Transportation Safety Board of Canada
Bureau de la sécurité des transports du Canada

AVIATION INVESTIGATION REPORT A16O0066

Avionics compartment fire

Air Canada
Embraer ERJ 190-100 IGW, C-FHOS
Boston, Massachusetts, United States, 97 nm WNW
25 May 2016

Canada

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Summary

On 25 May 2016, the Air Canada Embraer ERJ 190-100 IGW (registration C-FHOS, serial number 19000101) was operating as flight ACA361 from Boston/General Edward Lawrence Logan International Airport, Massachusetts, United States, to Toronto/Lester B. Pearson International Airport, Ontario. At 1652:12 Eastern Daylight Time, while en route at flight level 360, approximately 97 nm west-northwest of Boston/General Edward Lawrence Logan International Airport, a fire broke out in the right integrated control centre located in the middle avionics compartment. The flight crew did not receive any indication of fire. Numerous electrical systems failed, including most cockpit instrumentation. The ram air turbine automatically deployed, and the crew was eventually able to restore electrical power to the main buses. The flight continued to destination without further incident and landed with emergency services standing by. There were no injuries. The aircraft had significant damage to the right integrated control centre as a result of the fire.

Le présent rapport est également disponible en français.

Factual information

History of the flight

On 25 May 2016, at 1629,[1] the Embraer ERJ-190-100 IGW (registration C-FHOS, serial number 19000101) operating as Air Canada flight ACA361 departed Boston/General Edward Lawrence Logan International Airport (KBOS), Massachusetts, United States, on a regularly scheduled flight to Toronto/Lester B. Pearson International Airport (CYYZ), Ontario, with 61 passengers, 2 cabin crew members, and 2 flight crew members on board. The captain was the pilot flying, and the first officer was the pilot monitoring.

The flight reached its planned cruising altitude of flight level (FL) 360[2] at 1647 and levelled off under control of the autopilot. Visual meteorological conditions[3] were present throughout the flight.

At 1651:13, an audible tone sounded in the cockpit, and 2 system-fault messages briefly appeared on the engine indication and crew alerting system (EICAS).[4] Approximately 50 seconds later, an audible tone sounded again, and several more EICAS messages appeared, detailing numerous faults.

At 1652:12, the aircraft was 97 nm west-northwest of KBOS when the master warning[5] light illuminated and the associated alarm sounded. The autopilot disconnected, 3 of the 5 cockpit display panels went dark, and several more EICAS warnings appeared, including "ELEC EMERGENCY", "IDG 1 OFF BUS", and "IDG 2 OFF BUS". These messages informed the crew that an electrical emergency had occurred and that both integrated drive generators (IDG)—the main sources of electrical power—were offline.

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1 All times are Eastern Daylight Time (Coordinated Universal Time minus 4 hours).

2 Flight level (FL) is "the altitude expressed in hundreds of feet indicated on an altimeter set to 29.92 in. of mercury or 1013.2 mb." (Source: Transport Canada, TP 14371, *Transport Canada Aeronautical Information Manual* [TC AIM], GEN – General [13 October 2016], section 5.1) In this case, flight level 360 means 36 000 feet above mean sea level.

3 Visual meteorological conditions means meteorological conditions equal to or greater than minima specified in Division VI of Subpart 2 of Part VI, expressed in terms of visibility and distance from cloud. (Source: *Canadian Aviation Regulations*, SOR/96-433 [last amended on 01 January 2017, Subpart 101, subsection 101.01(01))

4 The engine indication and crew alerting system, located on the aircraft's centre electronic display, provides information regarding the status of various aircraft systems and alerts of system malfunctions.

5 "Master warning and caution lights are installed on the glareshield panel and blink when any warning or caution message shows on the EICAS or triggered by the Aural Warning Unit. It alerts to conditions that require action or caution related to the operation of the airplane." (Source: Air Canada, *E190 Aircraft Operating Manual*, Volume 2 [26 January 2015], section 2.31.21, p. P2)

The ram air turbine[6] (RAT) automatically deployed within moments of the electrical failure and had restored power to the essential buses by 1652:19.

The flight crew contacted Boston air traffic control (ATC) and informed them of the electrical malfunction. Although alternate navigational guidance was still available to the crew, they had not yet selected such guidance because they were not certain of the status of the electrical system. The crew informed ATC of the lack of navigation and autopilot and requested a heading and possible altitude deviation. ATC asked if the flight crew required assistance; the crew told ATC to stand by because they were uncertain of to the severity of the problem.

The crew discussed declaring an emergency but decided that they would attempt to restore main electrical power first. At this point, the aircraft was approximately 290 nm from CYYZ, or 100 nm from KBOS.

