Swissair Flight 111: Investigation Overview

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Introduction

The following represents a high-level overview of some of the key events associated with the investigation of the Swissair Flight 111 (SR111) accident by the Transportation Safety Board of Canada. Readers are cautioned against drawing inferences or conclusions from the limited information presented. The Board's final report will contain a more thorough and complete presentation of all of the relevant information uncovered during the investigation.

On Sept. 2, 1998, SR111 departed JFK Airport in New York, USA, at 21:18 Atlantic Daylight Time (00:18 Coordinated Universal Time), for Geneva, Switzerland. There were 215 passengers and 14 crew members onboard. About 53 minutes after departure, while the aircraft was cruising at Flight Level 330, the flight crew detected an abnormal odour in the cockpit. A flight attendant was summoned to the flight deck by the crew. She confirmed the presence of an abnormal smell in the cockpit, and indicated that there were no unusual odours in the first-class area of the cabin where she was working. Within a period of 3 minutes after the crew's first detection of the smell, the crew noted the presence of some smoke and suspected that it originated from the air conditioning system. The crew then decided to divert to another airport immediately. The crew made a PAN PAN PAN (1:14:15) radio transmission and requested an immediate diversion to a suitable airport, indicating Boston. Air Traffic Services (ATS) cleared SR111 for a right turn to Boston, and then offered Halifax International Airport as being a closer alternative. The SR111 crew elected to divert to Halifax and were cleared by ATS to the Halifax Airport, approximately 57 nautical miles (nm) away.

Approximately 30 nm from Halifax, the crew accepted vectors to Runway 06. They were still at 21,500 feet above sea level (ASL), and indicated that they would need more than 30 miles to set up for the landing. ATS offered them a turn to the north to lose altitude, which they accepted. As they flew north, still descending, the crew indicated that they would need to dump fuel. ATS offered SR111 the option of turning to the south to dump fuel, or staying closer to the airport. The crew opted to take a turn to the south. Other than the odour and smoke, the information from the recorders and ATS transmissions did not indicate any aircraft system anomalies at this point. There was no indication that there was any significant amount of smoke in the cockpit at this time. The cabin attendants did not report the presence of any smoke in the cabin at any time prior to recorder stoppage. About three-quarters of the way through the left turn to the south (approximately 11 minutes after the crew assessed that there was some smoke visible in the cockpit, or about 8 minutes after the clearance to Halifax airport), the autopilot disconnected. Over the next 90 seconds, up to the point of flight recorder stoppage, there was a rapid succession of FDR anomalies related to the loss of various aircraft systems. During the latter portion of this 90-second period, the flight crew declared an emergency. They indicated that they were starting to dump fuel and that they needed to land immediately. Less than a minute later, while the aircraft was in level flight at about 10,000 feet (ASL), both flight recorders stopped, radio communications were lost, and secondary radar contact with the aircraft was lost. The recorders were considered to have stopped as a result of systems failures as the fire spread.

Less than 6 minutes after the loss of the recorders (01:31:18 UTC), the aircraft crashed into the ocean about 5 nautical miles southwest of Peggy's Cove, Nova Scotia, Canada. The aircraft was destroyed and there were no survivors.

Several factors have combined to make this investigation particularly challenging, including the total destruction of the aircraft, the lack of recorded information with respect to the initi-

Figure 1: Bundle of heat-damaged wires

ating event, the stoppage of the flight recorders 6 minutes prior to the crash, and the extensive fire damage in the front ceiling area of the aircraft. The task of determining the source of ignition, the propagation of the fire, and the circumstances leading to the final impact with the water has been time consuming. Extensive work has taken place to recover the wreckage, to reconstruct the front 10 metres of the aircraft above the floor level, and to closely examine various system components, wires, aircraft structure, and interior pieces. Various important safety deficiencies have been identified and promulgated.

"The fact that the fire was extinguished by the entry of the aircraft into water has provided a unique opportunity to examine the fire damage from a fire-inflight perspective. The ability to look at material flammability issues, and other inflight firefighting issues from this perspective, has enabled us to validate deficiencies in several areas. This has led to several safety recommendations and advisory letters. Numerous safety actions have already been undertaken by regulatory authorities, manufacturers, and operators as a result of information revealed by the investigation.

