الهيئة العامة للطيران المدني
GENERAL CIVIL AVIATION AUTHORITY

United Arab Emirates

Air Accident Investigation Sector

Incident

- Summary Report -

AAIS Case Nº AIFN/0010/2015

Failure of the Integrated Primary Computer

Operator: Rotana Jet
Make and Model: Embraer EMB-145MP
Nationality and Registration: The United Arab Emirates, A6-RRA
Place of Occurrence: Inflight
State of Occurrence: Oman
Date of Occurrence: 12 September 2015

Investigation Objective

This Investigation is performed pursuant to the United Arab Emirates (UAE) *Federal Act 20 of 1991*, promulgating the *Civil Aviation Law, Chapter VII-Aircraft Accidents*, Article 48. It is in compliance with *Part VI, Chapter 3 of the UAE Civil Aviation Regulations*, in conformity with *Annex 13 to the Convention on International Civil Aviation,* and in adherence to the *Air Accidents and Incidents Investigation Manual*.

The sole objective of this Investigation is to prevent aircraft accidents and incidents. It is not the purpose of this activity to apportion blame or liability.

Investigation Process

The occurrence, involving Embraer EMB-145MP passenger Aircraft, registration A6-RRA, came to the attention of the AAIS through routine review of the General Civil Aviation Authority (GCAA) mandatory reporting system; Reporting of Safety Incidents (ROSI).

After the initial investigation, the occurrence was classified as 'incident'. Accordingly, the AAIS notified the Brazilian Centro de Investigação e Prevenção de Acidentes Aeronauticos (CENIPA), as Brazil is the State of Manufacture, and also notified the International Civil Aviation Organization (ICAO).

This Investigation was limited to the events leading up to the occurrence and no in-depth analysis of non-contributing factors was undertaken.

This Summary Report does not resort to any proof production procedure for the determination of civil or criminal liability, and is issued in accordance with paragraph 3.1, *Annex 13 to the Convention on International Civil Aviation*, which was incorporated in the UAE legal system.

The use of this Summary Report for any purpose other than that of preventing future accidents, may lead to erroneous interpretations and conclusions.

All AAIS reports are publicly available at:

http://www.gcaa.gov.ae/en/epublication/pages/investigationreport.aspx

Notes:

[1] Whenever the following words are mentioned in this Report with the first letter Capitalized, it shall mean:

- (Aircraft) - the aircraft involved in this incident
- (Investigation) - the investigation into this incident
- (Incident) - this investigated incident
- (Report) - this incident investigation Final Report.

[2] Unless otherwise mentioned, all times in this Report are Coordinated Universal Time (UTC), (UAE Local Time minus 4).

[3] Photos used in this Report are taken from different sources and are adjusted from the original for the sole purpose of improving the clarity of the Report. Modifications to images used in this Report are limited to cropping, magnification, file compression, or enhancement of color, brightness, contrast or insertion of text boxes, arrows or lines.

Factual Information

History of the Flight

On 12 September 2015, at approximately 1500 UTC, an Embraer EMB-145MP, operating scheduled flight number RJD123, took off from Abu Dhabi International Airport, UAE, at 1505UTC bound for Salalah International Airport, Oman, with two flight crewmembers, one cabin crewmember, and 11 passengers onboard.

The flight continued normally until the top of climb at flight level (FL)360 when the primary flight display (PFD)1, the multi-function flight display (MFD)1 and the engine indicating and crew alerting system (EICAS), went blank and displayed a red cross (X) along the diagonal.

The flight crew stated that from their experience and initial training, they believed that the cause of the blackout of the screens was the failure of No.1 integrated computer (IC-600).

The Commander, who was the pilot monitoring (PM), pushed the symbol generation (SG) button located on the No.1 reversionary panel which then resulted in the other IC-600 (No.2 IC-600) generating the indications for the PFD1, MFD1 and EICAS. In addition, IC BUS FAIL message was displayed on the EICAS.

The display failures were accompanied by autopilot disengagement, accordingly the pilot flying (PF), who was the copilot at the time of the event, flew the Aircraft manually until landing.

Soon after, the crew sensed, with no accompanying sign of smoke, an electrical odor which they suspected to be coming from the IC-600. Because of the increasing odor, the unidentified source, and the accompanying No.1 IC-600 malfunction, the Commander assessed the situation for the potential development of an electrical system fire.