The crew performed the *Quick Reference Handbook* (QRH) checklist for an electrical emergency (Appendix A). The first item on the list was to start the auxiliary power unit (APU). Because the aircraft was still at FL360, and because the published operational limitations indicate that the maximum altitude at which the APU can be started is 30 000 feet,[7] the crew requested a descent from ATC.

After starting the descent, the flight crew made an announcement to the passengers; however, unbeknownst to the flight crew, the noise generated by the RAT (because of its high rotation speed) prevented the passengers and the cabin crew from hearing the announcement. Shortly thereafter, the cabin crew communicated directly with the flight crew and were informed of the situation. The cabin crew then relayed the information to the passengers.

While descending through FL300 at 1659:37, the crew started the APU and proceeded to the next step on the checklist: resetting the IDGs. At 1701:41, IDG 1 was brought back online, followed by IDG 2 at 1702:04. At the same time, the aircraft was levelling off at FL240. With the IDGs back online, full power was restored to both main alternating current (AC) and both main direct current (DC) buses.[8]

With main power restored to the aircraft, the electrical emergency fault message cleared from the EICAS. The EICAS still registered a fault with the No. 2 transformer rectifier unit (TRU 2), but the systems connected to it were being powered by the No. 1 transformer rectifier unit (TRU 1). At this point, the electrical emergency was over and, although a few

6 The ram air turbine (RAT) is a wind-powered generator that, although normally stowed, can be extended into the relative airflow to provide a source of alternating current (AC) power should the power delivered by the main power generation system be insufficient.

7 Air Canada, *E190 Aircraft Operating Manual*, Volume 1 (26 January 2015), section 1.01.49, p. P1.

8 For a description of the electrical system, refer to the section of this report entitled "Electrical system description."

non-critical components were unavailable, the system as a whole was back to normal operation. The autopilot was re-engaged at 1708:43.

At 1710, while the aircraft was approximately 170 nm from CYYZ, the crew informed Boston ATC that they had restored some electrical power but were still requesting vectors for the final approach to CYYZ. The crew requested the longest runway available because they planned to land with decreased flap.[9] Boston ATC relayed this information to Cleveland ATC, who in turn relayed the information to Toronto ATC. All ATC units involved made accommodations to minimize delays for the aircraft for the rest of the flight.

At 1754, the aircraft landed on Runway 23 at CYYZ without further incident. Emergency services were standing by. The crew subsequently taxied to the gate, where the passengers were deplaned. There were no injuries.

Aircraft

General

Records indicate that the aircraft was certified, equipped, and maintained in accordance with existing regulations and approved procedures.

The occurrence flight was the first sector of the day for the flight crew with this aircraft, which they had taken over at KBOS. It was the third sector of the day for the aircraft, which had overnighted at LaGuardia Airport (KLGA), New York, New York, United States. During the flight crew's pre-flight inspection at KBOS, it was determined that there were no recorded deferred defects or reports of significant maintenance work accomplished.

Electrical system description

The electrical system on the Embraer ERJ 190-100 IGW consists of numerous systems that receive power distributed via several different buses.

The main source of electrical power is 2 integrated drive generators (IDG 1 and IDG 2). One IDG is connected to each engine. The IDGs supply AC power to their respective main AC buses (AC BUS 1 and AC BUS 2). Many AC-based systems are powered directly from these buses.

Connected to each main AC bus are the 2 transformer rectifier units: TRU 1 and TRU 2. The TRUs convert AC power to DC power and supply this power to their respective main DC buses (DC BUS 1 and DC BUS 2). Many DC systems are powered directly from these DC buses.

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[9] This plan was in accordance with the *Quick Reference Handbook* (QRH) guidance for electrical emergency.

The majority of the components that control, protect, and distribute the power from the IDG 2—including AC BUS 2, TRU 2, and DC BUS 2—are contained in the right integrated control centre (RICC) (Appendix B), which is located in the middle avionics compartment. This compartment is accessed through a small door on the exterior of the fuselage, just aft of the wing root, and requires a small ladder to gain entry. In practice, it is entered only when specific maintenance work needs to be done.

Connected to each IDG is a general line contactor (GLC 1 and GLC 2), which is controlled by a generator control unit (GCU 1 and GCU 2). The GLC isolates the IDG from the system when the GCU senses a significant fault or when commanded via a switch in the cockpit. GCU 2 is also located in the RICC.

Generally speaking, the left and right (No. 1 and No. 2) main electrical power distribution systems are isolated from each other; however, power can be automatically transferred between the systems when necessary, using dedicated bus tie connectors.

The essential electrical system is separated from the main electrical system to isolate the components if both main electrical systems fail and includes the components that are considered more critical to continue safe flight. Essential power is distributed through the essential buses (AC ESS BUS, DC ESS BUS 1, and DC ESS BUS 2), which normally receive power from the main system through AC BUS 1 or AC BUS 2. However, the essential buses can be isolated and powered via the aircraft batteries or the RAT if an emergency arises.