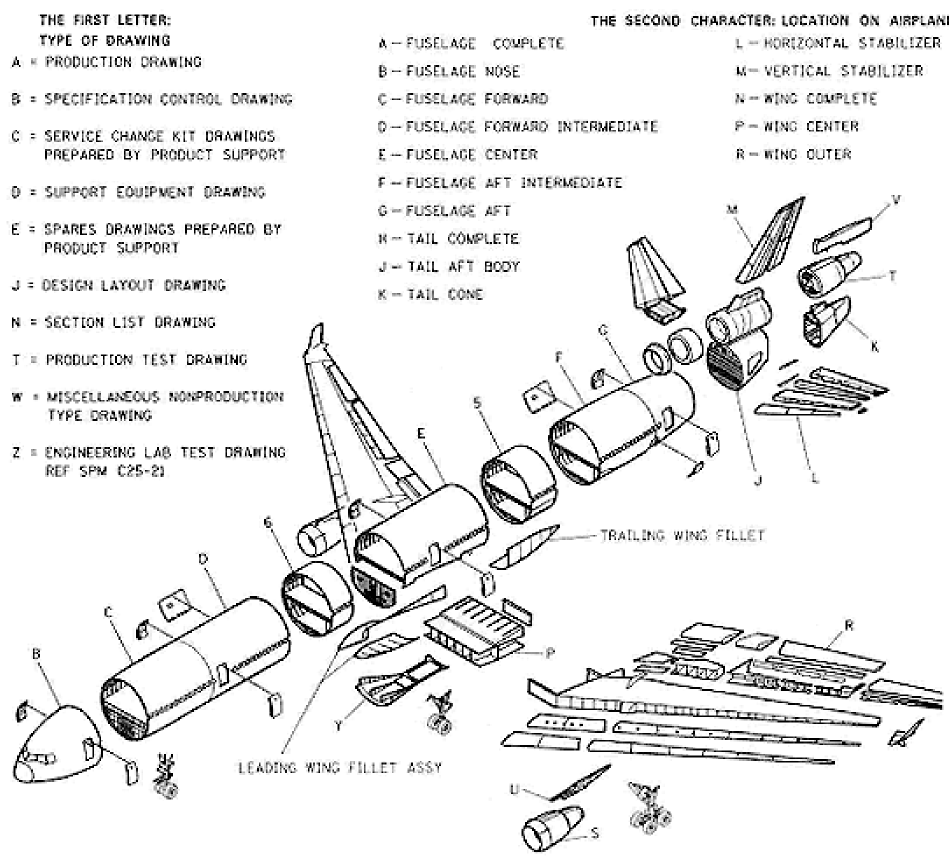
Initial response and sea operations

Numerous agencies and volunteers were involved in the initial response to the accident: the Canadian Forces Navy, Army, and Air force, the RCMP, the Department of Fisheries and Oceans, Canadian Coast Guard, Bedford Institute of Oceanography, Province of Nova Scotia's Chief Medical examiner's office, local municipal police, Emergency Preparedness Canada, provincial Emergency Measures Office, Health Canada, provincial Health Services, Canadian Security and Intelligence Service, Department of Public Works, various departments of the Province of Nova Scotia, and many others. International assistance was provided by the NTSB, Swiss AAIB, Swissair, Boeing (Douglas), the U.S. Navy's USS Grapple, the U.K. AAIB, the Air Line Pilots Association, and others. The wreckage recovery operation from the sea was long and complex, involving several thousand people, including more than 230 divers, multiple remotely operated vehicles, a heavy lift barge, a scallop dragger, and as a final cleanup operation a suction dredge ship to vacuum remaining debris from the ocean floor in the area of prime interest. After 12 months, we ended the sea operations with 98 percent of the aircraft (by weight) recovered.

The following statistics give an indication of the high volume of wreckage and data that an investigation such as SR111 entails:

- estimated 2 million pieces of wreckage/debris,
- more than 14,500 aircraft wreckage items being tracked in a database,
- 2,100 personal effects and 4,200 medical/other exhibits,
- more than 2,000 heat-damaged wires and electrical components,
- 250 km of wire,
- more than 14,000 hard-copy documents and 100,000 e-mails,
- 150,000 photos, and
- 500 videotapes.

Figure 2: Engineering drawing identification system



The logistics of the investigation has involved the use and adaptation of numerous computer databases. We have applied 3D CAD modelling and photogrammetry techniques, as well as an electronic document scanning and search system to capture, collate, and retrieve the many thousands of pages of documents and drawings. Techniques used include

- photo/video database (tracking and recording),
- victim information database (personal details and DNA),
- body modelling/crashworthiness,
- wreckage inventory and tracking,
- photogrammetry and panoramas for virtual aircraft reconstruction,
- 3D CAD modelling for fire pattern, ignition, and propagation, and
- electronic document scanning, archive, and retrieval system.