The Commander decided to initiate the memory items[1] for *Electrical System Fire or Smoke* (appendix 1) and both crewmembers donned their emergency oxygen masks.

Flight crew communication was normal with their oxygen masks on and the copilot continued to fly the Aircraft manually, as the Commander broadcast a MAYDAY to Muscat Airport, Oman.

The Commander then reviewed the *Electrical System Fire or Smoke* procedure from the *Quick Reference Handbook (QRH)*. He confirmed that the memory items had been completed and that the Aircraft was being diverted to land at Muscat International Airport, Oman, as this was the nearest suitable airport.

Upon receiving air traffic control (ATC) clearance, the crew initiated a fast descent (3,000-6,000 feet per minute) to the initially cleared altitude of 12,000 ft, turned to the north and set the transponder to '7700'. Further descent clearance was given to 10,000 ft during the descent.

During descent, TERR INOP and GPWS INOP messages appeared on the EICAS. The Commander stated that he pressed the AC power button to isolate the affected systems and decided to divert to Al Ain Airport, UAE, due to high terrain in the vicinity of Muscat Airport.

The Electrical System Fire or Smoke, *IC Failure/IC Bus Failure*, and *GPWS INOP* checklists were completed.

The cabin crewmember called the cockpit, using the interphone, reporting a burning odor in the cabin, and the Commander briefly explained that there was a technical fault, and he would give her a NITS[2] briefing shortly. Upon establishing the Aircraft on a track to Al Ain, and completing various other procedures, the Commander contacted the cabin crewmember and requested her to open the cockpit door for a NITS briefing. The Commander asked the cabin crewmember if she could smell any burning, or see any smoke, and she responded that there was no smell or smoke.

The Commander stated that the NITS briefing verified that the landing would be precautionary unless smoke developed and if this happened, he required the cabin crewmember to inform him and prepare for an evacuation.

After the NITS briefing had been completed, the cabin crewmember secured the cabin and informed the passengers that the Aircraft was diverting to Al Ain due to technical issue.

The flight continued with the copilot flying manually and wearing his oxygen mask. The descent, descent transition, approach and landing checklists were completed and the Aircraft was configured for landing.

The Aircraft landed uneventfully on runway 01 at Al Ain International Airport at approximately 1613UTC.

After landing, the airport rescue and firefighting staff attended the Aircraft and reported no smoke or fire. The Aircraft then taxied to the stand normally.

After parking, the engines were shutdown normally and the passengers disembarked.

There were no injuries to the crew or passengers, and the Aircraft was undamaged.

Personnel Information

The 27-year Commander and 29-year copilot held valid ATPL[3] issued by the GCAA with an EMB 135/145 type rating. Both pilots held valid class 1 medical certificates.

The most recent line and proficiency checks for the Commander were on 19 August and 8 August

[1] Memory items are Immediate Actions (IA) to be done from memory

[2] 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

[3] ATPL: Airline Transport Pilot License

2015, respectively, and for the copilot were on 12 June and 2 September 2015, respectively.

The Commander's flying experience was 3,743 hours, and the copilot had flown a total of 3,630 hours. On-type experience was 2,443 for the Commander and 370 for the copilot.

The Commander had rested for 24 hours prior to the Incident flight. The copilot's flying time was about 2:10 hours during the 24 hours prior to the Incident flight.

Aircraft Information

General

The Embraer EMB-145MP is a glass cockpit, narrow body, Rolls-Royce AE3007A1 twin-engine powered, single-aisle aircraft.

The Incident Aircraft, MSN 145398, was manufactured in 2001, and registered in the United Arab Emirates on 8 September 2015, under registration A6-RRA, for the owner Papide Aircraft Leasing 1 Ltd, and the Operator Rotana Jet Aviation. The certificate of airworthiness was re-issued on 28 October 2014 and was valid to 2 April 2016.

The Aircraft total hours and cycles since new were 23,330 and 21,734, respectively. The last check was an A-check, completed on 9 September 2015 at 23,321 hours, 21,727 cycles.

The maximum takeoff and landing weights were 20,990 and 19,300 kg, respectively.

The cabin was configured for 50 passenger seats and two cabin crewmember seats.