The RAT will deploy automatically if either of the secondary power distribution assemblies, which serve as electrical load management units, senses that the main AC buses are unpowered. The RAT can also be deployed manually using a lever in the cockpit. If the RAT deploys successfully, a green RAT icon and the associated output voltage appear on the appropriate cockpit display. If the RAT does not deploy, the batteries will maintain essential power for a minimum of 10 minutes, as demonstrated during certification tests. Continued power supply beyond this period is uncertain, because it depends on several factors.

Sequence of electrical failure and fire

After the occurrence, data was downloaded and examined from the aircraft's 2 digital voice data recorders and from non-volatile memory contained in the 2 GCUs.

At 1651:36, GCU 2 sensed a fault in the AC circuit breaker section of AC BUS 2. This fault indication likely occurred at the same time that smoke started to be produced.

At 1652:06, GCU 2 sensed a distortion in the voltage caused by high-impedance arcing in the bus bar area of AC BUS 2. GCU 2 tripped GLC 2, disconnecting IDG 2 from the system. In short succession, the bus tie connectors connecting AC BUS 1 and AC BUS 2 automatically closed, allowing IDG 1 to power AC BUS 2 for the next 6 seconds.

At 1652:12, because the fault had progressed to sustained arcing with smoke and fire, GCU 1 sensed an overcurrent and tripped GLC 1, disconnecting IDG 1 from the system. With both IDGs now offline, no power was being supplied to the main buses (AC BUS 1, AC BUS 2, DC BUS 1, and DC BUS 2). The loss of power to the main buses triggered a master warning, an audible alarm, and an EICAS message in the cockpit.

With the loss of power to AC BUS 2, the area in which the fire had started was no longer being provided with electrical current, and with limited combustible material nearby, the fire began to subside.

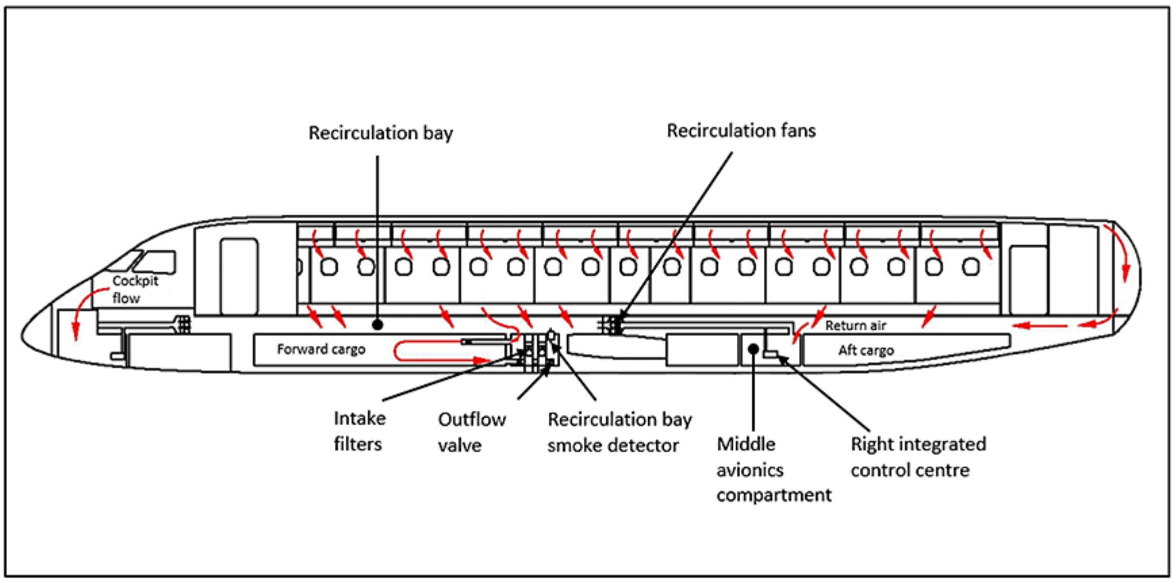
The No. 1 secondary power distribution assembly, which was still being powered by the DC essential buses, sensed that AC BUS 1 and AC BUS 2 were unpowered and, within 300 milliseconds, commanded the RAT to deploy.

By 1652:20, the RAT had deployed and was supplying power to the essential buses; however, the main buses remained unpowered until the APU was started, approximately 8 minutes later.

Smoke detection

Air from the middle avionics compartment is normally circulated through the cabin via the recirculation bay as a means of providing heat for the cabin and cooling for the avionics (Figure 1). Recirculation fans and ductwork connect the 2 areas and are powered from AC BUS 2.

Figure 1. Schematic showing air recirculation on Embraer ERJ 190-100 IGW (Source: Air Canada, *E190 Aircraft Operating Manual*, Volume 2 (26 January 2015), section 2.21.20, p. P5, with TSB annotations.)