Identification of wreckage

When a large transport aircraft such as the MD-11 is involved, the identification and subsequent tracking of wreckage can be a daunting task, particularly if it is in hundreds of thousands of pieces. The TSB worked with the RCMP, the manufacturer, and the operator to put in place a system to ensure that all of the wreckage that was recovered was examined, identified, and catalogued.

The RCMP Post-Blast National Response Team, consisting of experts in forensic chemistry, identification, and explosive devices, examined all heat-damaged pieces to determine whether there were any signs of explosives or incendiary devices. Based on the direction of the TSB investigation, and their own Post-Blast Team evaluation, the RCMP concluded that there was no evidence of explosives or incendiary devices onboard SR111. In June 2000, they parked their investigation.

From the outset, the RCMP provided extensive logistical support, and their efforts ensured that all significant pieces of wreckage were documented, given an exhibit number, and entered into a database. A RCMP database called Evidence and Reports was adapted and used for this purpose. The data were subsequently imported into a software system that the TSB adopted for this investigation. The system is also capable of scanning, cataloguing, and retrieving documents, images, and photos.

The TSB utilized the expertise of the Douglas (Boeing Company) RAMs team from structures and systems, along with personnel from structural engineering, to help identify the thousands of wreckage pieces of interest. They utilized a direct computer link to their base in Long Beach, Calif., which allowed them to quickly identify the structure or component of interest. They could then obtain the necessary drawings to help in determining the proper location for any significant wreckage piece for reconstruction.

Swissair provided help on all fronts. One early contribution that was of considerable benefit was its provision of large (1:1 scale) photographs of the cockpit and avionics compartment. These photos were invaluable when attempting to identify pieces from the cockpit, as the pieces could be compared for colour and scale.

Based upon early information in the investigation, the Systems and Fire Groups focussed on the determination of the possible origin, sources of ignition, and propagation of the fire. The following is a brief overview of some of the significant areas that the Systems and Fire Groups have been involved with, and is still involved with, at the time of writing this paper.

Figure 3: Left emergency DC bus cable

Wire identification and examination

Heat-damaged wires were found early during the wreckage recovery stage (Figure 1).

The task of identifying and cataloguing the many kilometres of damaged wire required a systematic approach, which involved an assembly line to examine all of the recovered wires. It took almost 12 months to accomplish this task.

Many of the wires in the aircraft were stamped at the time of manufacture with a specific alphanumeric designation (wire number). This number corresponded to a particular wire run in the MD-11. Each stamped wire number starts with a letter, such as "B," that specifies that it is from a specific area of the fuselage. For the accident aircraft, the primary area of interest was in the barrel of the aircraft (Figure 2). All wires of interest, such as those with heat damage or with the designator, were further catalogued by adding them to a database where the wire number, length, heat damage, etc., was recorded. This database contained more than 1,100 entries of wires that had heat, soot, or arc damage. Some of the wires used in the aircraft were not stamped; therefore, it was not possible to place them in the aircraft unless their termination points could be identified. Although thousands of wires were examined, very few could be placed into a specific location within the airframe.

Arced wires

A total of 21 wires were recovered that exhibited copper melt damage. Of these, one was identified as the left emergency DC bus cable, and the melted copper was considered to have been the result of a brazing procedure during manufacture (Figures 3 and 4). The remaining 20 wires were considered to have been the result of arcing events.

The wiring used in the MD-11 was predominately of type MIL-W-81381, an aromatic polyimide, with a nickel-plated copper conductor. However, type MIL-W22759, a fluoropolymer insulation, specifically ethylene-tetrafluoroethylene, with a tin-plated copper conductor, was also used by Douglas as well as by the installers of the inflight entertainment system. Twelve of the 20 arced damaged copper conductors were tin-plated and eight were nickel plated. One of the tin-plated wires was insulated with polyimide insulation. The wires exhibiting arc damaged

Figure 4: Close up of Figure 3 (arrow) showing solid slug of copper considered to be from a braze operation during manufacture

sections ranged in length from approximately 122 cm (48 inches) to 1.3 cm (0.5 inch).

Only seven of the arc damaged wires were positively identified as to circuit function, and only two of these could be positively located within the airframe.