The cockpit was equipped to be flown by two pilots with provision for one observer. The cockpit was equipped with:

- pilot and copilot consoles,
- pilot and copilot panels,
- center panel,
- overhead panel,
- glareshield panel,
- circuit breaker panel, and
- control pedestal, stands equipped with panels.

Indication, and alerting systems

The IC-600 is the primary computer which exchanges information with all other components, either directly, or through auxiliary computers. The two IC-600 computers interface with other systems and manage the information flow to the cockpit.

The data acquisition units (DAU) are the central data collection points for the EICAS. DAU1 collects data from the forward aircraft systems and left engine, and DAU2 collects data from the aft aircraft systems and the right engine. Engine data is supplied to the DAUs through the full authority digital electronic control (FADEC), and directly from the engine sensors.

The discrete signals collected by the DAUs are converted into digital signals and sent to the IC-600 computers which contain a symbol generator (SG)[4] that provides images to the display units. Each DAU is a dual (A and B) channel unit. Channel B on both DAUs is a standby source, which must be manually selected through the DAU reversionary button in case of a channel 'A' DAU failure. Both IC-600 use channel 'A' of DAU (1 or 2) as the primary source of information.

The PFD (figure 1) presents the primary information to the pilots in digital form and in analogue form for some parameters. In case of PFD failure, information may be presented on the MFD by setting the MFD selector knob on the reversionary panel. The radio management unit (RMU) is also able to present some PFD indications.

The MFD presents radar, traffic collision avoidance system (TCAS), flight management system (FMS), central maintenance computer (CMC), and other navigation information and fuel, electrical, environmental, hydraulic, and take-off system pages. The MFD also operates as a backup display for the PFD and EICAS, by appropriate selection on the reversionary panel.

The EICAS presents analogue engine indications and some systems parameters. The EICAS also presents warning, caution and advisory messages to the crew. In case of an EICAS failure, information may be presented on the MFD if selected from the reversionary panel. The RMU can also present some of the EICAS information.

[4] SG1 and SG2 buttons are located on the reversionary panels and one of them can supply the displays of left and right sides. The corresponding SG will be annunciated on the upper left of the attitude sphere on both PFDs

Figure 1. Front panel view

In normal operation, PFD1 and MFD1 (left side) and EICAS are provided by the No.1 IC-600, whereas the No.2 IC-600 provides images to PFD 2 and MFD 2 (right side). Both IC-600 interact to send output to the aural warning unit.

If the No.1 IC-600 fails, RMU1 will display engine backup 'page 1' automatically, and a red (X) is presented on PFD1, MFD1, and the EICAS. Also, in the event of a No.1 IC-600 failure, the No.2 IC-600 can control both PFDs, MFDs, and the EICAS, if the SG button on the left reversion panel is pressed. In this case, RMU1 reverts to normal mode.

If the No.2 IC-600 fails, a red (X) is displayed on PFD2 and MFD2. In such an event, the No.1 IC-600 can control the PFDs, MFDs, and the EICAS, if the SG button on the right reversion panel is pressed. In this case, RMU1 remains operating normally.

If both IC-600 fail, all displays will show a red (X) and RMU1 automatically displays engine backup 'page 1'.

The *Display Failure* checklist in the *QRH* reflects three scenarios of display failure:

- Failed displays presented red (X). The *QRH* requires to perform the *Emergency/Abnormal Procedures (EAP) 2-11*
- If no red (X) is displayed, but all five displays failed, the *QRH* directs landing at the nearest suitable airport.

If no red (X) is displayed, and not all five displays have failed, the *QRH* requires using the selector knob of the affected display to switch to the other display.

During aircraft startup, the system performs a self-test to check for any abnormal conditions in the displays, and once powered up, default information appears on each of the displays and remains until selections are made to show other information.

In case of a multiple systems failure, especially in malfunctions relevant to electrical power supply loss, or a computer malfunction, the crew will be presented with essential information by using the standby instruments.

In case of an electrical system failure, the displays are powered by electrical power from the remaining buses. Each display is supplied by four different busses (two DC and two essential), and each duplicated display is supplied by a different bus.

In case of computer failure, the IC-600s receive data from duplicated sources which prevents loss of information to the flight crew by appropriate selections on the reversion panel.

In the case of a PFD or EICAS display failure, the information can be presented on any of the remaining displays by selection on the reversionary panel. If all displays are lost, the RMU is capable of providing essential flight data.