A smoke detector is located near the intake filters in the recirculation bay and is powered solely by DC BUS 2. The main purposes of the smoke detector are to alert the flight crew to the presence of smoke that has been generated in one of the connected compartments and to prevent the smoke from being recirculated into the cabin.

If smoke is detected in the recirculation bay, the flight crew receives a “RECIRC SMOKE” indication on the EICAS. There was no report of a smoke warning during the occurrence, and no smoke warning was recorded on either of the digital voice data recorders.

TSB laboratory examination

Damage to the right integrated control centre

Air Canada maintenance personnel inspected the aircraft after it arrived at CYYZ and observed that the RICC had been extensively damaged by fire and smoke. The entire RICC was removed from the aircraft and shipped to the TSB Engineering Laboratory for further examination.

The initial inspection noted that there had been severe arcing of the 3-phase bus bars that connect to the thermal circuit breakers in AC BUS 2 (Appendix B). Further inspection revealed evidence of a fluid contaminant that had entered the vented top surface of the RICC and into the TRU 2 compartment.

It was determined that the fluid had been spilled directly on top of the RICC. The fluid then flowed down the face and through the interior of the RICC and entered the circuit breaker panel compartment, where it came into contact with the bus bars and other conductive surfaces, eventually causing the arcing that led to the smoke and fire.

The arcing, melting, and fire damaged AC BUS 2 and disabled power distribution to several connected systems, including TRU 2. The damage was limited to the RICC and did not spread to any other nearby components.

Source of the fluid

A sample of the dried fluid contaminant was examined and it was determined that the fluid was a beverage, possibly coffee or a soft drink.

It could not be determined exactly how much time took place between the spill and the resultant arcing; however, it was determined that the contaminant was significantly more conductive when in a liquid state.

Similar fluids were tested and it was determined that fluids spilled in environmental conditions similar to those surrounding the RICC would remain in liquid state for less than 6 hours.

Drip trays are located above the RICC to prevent fluid spilled in the cabin above the middle avionics compartment from coming into contact with the RICC or other equipment nearby. The drip trays and the area surrounding the RICC were examined after the occurrence and showed no evidence of contaminants.

Cabin crew who flew on the aircraft in the days leading up to the occurrence did not report any spills, and no cabin defects or rectifications were recorded that would have required carpet cleaning.

A general inspection of the middle avionics compartment after the occurrence did not reveal any debris or beverage containers.

Operator

Maintenance

For the Embraer fleet, Air Canada completes basic line maintenance in the form of service checks and routine checks. Service checks must be completed at intervals not to exceed 48 hours, whereas routine checks are carried out at intervals of 120 flight hours or 14 calendar days, whichever occurs first.

At KLGA, where the aircraft overnighted the night before the occurrence, a routine check was completed by the Air Canada maintenance staff who are stationed there. The inspection did not require anyone to enter the middle avionics compartment.

The most recent recorded maintenance task that would have required someone to enter the middle avionics compartment was completed on 26 October 2015, almost 7 months before the occurrence.

Maintenance guidance

Air Canada maintenance personnel are guided by policies, processes, and standards that are detailed in the *AC – Maintenance Control Manual* and the *AC – Maintenance Policy Manual*.

The only restriction in the manuals with regard to eating or drinking in the workplace is related to the prevention of food becoming contaminated in areas where food is consumed.

There are no restrictions currently in place that are intended to prevent food or drink from contaminating sensitive equipment. However, if a spill occurs, the maintenance policy manual contains a detailed standard that requires the spill to be reported immediately to Maintenance Operations Control and the spill to be recorded in the aircraft logbook. The standard describes different kinds of spills and states that "even clear water can cause serious electrical malfunction in electronic components and electrical systems."[10]

The maintenance control manual contains Air Canada's non-punitive process for safety reporting.

Flight crew guidance

Air Canada's *Aircraft Operating Manual* (AOM) contains detailed procedures for operating the Embraer E190.

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10 Air Canada, *AC – Maintenance Policy Manual*, Rev. 2016-2, section 9: Fluid Spills.

In the cockpit, crews use the *Quick Reference Handbook* (QRH) to provide quick and simple access to the most critical information in a timely fashion. The QRH is divided into 2 sections (normal and abnormal) and includes checklists, procedures, policies, guidance, and reference information.

Electrical emergency checklist

When an electrical emergency condition is detected, the master warning light illuminates, an associated audible alarm is heard, and "ELEC EMERGENCY" is displayed on the EICAS. When the crew receives this warning, they are to carry out the QRH checklist for electrical emergency (Appendix A).