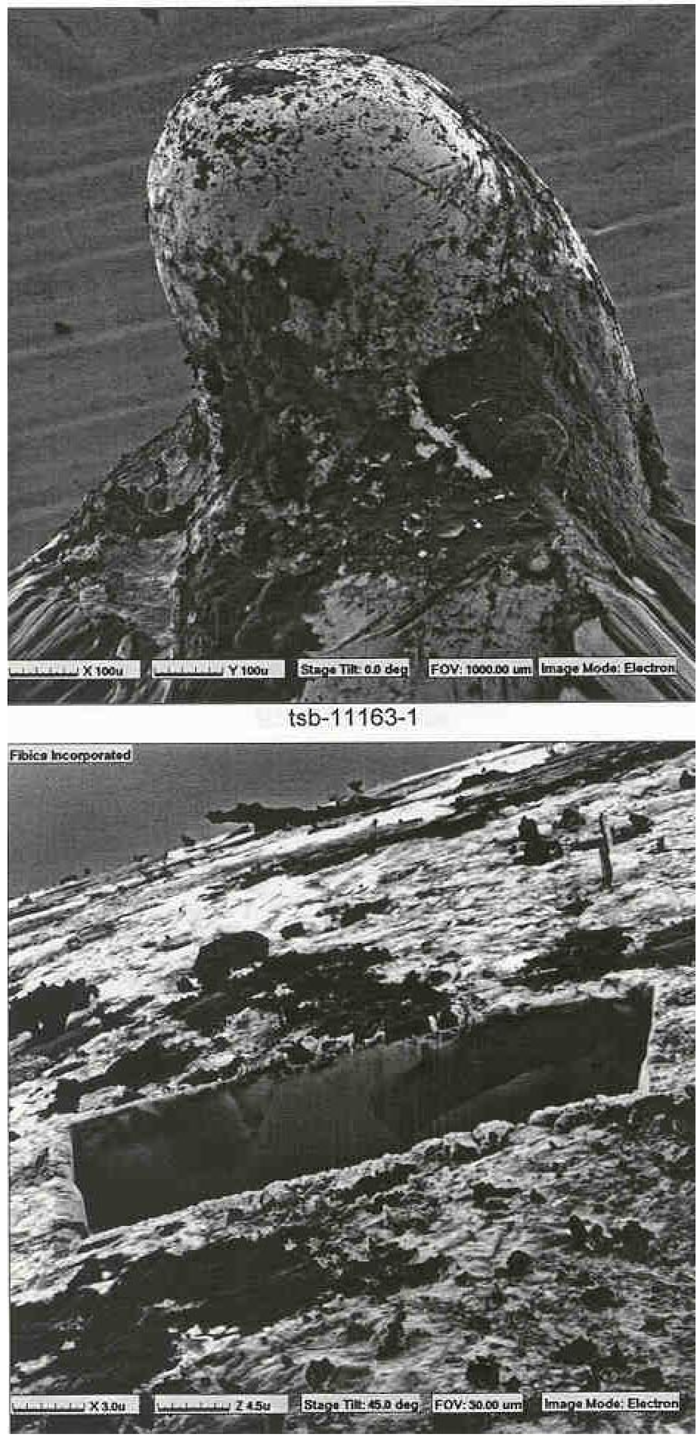
Examination of the copper arc beads

One potential fire-ignition scenario under investigation is an arcing event that ignited nearby flammable material, such as the metallized polyethylene terephthalate (PET) thermal acoustic insulation blankets. In this scenario, any one of the 20 arced wires that was recovered could have potentially been an ignition source.

Attempts are ongoing to determine if one of these wires was the initiating event. A literature review described a method using auger[1] electron spectroscopy (AES) and scanning auger microscopy (SAM) to differentiate between a wire arc that occurred in a clean environment (initiating event) and a wire that arced in a fire-contaminated environment as a result of compromised insulation. The literature reported that only small sample sizes had been examined by AES with some positive, but challenged, results. A positive aspect of this method was that it allowed for a chemical examination of the copper bead surfaces without destroying the sample.

To determine if this method of analysis had merit in this investigation, many exemplar wires were intentionally arced under various conditions to produce copper beads. This was done under controlled conditions at the Boeing electrical labs. Three methods of generating the wire samples were used: 1) wires were arced in a clean environment to simulate an initiating event, 2) wires were burned to initiate arcing—this simulated arcing caused by a fire in progress, and 3) arced beads that had previously been created in a clean environment were subjected to a fire that consisted of a Bunsen burner gas flame and aircraft materials to generate smoke that simulated a smoke environment following an arcing event. These samples were then analysed at the Materials Technology Laboratory of Natural Resources Canada using a scanning auger multiprobe. This was used as a blind test to evaluate the AES methodology.

