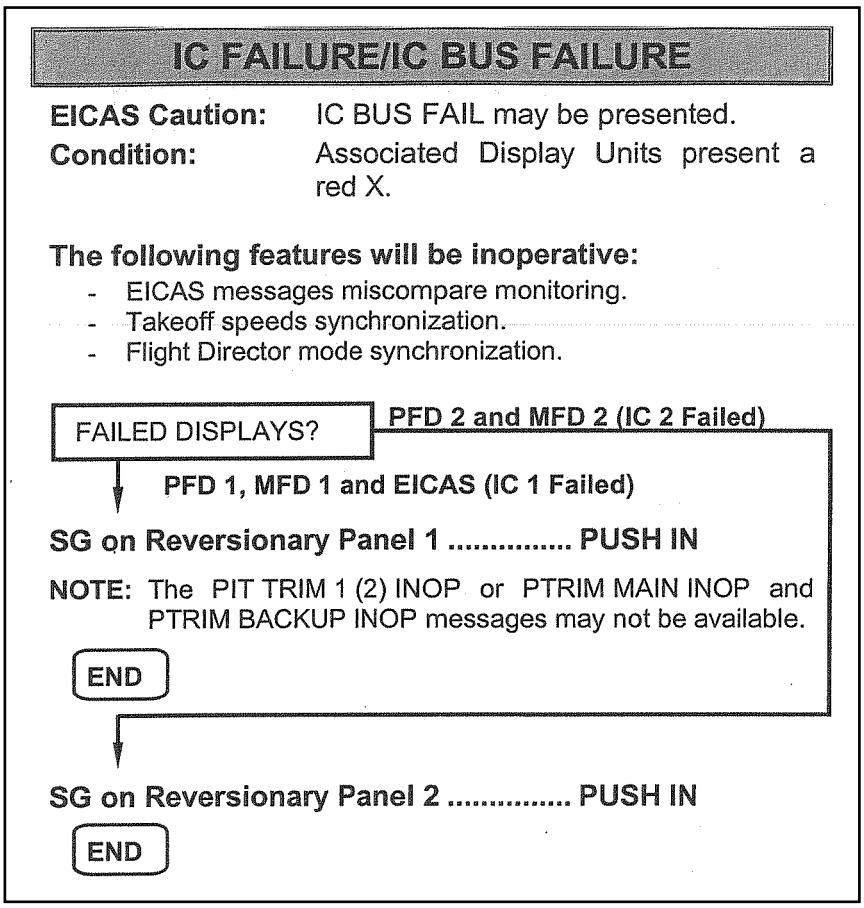

Figure 3

Weather information

The METAR for Aberdeen Airport, issued at 1220 hrs, reported that the wind was from 020º at 9 kt, there were FEW clouds at 900 ft aal and BROKEN clouds at 1,000 ft aal, the air temperature was 8ºC, the dew point was 7ºC and the QNH was 995 mb.

Crew's comments

Commander's comments

The commander had been with the operator since September 2000. He had a total of 5,000 hrs, 3,000 of which were on type, with 1,500 hrs in command.

The commander commented that he did not put his oxygen mask on as there was only a small amount of smoke. After the smoke had cleared, and having discussed it with the co-pilot, he did not want to put his oxygen mask on as he was concentrating on monitoring the co-pilot, thought it might "hamper things" and did not want to cause undue concern to the passengers in the event of doing an announcement with the mask on. He added that if the smoke returned, or if he felt "giddy", he would have put on his oxygen mask.

The commander said that a training captain had demonstrated the smoke removal Immediate Actions

to him during a simulator check and had told him that this was the best way to deal with smoke events in the cockpit.

Co-pilot's comments

The co-pilot had been with the operator since January 2006. He had a total of 2,200 hrs with 700 hrs on type.

The co-pilot commented that he did not call for the appropriate QRH checklist as he was concentrating on manually flying the aircraft. Additionally, he was worried his screens might go blank too.

He added he had done some screen failure training in the simulator but had not done any 'IC failure' training.