Instruction to land

The beginning of the electrical emergency checklist states, "LAND AT THE NEAREST SUITABLE AIRPORT."[11]

The introduction to the section of the AOM entitled "Abnormals" explains the usage of this phrase and its more critical counterpart, "INITIATE DIVERSION TO NEAREST SUITABLE AIRPORT":

> […] there are some situations which always require to 'INITIATE DIVERSION TO NEAREST SUITABLE AIRPORT' where a safe landing can be accomplished.
>
> These situations include, but are not limited to:
> - landing gear bay fire.
> - smoke, fire or fumes which cannot be positively verified extinguished.
> - cargo compartment fire.
>
> Procedures which are not as time critical as those mentioned above and where the judgement of the Captain is required to determine the best course of action and the best destination for an early landing, contain the statement 'LAND AT NEAREST SUITABLE AIRPORT'. In those cases, the Captain considers operational constraints in the decision process.[12]

Starting the auxiliary power unit

The first action item on the electrical emergency checklist is to start the APU.[13] However, the maximum altitude at which the APU can be started on the Embraer ERJ 190-100 IGW is 30 000 feet.

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11 Air Canada, *Quick Reference Handbook E190* (26 January 2015), section 5: Emergency and Abnormal Electrical Power, p. EAP5-4.

12 Air Canada, *E190 Aircraft Operating Manual*, Volume 1 (26 January 2015), section 1.02.00, pp. P1–P2.

13 Air Canada, *Quick Reference Handbook E190* (26 January 2015), section 5: Emergency and Abnormal Electrical Power, p. EAP5-4.

The electrical emergency occurred while the aircraft was cruising at FL360. The crew, being aware of the maximum altitude at which the APU could be started, did not attempt to start the APU until the aircraft was in descent below FL300. It took approximately 7 minutes for the aircraft to descend the required 6000 feet.

Re-cycling the integrated drive generator selectors

The next items on the checklist instruct the crew to re-cycle the IDG 1 and IDG 2 selectors by rotating the knobs to OFF and then back to AUTO. This commands the GCUs to close the GLCs and re-engage the IDGs. The GCUs receive power from several different sources and do not need power from the APU to complete these actions.

Because the instruction to re-cycle the IDG selectors came after the instruction to start the APU on the checklist, the crew waited until the APU had been started before performing this task.

Ram air turbine

The next step on the checklist after starting the APU and re-cycling the IDGs is to determine if the electrical emergency condition still exists. If it does, and if a battery discharge warning is present, crews are to attempt to deploy the RAT manually, and to disable both TRUs to conserve power.

Declaration of emergency

The Air Canada *Flight Operations Manual* includes regulations, policies, and procedures that pertain to the conduct of all flights, regardless of aircraft type. The *Flight Operations Manual* contains the following section with regard to declaring an emergency:

> **12.3.1 Declaration of Emergency**
>
> The Pilot-in-Command shall declare an emergency in either of the following circumstances:
>
> 1. When they become aware of any condition or combination of circumstances which jeopardizes the safety of the aircraft; and/or
>
> 2. When navigation or approach instruments are impaired or malfunctioning to such an extent that orientation and/or instrument approach is no longer possible.[14]

The crew did not declare an emergency with ATC during the event; however, they did inform ATC that they had lost all electrical and navigation systems. All involved ATC units

[14] Air Canada, *Flight Operations Manual* (30 June 2015), Chapter 12: Aircraft Accident, Incident and Emergency, p. 4.

provided increased accommodations for the flight on their own accord, and Toronto ATC instructed emergency services to be on standby for the aircraft's arrival.

Several previous TSB aviation investigation reports[15] have identified a risk associated with crews not declaring an emergency following a situation that may jeopardize continued safe flight.

Flight crew

Records indicate that both flight crew members were certified and qualified for the flight in accordance with existing regulations.

The captain had approximately 8000 hours of flight experience and was operating as an initial operating experience training captain for the series of flights with the first officer.

The first officer had approximately 8500 hours of flight experience but was new to Air Canada. The first officer had recently completed the required ground-based and simulator training. The series of flights, of which the occurrence flight was one, was to serve as initial operating experience before the first officer was given his operational evaluation, which needed to be completed before the first officer could be released to normal line operations.

TSB laboratory reports

The TSB completed the following laboratory reports in support of this investigation:

- LP128/2016 – DFDR [digital flight data recorder] Download & Analysis
- LP130/2016 – Right Integrated Control Center Analysis

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[15] TSB aviation investigation reports A00P0101, A05F0047, A09Q0181, A10Q0019, and A13Q0098.

Analysis

General

The incident was initiated by a fluid contaminant spilling on sensitive electronic equipment. However, several underlying factors were identified that played a role in increasing the actual or potential severity of the event.

The analysis will focus on the source of the fluid contamination, why the resultant fire was not detected, and how the flight crew dealt with the situation with regard to checklist procedures and air traffic control (ATC) assistance.