Figure 5: Exhibit 1-10503, #16 AWG wire 5 inches long with copper bead caused by an arcing event



Auger analysis of the sample beads

To evaluate the AES methodology, 24 of the arced sample beads were provided for AES interpretation. For the samples produced in a clean environment, the method was considered to have some potential. However, for those beads having a contamination layer produced in a fire environment, the determination was more difficult, and the results were less definitive. Nevertheless, during the proof-of-concept examination work, the methodology

Figure 6: Exhibit 1-10503, #16 AWG tin-plated wire showing location where a section was removed by focus ion beam mining for TEM analysis

Figure 7: Front view of avionics panel

for examining the beads continued to evolve, generating the belief that certain refinements to the process might provide more consistent information, thereby increasing the confidence level in the results. Although the results from this testing were not encouraging, it was decided to examine all of the SR111 beads. This decision was partially based on the fact that this method was basically a nondestructive technique that would at least provide some chemical information about the arced beads.

Auger analysis of the SR111 arced bead

The SR111 arced beads had a further complication in that they were extensively contaminated with sea water, and many carried the additional complication of a heavy environmental crust or cap. A technique using focus ion beam technology[2] was used to cut and remove a plug from the bead (Figures 5 and 6). This cross-section, approximately 5 by 24 microns, was then analysed in a transmission electron microscope. Amongst other things, this process allowed for an interpretation to be made of the depth of the environmental cap. This part of the analysis is ongoing at this time.

Figure 8: Rear view of avionics CB panel

All of the SR111 arced copper beads were also examined by an X-ray transmission technique with tomographical reconstruction to obtain a 3-D image of the internal microstructure.[3] This method allows an internal area to be reconstructed as a set of flat cross sections, which can be used to identify porosity and morphological parameters such as the extent of melting and solidification, single or multiple arcing events, and inclusions. One of the benefits of using this method is that the sample is not destroyed.

Reconstruction of the avionics and overhead circuit breaker panel

The analysis of the systems anomalies recorded by the flight recorders suggested that their origin was associated with either the avionics circuit breaker panels or overhead circuit breaker panels located in the cockpit.

The numerous small pieces identified as being part of the avionics panel were painstakingly reconstructed on plexiglass (Figures 7 and 8). This allowed the fire pattern to be assessed by virtue of the change in paint colour on the front of the panel and the loss of the insulation material on the bus bars on the back of the panel. The light plate assemblies from the front of the avionics panel (made from a thermal formable plastic) were also identified, and they were added to the panel in a further attempt to determine the heat patterns.

The reconstruction proved quite useful in documenting the heat pattern across the inboard side of the avionics panel. This, along with the missing bus bar insulation from heat on the outboard side, showed a pattern that gave credibility to the theory that some circuit breakers tripped from ambient heat. A circuit breaker will trip when the ambient temperature reaches approximately 177 C (350 F).

In the production aircraft, the overhead circuit breaker panel (Figure 9) is mounted in a fibreglass tub. A plexiglass mock-up of this tub was constructed, and the pieces making up the overhead circuit breaker panel were attached to it. This allowed the power wires to the busses, and numerous other wires that entered this area to be integrated into the tub in their correct orientation.

Some pieces of the circuit breaker panels also contained the circuit breaker actuator buttons that had been captured within the folds of metal at impact. These buttons have a white indicating ring for identification of a tripped circuit breaker in service.

Figure 9: Front view of overhead reconstructed CB panel. Arrows show location of melted light plate