CAP 768 - Guidance Material for Operators

Chapter 15, Emergency Procedures and Oxygen Requirements, of CAP 768 contains the following:

> ***'2 Use of Oxygen***
>
> ***2.1 Smoke and Fumes in the Flight Deck***
>
> *2.1.1 The first action in the event of smoke or fumes in the flight deck should be for the flight crew to don oxygen masks and establish communications. If during flight it appears that both pilots are suffering from some form of incapacitation or that one pilot appears to be in any way incapacitated for no obvious reason, then the flight crew should don oxygen masks without delay.*
>
> ***2.1.2 Operations manual procedures should contain detailed instructions to crews on the necessity to use oxygen masks at 100% whenever contamination is present or suspected and the need to establish communications by the appropriate switch selections. In addition, cabin crew should monitor the flight deck, but this should not be to the detriment of other emergency procedures such as dealing with cabin smoke or fires, especially where only one cabin crew member is carried.*** *Incapacitation procedures should be practised regularly during recurrent training and case based studies are discussed at joint flight deck/cabin crews' safety training. The potential for a smoke/fumes event to adversely affect the subsequent operating effectiveness of the flight or cabin crew must be considered.* ***Flight crews should be aware that the first action in the event of smoke or fumes in the flight deck should be to don oxygen masks and establish communications.' (****AAIB Bold type****)***

This guidance is contained in Part B, Section 3.3 of the operator's Operation Manual.

The operator commented that all crews should complete the IA stated in the QRH at the first signs of smoke and should refer to the QRH before completing any complex checklist such as smoke evacuation.

Crew training

During their initial conversion and recurrent training in the simulator, crews regularly practise operating the aircraft with oxygen masks on during an appropriate emergency. Additionally, they practise monitoring the PF, while the aircraft is being flown manually, at the same time as completing checklists and wearing oxygen masks during high workload scenarios.

Flight Recorders

General

The aircraft was equipped with a flight data recorder (FDR) and a cockpit voice recorder (CVR), capable of recording a minimum duration of 25 hours of data and

120 minutes of audio respectively. The architecture of the FDR system was such that the majority of recorded parameters were acquired from the No 1 IC-600. In the event of the IC-600 failing, the FDR would continue to operate, but all associated parameters would stop being recorded, with no provision for alternate data sources. Unaffected FDR parameters were: tri-axial accelerations, control column and control wheel positions, rudder pedal positions, brake pressures and the clock.

Incident data

Both the FDR and CVR were removed from the aircraft and successfully replayed at the AAIB. The CVR provided audio for the entire flight; from pre-flight checks to final shutdown. All the recorded parameters were available from the FDR, until the failure of the No 1 IC-600. This occurred at 1154 hrs as the aircraft was climbing through FL116 and the aircraft had been airborne for about four and a half minutes. The aircraft landed at about 1209 hrs, with the FDR and CVR stopping about one minute later as the aircraft was shut down.

Engineering

System description

The aircraft is fitted with two IC-600 computers which are the primary components of the integrated avionics system. They exchange information with all other components, perform a cross-check with each other and manage all the information for the flight displays. Each IC-600 unit has a symbol generator and flight director. The No 1 IC-600 has an additional autopilot function.

There are two PFDs, two MFDs and one EICAS display. In normal operation the left PFD, MFD and the EICAS display are driven from the No 1 IC-600 computer, and the right PFD and MFD driven by No 2 IC-600 computer. In the event of an IC-600 computer failure, the corresponding PFD, MFD and EICAS displays will go blank and the No 1 Radio Management Unit (RMU) display on the control pedestal forward panel will automatically switch over to display the ENGINE BACKUP 1 page.

A reversionary panel is located outboard of each PFD. This is used to select the format of the display for the MFD and select the source of the Air Data Computer (ADC), Attitude and Heading Reference System (AHRS), and the IC-600 signal generator for the PFD and MFD. By pressing the symbol generator button (SG) the alternate IC-600 is used as the source for the displays.

Engineering investigation

The operator determined that the smoke had been caused by the failure of the No 1 IC-600 computer. Two circuit breakers (CBs) associated with the No 1 IC-600 computer were found to have 'popped'. An IC-600 Input Bus Fail message was recorded at 11:54:40 hrs by the Central Maintenance Computer (CMC). The unit was replaced, the aircraft wiring was checked, and the aircraft was returned to service and operated without further incident.

The IC-600 unit, Part No 7017000-82340 Serial No 01013899, which had been removed, was taken to the manufacturer's facility in the UK and then sent for further examination in the USA. The failure was traced to a ceramic capacitor on the power supply A1 Circuit Card Assembly (CCA) which is one of four filter capacitors used to eliminate noise on the 150 VDC input. The capacitor is not part of an active circuit and its failure alone would not affect unit operation.

There are two possible failure modes for a capacitor: 'open' or 'shorted'. Had the capacitor shorted, the power supply over-voltage protection would have triggered and an immediate shutdown of the IC-600 would have occurred.