Fluid contamination

At some point shortly before the electrical failure, a fluid contaminant came into contact with the top of the right integrated control centre (RICC). It could not be determined exactly when or how it was introduced into the avionics compartment. However, because the contaminant's conductivity over distance is much higher when it is a fluid, and the contaminant would remain in this state for less than 6 hours after being spilled, the period between the fluid coming into contact with the RICC and the arcing was relatively short.

There was no record of maintenance personnel entering the middle avionics compartment in the 7 months preceding the flight. Given the relatively tight access to the area and the fact that anyone wanting to enter the compartment would need a ladder to do so, it would be uncommon for someone to enter the compartment without a required, and therefore documented, task to complete.

Because the area is accessed infrequently, a beverage container could be brought into the compartment and potentially remain unnoticed for a long time. However, the time it takes for a beverage in an open container to evaporate can vary considerably depending on temperature, humidity, airflow and surface area, and it is unlikely that a beverage would remain liquid for 7 months. No empty beverage container was found after the occurrence. The investigation could not determine the source of the fluid contaminant.

Air Canada has no restrictions currently in place that are intended to prevent food or drink from contaminating sensitive equipment. It does, however, have a detailed standard that requires any spills to be reported and recorded immediately. If maintenance personnel knew about a spill, it is not known why it would not have been reported and cleaned up.

While Air Canada's non-punitive reporting policy on spill reporting is an important mechanism to address the hazard, the policy is effective only if somebody knows about the spill. If company policies do not restrict outside fluids in areas where they may cause harm to sensitive equipment, then there is a continued risk of contamination causing component malfunctions or failures.

Fire and smoke detection

The fluid contaminant came into contact with electrical components in one of the alternating current bus bars. This caused arcing, which led to smoke and fire. The resultant component failures eventually disabled the main electrical system.

When the initial arcing began, various systems began to record faults and smoke began to accumulate in the middle avionics compartment. Within 36 seconds of the initial fault, power was lost to all main bus bars and, as a result, the smoke detector in the recirculation bay and the recirculation fans lost power.

The smoke that had developed during this time did not travel through the recirculation ducts and onto the detector in a sufficient quantity to trigger a warning before the power supply to the detector was lost. Without power, the recirculation fans did not transfer air between the middle avionics compartment and the cabin; as a result, the smoke did not enter the cabin and was not detected by the crew.

Once the main power was lost, the smoke likely began to vent overboard from the recirculation bay through the outflow valve, which remained powered through the essential bus. By the time power was restored to the smoke detector when the No. 1 integrated drive generator (IDG 1) was reset, almost 10 minutes later, the smoke had likely dissipated to a level that was no longer detectable.

Because the flight crew received no warning of smoke or fire, they were unaware of the severity of the situation and elected to continue to destination.

Electrical emergency checklist

The crew performed the electrical emergency checklist in the *Quick Reference Handbook* (QRH) when they were presented with numerous failure indications, engine indication and crew alerting system messages, and after the ram air turbine (RAT) deployed.

Nearest suitable airport

The flight was less than 100 nm from departure and had been airborne for only about 22 minutes. The checklist instructed the crew to land at the nearest suitable airport. There were several suitable options that would have been closer than their planned destination of CYYZ. Although the checklist guidance is explicit, the aircraft operating manual gives the captain discretion to consider operational constraints in the decision-making process.

An electrical emergency involving loss of all main power on the Embraer ERJ 190-100 IGW is a serious event and involves multiple failures. Even with a complex understanding of the aircraft systems, it is unlikely that a crew would be completely aware of the source of the fault and the likelihood of continued safe operation or increased risk. As shown in this occurrence, an event as serious as a fire may go undetected.

Because the crew was not aware of the fire and the checklist did not call for a diversion, the captain exercised the operational discretion provided in the *Aircraft Operating Manual* and elected to continue to destination following the electrical failure, because the aircraft was under control and was operating in clear skies.

If flight crews are not fully aware of the severity of the emergency situation and exercise their discretion as provided in the *Aircraft Operating Manual* to not land at the nearest suitable airport as prescribed in the QRH, then there is an increased risk that a flight will be continued to destination when safer options exist.

Starting up the auxiliary power unit

The first action item on the QRH checklist is to start the aircraft's auxiliary power unit (APU). Although the checklist did not state the maximum altitude at which the APU can be started, the crew knew this limit and did not attempt to start it when they were at 36 000 feet; instead, the crew initiated a descent. Because the aircraft was being operated in visual meteorological conditions and had numerous systems disabled, including the autopilot, the crew decided to complete this descent at a moderate, rather than rapid, rate.

Re-cycling the integrated drive generator selectors

The next 2 items on the QRH checklist covered re-cycling the IDG selectors. The crew understood the order of the checklist items to mean that they should be completed only after the crew had attempted to start the APU. Because the aircraft was being operated above the altitude limit for starting the APU, this checklist sequence resulted in a period of nearly 10 minutes during which the aircraft was without its main power supply while it descended to an altitude at which the crew could attempt to start the APU.