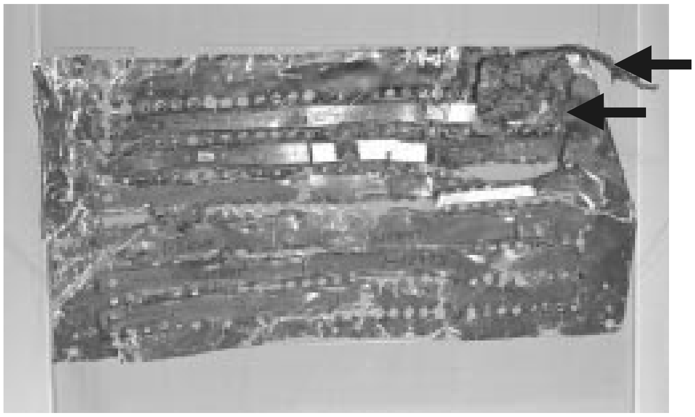


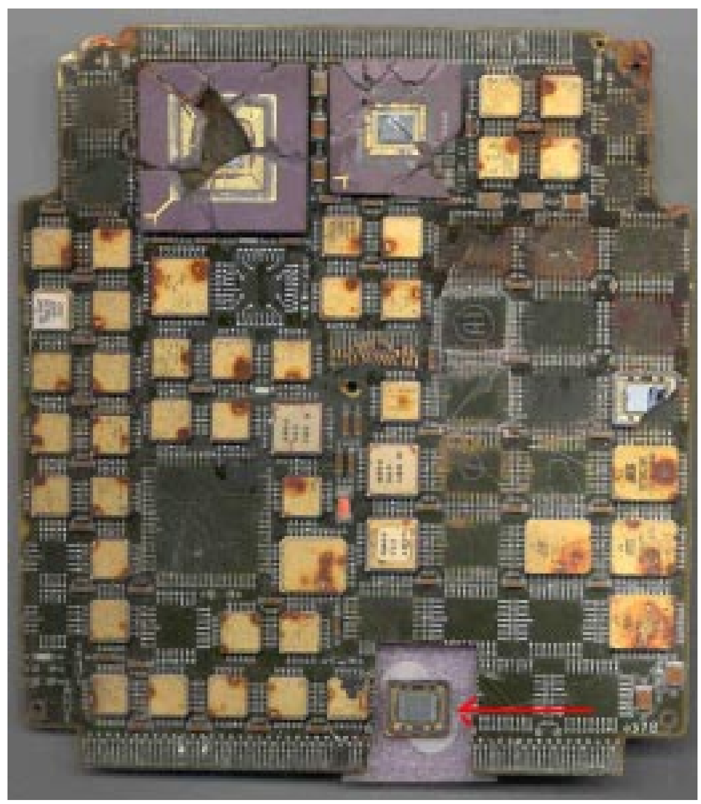
Figure 10: Upper right corner of overhead CB panel showing CB white trip indicator rings clean (upper arrow) and sooted

Some of these white rings were sooted, indicating that they had tripped prior to impact (Figure 10).

Circuit breaker study

Given that some of the recorded systems anomalies on the FDR could be associated with a tripped circuit breaker, and many of the recovered circuit breaker indicator rings were sooted, the CVR was reviewed in an attempt to determine if a circuit breaker trip could be confirmed from the CVR information. There was also the possibility that an initiating event may have tripped a circuit breaker, so the CVR was also reviewed with this in mind. Numerous clicks were recorded that could not be readily explained as microphone-keying or other known events. Therefore, it was decided to analyse the numerous clicks recorded on the CVR by comparing them to the signature of known circuit breakers tripped on another MD-11. Various methods of tripping the circuit breakers were used, such as an overload condition, or by simply pulling an unpowered circuit breaker; a lanyard was used to pull the circuit breaker to prevent any damping effect that would have been caused by using fingers. The CVR was also analysed to assess when some events took place, such as the A/P 2 disconnect event, to determine if it was caused by the tripping of a circuit breaker. Unfortunately, despite considerable effort, the results were inconclusive. The possibility that a click prior to the crew noting the smell being associated with a circuit breaker has not been ruled out. The difficulty associated with using the CVR to determine the status of circuit breakers has led the TSB to further consider the requirement for image recorders (video recording) in the cockpit as a more direct means of capturing the status of these types of events.

Figure 11: FCC printed circuit board showing NVM chip already removed. Note extent of physical damage to remaining devices



Airflow tests

To help determine a potential origin for the smoke, it was necessary to understand the airflow pattern in the hidden areas above the cockpit and forward drop ceiling. To obtain an appreciation of what the air flow pattern was in the accident aircraft prior to any smell/smoke being noted, an MD-11 was outfitted with a smoke generator and cameras, and configured as best could be determined to that of the accident aircraft. A test flight was conducted to record the airflow patterns. When doing this type of test, it is imperative to generate sufficient smoke to be picked up by the cameras, and to ensure that none of the smoke generator tubing is pinched, which could result in a reduction of smoke.

NVM identification and data recovery

With the loss of the FDR and CVR 6 minutes before water impact, other avenues to collect electronically stored data were ex-

Figure 12: FADEC electronic control for Engine 2

Figure 13: FADEC electronic engine control for Engine 3

plored. Many of the line replaceable units (LRUs) onboard the MD-11 contained nonvolatile memory chips from which useful aircraft performance data could potentially be extracted. Unfortunately, nearly all of the LRUs located in the avionics compartment were destroyed at impact. This dislodged the circuit boards, which broke into numerous pieces. Once a circuit board is no longer attached to its housing, simple identification as to which unit it came from becomes a challenge.