Autopilot

The Aircraft was equipped with an autopilot as part of the fully integrated automatic flight control system (AFCS), a three-axis flight control system which incorporates lateral and vertical guidance, and a yaw damper and automatic pitch trim functions.

The AFCS consists of dual IC-600 computers, autopilot servos, flight guidance controller, pitch and turn controller, and display controller. (Figure 2).

The IC-600 computers are the primary components of the AFCS. The computers control the SG, the monitors, the flight director, and autopilot, but only the No.1 IC-600 incorporates the autopilot functions.

The flight guidance system can perform three separate functions: flight director, autopilot, and autopilot monitoring:

- The flight director provides pitch and roll attitude commands based on data from a variety of sensors, including attitude, heading, air data, radio altimeter, navigation, and pilot inputs. These attitude commands are sent to the PFD for pilot display, to the

autopilot for automatic airplane control, and to the autopilot monitors.

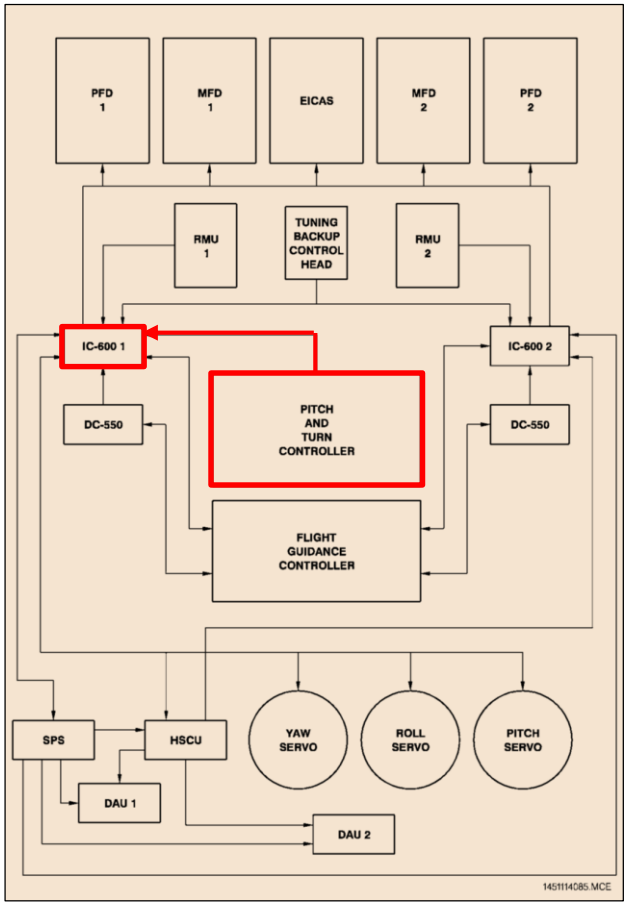

Figure 2. Autoflight system schematic [Source: *AOM*]

- The autopilot provides yaw stabilization and follows pitch and roll attitude commands from the flight director. The autopilot/yaw damper monitors continuously autopilot functions and operation. In case of failure, they are capable of disengaging the autopilot and yaw damper, independent of the autopilot processor hardware.

A voice message AUTOPILOT is generated when the autopilot is disengaged. The voice message occurs at any altitude in case of intentional disengagement, or due to an autopilot failure, and may be cancelled according to associated conditions mentioned in the *AFM*. Associated AUTOPILOT FAIL message will appear on the EICAS associated with aural warning.

Maintenance records

Reviewing the maintenance records of the affected IC-600 (P/N: 7017000-82432, S/N: 00123605) revealed that the component's last manufacturer shop visit was on 10 May 2015 (four months prior to the Incident). Since its production in December 2000, the component had gone through two modifications and three repairs.

Airplane Operations Manual (AOM) and *Quick Reference Handbook (QRH)*

(Refer to appendix 1 to this Report).