The failure mode in this case indicates the capacitor failed 'open' and the 150 V supply line would have continued to 'fuel' the open capacitor causing it to overheat, damaging the power supply card and adjacent analogue interface circuit card, and emitting the smoke detected on the flight deck. Eventually, as the damage developed, the over-voltage safety mechanism was triggered and the unit shut down as indicated by the blanking of the PFDs.

The unit manufacturer considers that this was an isolated component failure event among the combined millions of flight hours on the IC-600 product line and no similar failure within an IC-600 unit has been recorded.

Previous events

An event occurred to another Embraer EMB-145EP, G-ERJG, on 20 February 2005 which also resulted in the loss of flight displays and the EICAS. Subsequent investigation by the manufacturer found that a transistor on the A5 Autopilot CCA had failed and concluded that this was an isolated incident.

The aircraft manufacturer provided information regarding the current reliability of the IC-600 unit. The 'target' Mean Time Between Unscheduled Removals (MTBUR) was 3,500 flight hours (FH). The average MTBUR achieved worldwide was 5,400 FH; the average MTBUR for this operator was 1,715 FH.

Analysis

This incident was as a result of a No 1 IC-600 failure. It appeared, initially, to have been reasonably handled, in that the aircraft was landed and evacuated within 15 minutes of the initial appearance of smoke. However, upon closer analysis of the procedures employed by the crew during the recovery to Aberdeen, a number of important omissions became apparent that could have had very serious consequences.

Crew's actions

The crew did not don their oxygen masks and establish communications at the first sign of smoke, as required in the operator's Operations Manual and the aircraft's QRH. They should have done this irrespective of the amount of smoke present. Had they done this the crew would have been protected from any invisible gases that might have been present during the recovery (the smell persisted for some time). This potentially endangered themselves, the cabin crew and the passengers. If the crew subsequently felt "giddy" they might have become incapacitated and thus been unable to put on their masks without assistance. Once the smoke started to appear, they had no way of knowing whether it would stop quickly or continue to fill the cockpit.

The commander attempted to do the 'Smoke Evacuation' checklist from memory and only completed two items, from the middle of the checklist. He informed the co-pilot that he was doing it, rather than discussing with him whether it was a sensible course of action, thus showing poor Crew Resource Management. Having done this, he did not refer to the QRH to clarify if these actions were correct. The 'Smoke Evacuation' checklist is to be used once the source of the smoke has been identified and extinguished. The aim of the checklist is to increase the airflow through the aircraft so as to evacuate the smoke overboard. If the smoke was still being generated the increased airflow could have fanned the source and exacerbated the situation.

Throughout the descent, while the commander was PNF, he handled all communications with ATC and the cabin crew. Had he given control of this communication to the co-pilot, he would have reduced his workload and probably have given himself time to refer to the QRH.

There was no fault diagnosis of the commander's blank

screens. As a result the Display Failure/IC-600 failure checklist was not completed. Had the commander completed this checklist he would have had his PFD, MFD and EICAS restored to him. This would have made it much easier for him to monitor the co-pilot's flying. As they were in IMC, and he landed the aircraft using the standby instruments, this would have been prudent. The commander's request to the co-pilot to contact the cabin crew at 300 ft aal was inappropriate. As the commander landed the aircraft using the standby instruments, the co-pilot should have been closely monitoring the commander during the final stages of the approach.

The crew correctly believed, during the later stages of the descent, that the smoke had stopped being generated, despite the lingering smell. Therefore they had as much time as they needed to complete all the necessary checklists before landing the aircraft.

The crew's actions should have been to don their oxygen masks, establish communications, complete the 'Air Conditioning Smoke' or 'Electrical System Fire Or Smoke' checklist, as they saw appropriate, then the 'Display Failure' checklist, followed by the 'Smoke Evacuation' checklist, if smoke was still present. Once these were complete they could then take their masks off, one at a time, to make sure there were no longer noxious fumes present, or land with their oxygen masks on.

Crew training

Crews train in the simulator, during appropriate situations, with oxygen masks on, so that when it comes to a real incident they are able to operate the aircraft unhindered while wearing them.

The correct use of the QRH checklist is instilled into crews during their initial and recurrent training. These checklists are carefully developed and tested by the aircraft manufacturer and are designed to keep the crew and the aircraft safe. If crews create their own procedures they run a risk of going into unknown situations, for which they do not have training or QRH checklists, that could have serious consequences.

Safety action

Following this incident, the operator conducted a series of simulator exercises with the operating flight crew. As a result, the operator is reviewing guidance on the donning of oxygen masks and other sections of their operating procedures.