The LRU manufacturers provided binders of photographs detailing the circuit boards contained in their LRUs and assisted in the identification work. However, even when a circuit board was matched to a particular avionics box, it was difficult to identify which device contained the memory. Of all of the hundreds of circuit boards examined, only a single flight control computer (FCC) chip was identified (Figure 11). Analysis of this particular device provided information that was already available from the FDR. What would have helped significantly

Figure 14: Crew oxygen line above cockpit ceiling showing an AN929-6 aluminum cap on the end of a stainless steel fitting

in the initial wreckage sorting operations would have been the ability to quickly determine which circuit boards contained NVM chips by having them readily identifiable as NVM chips.

The Pratt and Whitney PW4462 engines were equipped with full authority digital electronic controls (FADECs) that contained NVM (EEPROM) chips. The FADECs from Engines 2 and 3 (Figures 12 and 13, respectively) were recovered, along with the NVM chips, which were downloaded. Only pieces of the FADEC 1 were recovered, and the NVM chips had been stripped from their circuit board.

The FADEC fault information is stored in 20-minute increments and is not correlated to aircraft time. Furthermore, the faults are not stored in chronological sequence, making it more of a challenge to determine when a particular fault was logged. The information recovered from FADEC 2 enabled a determination that Engine 2 was shut down by use of the fuel shut-off switch at approximately 1,800 feet.

Crew oxygen system

The crew oxygen line consisted of stainless steel tubing. It was routed from the oxygen bottle in the avionics compartment, up the left side of the aircraft, across the top of the cockpit ceiling, and then down the right side. Of particular interest was an aluminum AN929-6 cap attached to a stainless steel tube located above the cockpit ceiling (Figure 14). There was a possibility that heat could cause the aluminum cap to fail, depleting the oxygen to the crew and possibly aggravating a fire. The MD-11 uses stainless tubing in many areas, and it was not obvious which tubing came from the oxygen line. All of the recovered tubing was segregated and sorted, and those pieces that appeared to meet the material requirements for the oxygen line were further tested by energy dispersive X-ray analysis for material confirmation.

Inflight entertainment system

The involvement of the IFE system as a potential ignition source for the fire stems from the fact that the four sets of triple twisted power wires that provide power to the IFE power supplies all exhibited arcing damage. These wires were examined along with the other arced wires from the aircraft. None of the IFE components recovered and examined exhibited any evidence of being significantly heat damaged.

One of the initial observations from the investigation was that the IFE system installed in first and business class areas was connected to a power source that could not be disconnected with the cabin bus switch. Selecting the cabin bus switch was the first item in the checklist for smoke/fumes of unknown origin. Activation of the cabin bus switch turns off the majority of non-essential power to the cabin and isolates the cabin equipment to allow the crew to assess if the smoke is being generated by the cabin equipment. Early in the investigation, Swissair disconnected the IFE systems in the remainder of its aircraft, and subsequently removed the systems entirely.

Subsequently, the FAA looked at another 180 IFE STC installations and issued airworthiness directives against 14 of them.

HIRF/EMI

There has been considerable media interest associated with high-intensity radiated field and electromagnetic interference with respect to aircraft accidents. To date, there has been no factual information uncovered to support that HIRF/EMI played any role in the SR111 accident. TSB reviewed the MD-11 certification program and collected information about any potential HIRF/EMI threats, fixed and mobile. A review of this information indicated that the MD-11 aircraft was tested and certified to withstand electromagnetic field strengths that exceeded the maximum theoretical field strengths produced by known commercial and military emitters.

After departing from JFK International Airport, the most significant source of HIRF, for SR111, originated from an AN/FPS-117 air route surveillance radar located near Barrington, Nova Scotia. The maximum electromagnetic field strength produced by the Barrington radar site was substantially lower than the field strength predicted to exist at major commercial airports during normal arrival and departure operations. The corresponding power density was much lower than the power density of solar radiation at sea level. The electromagnetic fields, to which SR111 was exposed, were several orders of magnitude lower than the field strength required to induce sparking between exposed wires separated by a narrow gap or to ignite other materials in the fire-damaged area.

Safety issues and future direction

Throughout the investigation, the TSB has taken a broad, systemic approach to the evaluation of various safety deficiencies that have been identified. Considerable effort has been devoted to the validation and promulgation of these deficiencies. To date, the TSB has issued 14 air safety recommendations to address a number of concerns in the areas of equipment design, certification and equipment, material flammability standards, testing procedures, inflight firefighting measures, and crew training and procedures. The TSB is validating a number of additional safety issues as the report is being finalised.