If the main power supply had been restored sooner by re-cycling the IDG selectors shortly after the failure, the re-powered smoke detector may have provided a warning of the fire and smoke, and the crew could have escalated the urgency of their response.

However, the flight crew followed the instructions in the QRH's electrical emergency checklist and delayed resetting the IDGs until the APU had been started. As a result, the smoke detector in the recirculation bay remained unpowered during the period of time when smoke was likely detectable.

Ram air turbine

The next item on the QRH checklist is to evaluate battery discharge and possibly manually deploy the RAT. In a situation where the RAT does not deploy or is not able to provide power, aircraft batteries have been demonstrated to supply power to the essential buses for at least 10 minutes. However, further power supply beyond this time is uncertain.

In the unlikely event that the RAT does not deploy successfully after an electrical emergency, and the crew, following current checklist guidance, waits to attempt to start the APU for a similar amount of time, it is possible that the batteries would be depleted and would no longer provide power to the essential buses. In addition, the depleted batteries would not be able to start the APU. In this condition, if the crew did not reach the step in the QRH procedures to re-engage the IDGs, it would be significantly less likely for safe flight to continue, because there would be no engaged source of electrical power.

If flight crew guidance for electrical emergencies does not include an early evaluation of battery discharge or confirmation of a supplementary power source, then there is an increased risk that battery power will be insufficient to ensure that essential equipment remains powered until the aircraft can be landed.

Declaring an emergency

In addition to the decision to continue to destination, the crew's perception that an emergency existed only if the power could not be restored led them to delay declaring an emergency with ATC. Once main power had been restored, the crew believed that because they did not require priority for their approach into CYYZ, declaring an emergency was also not necessary.

However, due to the content of the flight crew's transmissions to ATC, including informing them of complete electrical failure and loss of all navigation, all ATC units treated the flight as an emergency on their own accord, provided priority handling throughout the flight, and instructed emergency vehicles at CYYZ to be on standby.

If flight crews become aware of a situation that may jeopardize safety but do not declare an emergency with ATC, then there is an increased risk that should the situation worsen, the flight will still be airborne due to a lack of priority handling, or that it will land without emergency services standing by.

Findings

Findings as to causes and contributing factors

1. At some point, a fluid contaminant came into contact with the top of the right integrated control centre. It could not be determined exactly when or how it was introduced into the avionics compartment.

2. The fluid contaminant came into contact with electrical components in one of the alternating current bus bars. This caused arcing, which led to smoke and fire. The resultant failures eventually disabled the main electrical system.

3. Within 36 seconds of the initial fault, power was lost to all main bus bars and, as a result, the smoke detector in the recirculation bay and the recirculation fans lost power.

4. The smoke that had developed during this time did not travel through the recirculation ducts and onto the detector in a sufficient quantity to trigger a warning before the power supply to the detector was lost.

5. Without power, the recirculation fans did not transfer air between the middle avionics compartment and the cabin; as a result, the smoke did not enter the cabin and was not detected by the crew.

6. The flight crew followed the instructions in the *Quick Reference Handbook*'s electrical emergency checklist and delayed resetting the integrated drive generators until the auxiliary power unit was started. As a result, the smoke detector in the recirculation bay remained unpowered during the period of time when smoke was likely detectable.

7. Due to the lack of warning of smoke or fire, the flight crew was unaware of the severity of the situation and elected to continue to destination.

Findings as to risk

1. If company policies do not restrict outside fluids in areas where they may cause harm to sensitive equipment, then there is a continued risk of contamination causing component malfunctions or failures.

2. If flight crews are not fully aware of the severity of the emergency situation and exercise their discretion as provided in the *Aircraft Operating Manual* to not land at the nearest suitable airport as prescribed in the *Quick Reference Handbook*, then there is an increased risk that a flight will be continued to destination when safer options exist.

3. If flight crew guidance for electrical emergencies does not include an early evaluation of battery discharge or confirmation of a supplementary power source, then there is

an increased risk that battery power will be insufficient to ensure that essential equipment remains powered until the aircraft can be landed.

4. If flight crews become aware of a situation that may jeopardize safety, but do not declare an emergency with air traffic control, then there is an increased risk that should the situation worsen, the flight will still be airborne due to a lack of priority handling, or that it will land without emergency services standing by.

Safety action

Safety action taken

Embraer

In January 2017, Embraer submitted a proposal to the regulator to change the electrical emergency procedure and checklist in the *Aircraft Flight Manual*.

The new proposed procedure includes the following sequence of instructions:

> LAND AT THE NEAREST SUITABLE AIRPORT.
>
> Limit the airspeed to 150 KIAS minimum, deploy the RAT manually, reset (set to off, then to auto) IDG 1 and IDG 2, start the APU, and set the emergency lights to off.[16]

This report concludes the Transportation Safety Board of Canada's investigation into this occurrence. The Board authorized the release of this report on 05 September 2017. It was officially released on 11 September 2017.