The main references for the flight crew for the emergency and abnormal procedures are contained in the *AOM* and *QRH.*

The Investigation reviewed the checklists and procedures relevant to the Incident and found that:

- The *Electrical System Fire or Smoke* checklist contained in the *AOM* and *QRH*, were inconsistent. The latter did not contain a reference to 'Odor' in 'Condition' in the checklist.
- There was no explicit precautionary note in the *IC Failure/IC Bus Failure* checklist about autopilot automatic disengagement as a consequence of IC failure.
- The *Autopilot Failure* checklist in the *AOM* and *QRH* were inconsistent. The *AOM* mentioned that the autopilot aural warning is activated only below 2,500 ft radio altitude when the autopilot is disconnected, but this was not mentioned in the *QRH*. In addition, the *Autopilot Disengagement* page in the *AOM* did not reflect this information and contained a note referring to 'voice message self-cancellation' if the autopilot disengages above 2,500 ft with a valid radio altimeter signal.

Flight Recorders

The cockpit voice recorder (CVR) and the flight data recorder (FDR) were overwritten because notification of the Incident to the Investigation was delayed for four days after the occurrence date. Because the Aircraft operated flights within that period, the CVR and FDR recording capacity were exceeded.

Survival Aspects

Both flight crewmembers donned their oxygen masks on sensing the odor and continued the flight with normal communication.

On receiving ATC clearance, the crew initiated a fast descent (3,000-6,000 feet per minute). The

Commander provided a NITS briefing to the cabin crewmember.

When the Commander was advised by the cabin crewmember that there was no visible smoke in the cabin, he decided to carry out a precautionary landing. He advised the cabin crewmember that should smoke develop, he would then require the cabin crewmember to inform him and to prepare for an evacuation.

The Aircraft landed uneventfully and taxied to stand 7 where it was parked and the passengers disembarked normally.

Tests and Research

The failed IC-600 was shipped to the manufacturer (Honeywell) for laboratory examination. When opening the unit, a smell of electrical burning from the front of the unit was noticed, and the power supply printed board assembly (PBA) number A1Q1 exhibited evidence of damage caused by overheating.

According to the Honeywell examination report: "Some areas on the reverse side of the card showed that the component had been subjected to excessive heat. When the daughter card A1A2 was removed, it was found that A1R27 and A1R28 had been charred. There was evidence of charring and component failure on the A1A2Q4 and daughter card."

The affected PBA was removed for detailed examination and sent to a specialist in analog circuits and power supply design with the objective of investigating the root cause of the power supply failure, but because the PBA was severely damaged by heat, it was not possible to conduct various types of examination and tests on it. Therefore, the examiner used an experimental PBA of similar revision, and carried out specific tests to study the behavior of a similar PBA after exposing it to various inputs. It was not possible to replicate the failure by these test methods. But from other similar historical examinations, the examiner indicated that, most likely, the internal breakdown of the transformer (T1) was the reason for the short circuit which resulted in the PBA heat buildup.

Additional Information

Incident- Heat damage to electrical component, EMB-145EP, 20 February 2005

On 20 February 2005, during climb, the pilots of an Embraer EMB-145EP were unable to keep the autopilot engaged before smoke and fumes started to dissipate in the cockpit followed by failure of the left PFD, MFD, RMU, and EICAS displays. The smoke was evident briefly in the cabin and the aircraft diverted to Paris Charles de Gaulle Airport. After landing, disembarkation was delayed whilst the crew attempted to follow complex taxi instructions. The source of the smoke was the No.1 IC-600, and started after failure of the transistor on the A5 autopilot circuit card assembly causing the yaw damper clutch line to short to ground and then excessive current to flow in the clutch circuit, which resulted in overheating and some charring of the circuit card and other adjacent components.

On the operations side, the investigation carried out by the United Kingdom Air Accidents Investigation Branch (AAIB) found that the procedure for recovering information to cockpit displays in the event of failure of an IC-600 had been omitted during a previous revision of the *quick reference handbook (QRH)*. One safety recommendation was made concerning restoration of the appropriate procedure in the *QRH*.

The AAIB issued safety recommendation 2005-080 reading:

> "Empresa Brasileira De Aeronautica SA (Embraer) should publish a readily identifiable procedure in the quick reference handbook of all ERJ135/140/145 series aircraft which restores information to flight instruments affected by the failure of either IC-600 avionics integrated computer."

The Embraer response to the AAIB's safety recommendation 2005-080 was:

> "Embraer is at present in the process of revising the current QRH to incorporate the suggested recommendation. Embraer expects to have this revision available for operators by the end of this calendar year [2005]."

Embraer incorporated the recommended changes on the second reissue of *QRH 145-1169*, published on 31 May 2006.