Recommendations posted to date include the following:

Flight recorder duration and power supply (March 9, 1999)

• As of Jan. 1, 2003, any CVR installed on an aircraft as a condition of that aircraft receiving an original certificate of airworthiness be required to have a recording capacity of at least 2 hours.
A99-01

• As of Jan. 1, 2005, all aircraft that require both an FDR and a CVR be required to be fitted with a CVR having a recording capacity of at least 2 hours.
A99-02

• As of Jan. 1, 2005, for all aircraft equipped with CVRs having a recording capacity of at least 2 hours, a dedicated independent power supply be required to be installed adjacent or integral to the CVR, to power the CVR and the cockpit area microphone for a period of 10 minutes whenever normal aircraft power sources to the CVR are interrupted.
A99-03

• Aircraft required to have two flight recorders be required to have those recorders powered from separate generator buses.
A99-04

Thermal acoustical insulation materials and flammability test criteria (Aug 11, 1999)

• Regulatory authorities confirm that sufficient action is being taken, on an urgent basis, to reduce or eliminate the risk associated with the use of metallized PET-covered insulation blankets in aircraft.
A99-07

• On an urgent basis, regulatory authorities validate all thermal acoustical insulation materials in use, or intended for use, in applicable aircraft, against test criteria that are more rigorous than those in Appendix F of FAR 25.853, and similar regulations, and that are representative of actual in-service system performance.
A99-08

Inflight firefighting (Dec. 4, 2000)

• Appropriate regulatory authorities, in conjunction with the aviation community, review the adequacy of inflight firefighting as a whole, to ensure that aircraft crews are provided with a system whose elements are complementary and optimized to provide the maximum probability of detecting and suppressing any inflight fire.
A00-16

• Appropriate regulatory authorities, together with the aviation community, review the methodology for establishing designated fire zones within the pressurized portion of the aircraft, with a view to providing improved detection and suppression capability.
A00-17

• Appropriate regulatory authorities take action to ensure that industry standards reflect a philosophy that when odour/smoke from an unknown source appears in an aircraft, the most appropriate course of action is to prepare to land the aircraft expeditiously.
A00-18

• Appropriate regulatory authorities ensure that emergency checklist procedures for the condition of odour/smoke of unknown origin be designed so as to be completed in a timeframe that will minimize the possibility of an inflight fire being ignited or sustained.
A00-19

• Appropriate regulatory authorities review current inflight firefighting standards including procedures, training, equipment, and accessibility to spaces such as attic areas to ensure that aircraft crews are prepared to respond immediately, effectively, and in a coordinated manner to any inflight fire.
A00-20

Materials flammability standards (Aug. 28, 2001)

• For the pressurized portion of an aircraft, flammability standards for material used in the manufacture of any aeronautical product be revised, based on realistic ignition scenarios, to prevent the use of any material that sustains or propagates fire.
A01-02

• A certification test regime be mandated that evaluates aircraft electrical wire failure characteristics under realistic operating conditions and against specified performance criteria, with the goal of mitigating the risk of ignition.
A01-03

• As a prerequisite to certification, all aircraft systems in the pressurized portion of an aircraft, including their sub-systems, components, and connections, be evaluated to ensure that those systems whose failure could exacerbate a fire in progress are designed to mitigate the risk of fire-induced failures.
A01-04

In addition to the 14 TSBC aviation safety recommendations listed above, several safety advisory letters have been promulgated to date, dealing with issues that include aircraft wiring, flight crew reading lights, overhead aisle and emergency lights, ATS controller training, and standby (secondary) flight instruments. These safety communications can be found at www.tsb.gc.ca.

Summary

In summary, the SR111 investigation to date has been a cooperative effort among dedicated people from all levels of governments within Canada, and serves as a fine example of international cooperation. International participation at the government, company, and citizen level has assisted us greatly in this challenging investigation. Some of the valuable outcomes so far have been the positive safety actions taken in many areas since this accident, at least partly in response to, or influenced by, the various formal and informal safety communications that the TSB has undertaken. A substantial effort has been made, and continues to be made internationally, by regulators, manufacturers, and operators to advance transportation safety in these and other areas highlighted during the SR111 investigation. There is more yet to be done, but it is gratifying to see that aviation safety is being advanced by our collective efforts. ◆

Footnotes

[1] AES and SAM identifies elemental compositions of surfaces by measuring the energies of Auger electrons. It can detect all elements except H and He in the outermost 20A of a solid.

[2] This work was accomplished though Fibics, Inc., Ottawa.

[3] This work was accomplished through SkyScan, Belgium.