Visit the Transportation Safety Board of Canada's website (www.tsb.gc.ca) for information about the TSB and its products and services. You will also find the Watchlist, which identifies the key safety issues that need to be addressed to make Canada's transportation system even safer. In each case, the TSB has found that actions taken to date are inadequate, and that industry and regulators need to take additional concrete measures to eliminate the risks.

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16 Embraer, Proposed improvement of Electrical Emergency Procedure in section 4 of the *Aircraft Flight Manual*, p. 8.

Appendices

Appendix A – Quick Reference Handbook *checklist for electrical emergency*

QRH E190	EMERGENCY AND ABNORMAL ELECTRICAL POWER	EAP5-4 MAR 14/16

ELEC EMERGENCY

LAND AT THE NEAREST SUITABLE AIRPORT.

Airspeed .... **MIN 150 KIAS**

Note: *If airspeed is below 200 KIAS, the IESS attitude indication may oscillate. If oscillation occurs, accomplish the* ***IESS ATTITUDE OSCILLATION WITH RAT DEPLOYED*** *Checklist* ***(NAP1-25)****.*

APU .... **START**

IDG 1 Selector .... **OFF, THEN AUTO**

IDG 2 Selector .... **OFF, THEN AUTO**

Emergency Lights .... **OFF**

CAUTION: ONLY TWO APU START ATTEMPTS ARE ALLOWED.

ELEC EMERGENCY WARNINGS PERSISTS? — No / Yes

BATT DISCHARGING WARNINGS PRESENTED? — No / Yes

RAT Manual Deploy Lever .... **PULL**

TRU 1 Switch .... **OFF**

TRU 2 Switch .... **OFF**

Icing Conditions .... **EXIT/AVOID**

Altitude .... **10,000 FT or MEA, WHICHEVER IS HIGHER**

Relevant inoperative items:

ADS 1 and 2	IRS 2
Anti-Ice System	MCDU 1
AOA Limit	Multi Function Spoilers L3, R3, L4, R4, L5 and R5
Autopilot	NAVCOM 2
Autothrottle	Nosewheel Steering
CCD 2	Pack 1 and 2
Display Unit 1, 4 and 5	Pax Masks Auto Deploy
Engine 1 and Engine 2 Reversers	Radio Altimeters 1 and 2
FMS 1	Service Interphone System (Normal Mode)
Flight Director	Speedbrake
Fuel AC Pump 1	TAT 1 and 2
GPS 1	TCAS
Ground Spoilers L1, R1, L2 and R2	Yaw Damper
Hyd Sys 1 Elec Pump	Weather Radar
Hyd Sys 2 Elec Pump	Windshear Detection
Hyd Sys 3 Elec Pump B	Windshield Heater 1 and 2
Ice Detectors 1 and 2	Windshield Wiper 1 and 2
Electromechanical Door Latch	

CONT'D

QRH E190	EMERGENCY AND ABNORMAL ELECTRICAL POWER	EAP5-5 JAN 26/15

(Continued from the previous page)

Note: – *Avoid side slipping the airplane.*
– *On ground, use differential braking and rudder to steer the airplane*
– *The slats and flaps will operate at low rate.*
– *The reinforced cockpit door can only be opened manually.*

Landing configuration:

Emergency Lights .... ARMED
Gnd Prox Flap Ovrd Button .... PUSH IN
LG WRN INHIB Button .... PUSH IN
Flap 3
Set VREF = VREF FULL + 20 KIAS or 130 KIAS (whichever is higher).

CAUTION: MULTIPLY THE FULL FLAPS UNFACTORED LANDING DISTANCE BY 1.90. ACARS WAT CODE: EP01

If go around is required:

Flap 3
Airspeed .... VREF FULL + 20 KIAS or 130 KIAS (whichever is higher)

END

Flight Controls Mode Buttons
(Spoilers, Elevators, Rudder) .... PUSH IN, THEN OUT

Landing configuration:

Emergency Lights .... ARMED
Gnd Prox Flap Ovrd Button .... PUSH IN
Flap 3
Set VREF = VREF FULL + 20 KIAS.

CAUTION: MULTIPLY THE FULL FLAPS UNFACTORED LANDING DISTANCE BY 1.90. ACARS WAT CODE: EP06

If go around is required:

Flap 3
Airspeed .... VREF FULL + 20 KIAS

END

A190 EAP5-5

Source: Air Canada, *Quick Reference Handbook E190* (26 January 2015), section 5: Emergency and Abnormal Electrical Power, pp. EAP5-4 to EAP5-5.

Appendix B – Damage to the right integrated control centre, viewed under normal and ultraviolet light