Incident- IC-600 failure, EMB-145EP, 10 May 2007

On 10 May 2007, at 1215 UTC, approximately four and a half minutes after takeoff, and during climb of EMB-145EP, an EICAS caution appeared accompanied by AUTOPILOT DISCONNECT aural warning. At the same time, the left PFD, MFD, and

EICAS went blank with red (X) displayed on the screens and smoke started to emit.

The crew declared an emergency, returned to the departure airport, and landed uneventfully.

The cause of displays disappearance and autopilot disconnection were referred to the failure of No.1 IC-600 caused by the failure of 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 VC input.

Analysis

General

The Investigation into this Incident collected data from various sources for the purpose of determining the causes and contributing factors.

This section of the Report explains the contribution of every investigation aspect to the Incident and to the severity of the consequences. The analysis also contains safety issues that may not be contributory to the Incident but are significant in adversely affecting safety.

Nothing in this section is to be understood as apportioning blame or liability.

The Failure of the No.1 IC-600 and its Consequences

The failure of No.1 IC-600, caused the PFD, MFD, and EICAS displays go blank, stop displaying data, and to display a red (X). In addition, the failure of No.1 IC-600, being the data processor for the autopilot, lead to autopilot disengagement.

During the Incident flight, when the Commander, who was the PM, pushed the SG button on the No.1 reversionary panel, the display units were recovered.

Since the autopilot functions are only linked to the No.1 IC-600, the autopilot disconnected after the No.1 IC-600 failure. The AUTOPILOT FAIL message appeared on the EICAS and the autopilot could not be re-engaged.

According to the design, if a flight director fails, an FD FAIL message is displayed on the lateral mode annunciator box, and the flight director mode annunciators, and the command cues are removed. The failure of the flight director causes the autopilot to disconnect automatically.

The Investigation did not discuss the sequence of GPWS malfunction messages during descent, and whether that happened before the Commander, as he stated, isolated the AC power during the descent or as a consequence of that.

Emergency/Abnormal Procedures

The Aircraft's *AOM* and *QRH* contained emergency/abnormal procedures related to failures of the displays, autopilot, and the IC-600 (appendix 1).

In the sequence of steps, the *IC Failure/IC Bus Failure* checklist ends with the crew pushing the corresponding SG on the reversionary panel. The *Autopilot Failure* checklist ends by disengaging the autopilot.

The differences between the emergency/abnormal procedures and checklists in the *AOM* and *QRH* in some topics may cause confusion to the crew and may indicate that part of the procedures are not as up to date as the other part.

For instance, missing the 'odor condition' in the *QRH*'s *Electrical System Fire or Smoke* checklist can prevent the crew from implementing the checklist in case of odor only.

The lack of an explicit precautionary note about autopilot loss in the case of a No.1 IC-600 failure does not help in preparing the crew mindset for changing the flight from AFCS to manual.

Mentioning in the *AOM* that the autopilot disconnection aural warning will activate only below 2,500 ft radio altitude, whereas this condition was not mentioned in the *QRH*, provides vague information to the crew.

The Investigation believes that the discrepancies in the checklists and procedures may add unnecessary workload to the crew in emergency/abnormal situations that require straightforward procedures leading to the recovery of safe conditions.

Crew Performance and Emergency Handling

The crewmembers experience and initial training assisted them in identifying that the cause of disappearance of the PFD, MFD and EICAS data from the screens, and the appearance of the red (X), was the failure of the No.1 IC-600. The Commander, who was the PM, pressed the SG button located on the No.1 reversionary panel in order to switch to the

No.2 IC-600. The IC BUS FAIL caution displayed on the EICAS, and the screens were recovered.

The odor sensed later was diagnosed by the crew to be electrical, and both crewmembers believed that the source was the No.1 IC-600 based on the displayed data having been replaced by red (X) marks.

The crew initiated the *Electrical System Fire or Smoke* checklist and both crewmembers donned their emergency oxygen masks.

When the TERR INOP and GPWS INOP messages appeared on the EICAS, the Commander pushed the AC power button to isolate the affected systems and decided to divert to Al Ain Airport, UAE, due to high terrain near Muscat Airport. This was appropriate action to mitigate the risk of flying above high terrain with a deactivated GPWS.

The crew practiced good crew resource management (CRM) with the copilot manually controlling the Aircraft. The cockpit-cabin communication was managed appropriately and the safety information was exchanged in a timely and accurate manner.

The Commander provided a NITS briefing for a precautionary landing since he believed that the situation did not require evacuation unless smoke developed, in which case he would declare an evacuation. The Commander was the flight crewmember who maintained communication with the cabin since he was the PM.

During the descent to Al Ain Airport, the applicable checklists were actioned normally.

Conclusions

General

From the evidence available, the following findings, causes and contributing factors were made with respect to this Incident. These shall not be read as apportioning blame or liability to any particular organization or individual.

To serve the objective of this Investigation, the following sections are included in the conclusions heading:

- **Findings-** are statements of all significant conditions, events or circumstances in this Incident. The findings are significant steps in this Incident sequence but they are not always causal or indicate deficiencies.
- **Causes-** are actions, omissions, events, conditions, or a combination thereof, which led to this Incident.

Findings

Findings relevant to the Aircraft

(a) The Aircraft was certified, equipped and maintained in accordance with the existing requirements of the *Civil Aviation Regulations* of the United Arab Emirates.

(b) The Aircraft was airworthy when it was released to service.

(c) The flight was uneventful until the PFD1, MFD1, and EICAS screens went blank and displayed a red (X).

(d) The display blanking was followed by an electrical odor coming from the No.1 IC-600.

(e) The odor was generated by the overheated A1Q1 power board.

(f) The overheat was due to a short circuit caused, most likely, by an internal breakdown of the transformer (T1).

(g) The crew changed the displays from PFD1 and MFD1 to PFD2 and MFD2 by pressing the SG button.

(h) The No.1 IC-600 failure caused loss of the autopilot and reversion to manual control of the Aircraft.

(i) The *AOM* and *QRH* contained relevant and specified checklists for failures of the IC-600, displays, and autopilot, but the checklists were inconsistent.

Findings relevant to the crew

(a) The flight and cabin crewmembers were licensed and qualified for the flight in accordance with the existing requirements of the *Civil Aviation Regulations* of the United Arab Emirates.

(b) The flight and cabin crewmembers were well-rested prior to the flight.

Findings relevant to the Operator and flight operation

(a) The copilot was the pilot flying (PF) and the Commander was the pilot monitoring (PM).

(b) The loss of the GPWS caused the crew to change the diversion airport from Muscat (airport surrounded by terrain) to Al Ain.

(c) The CRM was effective and worked well in a dynamic situation.

Causes

The Air Accident Investigation Sector determines that the cause of the No.1 IC-600 failure was the overheating of the power supply printed board assembly (PBA). It is most likely that an internal breakdown of the transformer (T1) caused a short circuit resulting in heat buildup on the PBA. The Investigation could not determine why the transformer (T1) had broken down.

The heat caused the power supply board to disconnect the No.1 IC-600 resulting in PFD1, MFD1, and EICAS displays going blank with a red (X), and the autopilot to automatically disengage.

Safety Recommendations

The Air Accident Investigation Sector recommends that:

Embraer

SR71/2016

Review the following checklists and procedures in the *Airplane Operations Manual (AOM)* and *Quick Reference Handbook (QRH)* and make the necessary revisions to achieve consistency:

- *Electrical System Fire or Smoke*
- *IC Failure/IC Bus Failure*
- *Autopilot Failure.*

Embraer may apply this safety recommendation for comprehensive review of both references in other procedures and checklists.

This Report is issued by:

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Appendix 1. *Emergency/Abnormal* Checklists

Electrical System Fire or Smoke Checklist

(a) *AOM*

EMERGENCY PROCEDURES — AIRPLANE OPERATIONS MANUAL — EMB145

ELECTRICAL SYSTEM FIRE OR SMOKE

CONDITION: Smoke visually confirmed as being from electrical source, or identified by odor.

If smoke source can be determined:
- Electrical Power to Associated Equipment ..... OFF

If smoke source cannot be determined:
- Shed Buses ..... OFF
- If smoke does not stop or decrease after a reasonable time, cut power to Central DC Bus as follows:
  - Bus Ties ..... OFF
  - APU Generator ..... OFF
  - Battery 2 ..... OFF
- If smoke does not stop or decrease after a reasonable time, cut power to DC Bus 1 and Essential DC Bus 1 as follows:
  - Fuel Pumps ..... 1B AND 2A OR 2C
  - Battery 2 ..... AUTO
  - Battery 1 ..... OFF
  - Generators 1 and 3 ..... OFF
- If smoke does not stop or decrease after a reasonable time, restore power to the previously deenergized buses and cut power to DC Bus 2 and Essential DC Bus 2 as follows:
  - Generators 1 and 3 ..... ON
  - Battery 1 ..... AUTO
  - Fuel Pumps ..... 2B AND 1A OR 1C
  - Battery 2 ..... OFF
  - Generators 2 and 4 ..... OFF
- If smoke does not stop or decrease after a reasonable time, restore power to the previously deenergized buses and cut power to Backup Buses as follows:
  - Generators 2 and 4 ..... ON
  - Battery 2 ..... AUTO
  - APU Generator ..... ON
  - Bus Ties ..... AUTO
  - Shed Buses ..... AUTO
  - Backup Battery ..... OFF

Land at the nearest suitable airport.

SMOKE EVACUATION
- Procedure (if necessary) ..... ACCOMPLISH

IC FAILURE/IC BUS FAILURE

EICAS Caution: IC BUS FAIL may be presented.

Condition: Associated Display Units blank and with a red X drawn over them.

The following features will be inoperative:
- EICAS messages miscompare monitoring.
- Takeoff speeds synchronization.
- Flight Director mode synchronization.

FAILED DISPLAYS? — **PFD 2 and MFD 2 (IC 2 Failed)**

PFD 1, MFD 1 and EICAS (IC 1 Failed)

On Reversionary Panel 1:
- **SG ..... PUSH IN**

NOTE: In case of IC 1 failure, the PIT TRIM 1(2) INOP message may not be available.

END

On Reversionary Panel 2:
- **SG ..... PUSH IN**

END

(b) *QRH*

EMERGENCY/ABNORMAL PROCEDURES

Smoke

ELECTRICAL SYSTEM FIRE OR SMOKE

Condition: Smoke confirmed from electrical source.

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

LAND AT THE NEAREST SUITABLE AIRPORT.

SMOKE ORIGIN IDENTIFIED? — No

Yes

Electrical Power to Affected Equipment ... OFF

SMOKE EVACUATION Procedure (S-11) ..... AS REQUIRED

END

EMERGENCY/ABNORMAL PROCEDURES

Autopilot, Flight Instruments & Navigation

DISPLAY FAILURE

EICAS Caution: CHECK PFD 1 (2) message is presented if PFD is the failed display.

FAILED DISPLAYS PRESENT A RED X? — No

Yes

IC FAILURE/IC BUS FAILURE Procedure (EAP 2-11) ..... ACCOMPLISH

END

ALL 5 DISPLAYS FAILED? — No

Yes

LAND AT THE NEAREST SUITABLE AIRPORT.
Icing Conditions ..... AVOID/EXIT
RMU ..... AS REQUIRED
Use RMU to access Engine and Navigation back up pages.

END

WHICH DISPLAY FAILED? — EICAS

PFD — MFD

Affected MFD Selector Knob ..... PFD

END

END

Any MFD Selector Knob ..... EICAS

END

Autopilot Failure Emergency Procedure

(a) *AOM*

EMB145

AIRPLANE OPERATIONS MANUAL

EMERGENCY PROCEDURES

AUTOPILOT FAILURE

EICAS WARNING: AUTOPILOT FAIL
LIGHT: Master Warning
AURAL WARNING: AUTOPILOT (only below 2500 ft radio altitude, when autopilot is disconnected)

Confirm message on PFD. If confirmed:
Autopilot ..... DISENGAGE
Check autopilot disengagement on PFD.
Trim the airplane as required.

NOTE: If associated with autopilot hardover a sudden deviation from the expected flight path may occur.

(b) *QRH*

EMERGENCY/ABNORMAL PROCEDURES

Autopilot, Flight Instruments & Navigation

AUTOPILOT FAILURE

EICAS Warning: AUTOPILOT FAIL
Aural Warning: **AUTOPILOT** Voice message

Autopilot .....DISENGAGE

END

AHRS ALIGNMENT FAULT

EICAS Caution: AHRS 1 (2) ALN FAULT

Check and reenter present position. If necessary, reenter present position once again.

END