4.0 Safety Action

Based on the safety deficiencies identified in this occurrence, the Board has issued a series of safety communications. Initiatives undertaken by others to enhance safety have also been identified. This part presents the following information:

- Safety actions taken—initiatives undertaken by aviation regulatory authorities and others;
- Safety actions required—recommendations the Board considers necessary to address systemic safety deficiencies posing the highest risk; and
- Safety concerns—issues the Board has deemed do not warrant recommendations at this time but that provide a marker to the industry and regulatory authorities.

Those issues dealing with systemic safety deficiencies are communicated to government aviation regulators, the aviation industry, and the public in the form of an Aviation Safety Recommendation (ASR). Safety deficiencies that are deemed to present lesser risks are communicated through either an Aviation Safety Advisory (ASA) or an Aviation Safety Information Letter (ASIL). In addition, informal communications with various stakeholders and the provision of public briefings complement the Transportation Safety Board of Canada's (TSB) formal safety communications.

4.1 Action Taken

This section is organized chronologically according to the TSB's safety communications. Each safety communication is followed by associated safety action undertaken by various stakeholders, Transport Canada (TC), the United States (US) National Transportation Safety Board (NTSB), the US Federal Aviation Administration (FAA), Boeing, Swissair, SR Technics, and so on.

4.1.1 MD-11 Wiring

4.1.1.1 Transportation Safety Board of Canada

Aircraft wiring was of immediate and ongoing interest to the investigation team. The team inspected several MD-11 aircraft in order to identify potential areas of arcing or sources of heat generation. These inspections yielded wiring discrepancies that included chafed, cut, and cracked wires. Inconsistencies in wire and wire bundle routing were also discovered, which raised concern about the overall integrity of the MD-11's wiring system. While the investigation team could not establish a direct relationship between the in-service wiring discrepancies and the wires recovered in the Swissair Flight 111 (SR 111) wreckage, the team felt that the data warranted a wider review to better define the risk to the MD-11 fleet. Therefore, on 22 December 1998, the TSB sent an ASA (980031-1) (STI4-1) to the NTSB concerning the MD-11 wiring issues.

4.1.1.2 United States National Transportation Safety Board

Shortly after receiving the TSB's ASA (980031-1), on 11 January 1999, the NTSB recommended that the FAA require an inspection of all MD-11 aircraft for wiring discrepancies (NTSB Recommendation A-99-3 available at www.ntsb.gov). The NTSB recommended that the inspection concentrate in and around the cockpit overhead circuit breaker (CB) panel and the avionics CB panel. The inspection should also include examinations for loose wire connections, inconsistent wire routing, broken bonding wires, small-wire bend radii, and chafed or cracked wire insulation.

4.1.1.3 United States Federal Aviation Administration
In early 1999, the FAA responded to the NTSB's recommendation by issuing an MD-11 Airworthiness Directive (AD) requiring inspections to determine whether wiring discrepancies exist that could cause electrical arcing. Such arcing could cause a fire or smoke or both in the cockpit or cabin. Based on the results of these inspections, the FAA launched a two-phase MD-11 Wiring Corrective Action Plan. The first phase consisted of three ADs that focused on the areas of concern highlighted in the TSB's safety advisory. Subsequently, the FAA, working closely with Boeing, launched the second phase, which consisted of five Corrective Action Packages, each comprising a series of ADs. Each AD was based on a Boeing-generated MD-11 Service Bulletin (SB). As of 10 May 2002, the MD-11 Wiring Corrective Action Plan had yielded 41 related ADs with additional SBs undergoing Notice of Proposed Rulemaking (NPRM) review. In a parallel initiative, the FAA used lessons learned from the SR 111 investigation to shape its "Aircraft Wiring Practices" interactive training program for FAA certification engineers, designated engineering representatives, and aviation safety inspectors. In addition, the FAA has produced an Internet-based training aid entitled, "Aircraft Wiring Practices (Job Aid)" (available at www.academy.jccbi.gov/AIRDL/wiringcourse).

In August 2001, the FAA launched the Enhanced Airworthiness Program for Airplane Systems (EAPAS), designed to address the realities of an aging transport aeroplane fleet. Presently, EAPAS is focused on aging wiring systems. Short-term objectives are those that raise awareness of aging wiring systems, and that implement basic changes to maintenance and training programs. Long-term objectives will concentrate on institutionalizing the management of aging wiring systems.

During the course of this investigation, the FAA requested that the Air Transport Association introduce a new reporting code (sub-chapter 97) to facilitate more accurate tracking of specific wire-related problems and anomalies.

4.1.1.4 The Boeing Company
In addition to its integral support for the FAA's MD-11 Wiring Corrective Action Plan, Boeing responded to the need for additional technical training with respect to wiring by developing a wiring inspection course for airline and government agencies. Furthermore, these initiatives have resulted in enhancements to Boeing's *Standard Wiring Practices Manual*.

4.1.1.5 Swissair
The need to enhance technical training with respect to wiring was also recognized by Swissair. Subsequently, SR Technics revised its technician training syllabus to include such topics as wire cleanliness, handling, protection, and grounding. They have also developed a series of engineering orders to comply with all applicable ADs called for in the FAA's MD-11 Wiring Corrective Action Plan, and have mandated several special inspections related to wiring issues.

4.1.1.6 Swiss Federal Office for Civil Aviation
As is the practice of the Swiss Federal Office for Civil Aviation (FOCA), all ADs issued by the FAA in relation to the MD-11 wiring issue have been reviewed and reissued as Swiss ADs.

4.1.2 Flight Recorder Duration and Power Supply

4.1.2.1 Transportation Safety Board of Canada
Shortcomings related to the duration of cockpit voice recorder (CVR) recordings and the supply of electrical power to the flight data recorder (FDR) have been identified during this and other aircraft accident investigations. Consequently, on 9 March 1999, the TSB issued four ASRs

(A99-01 through A99-04) (STI4-2) (STI4-3) (STI4-4) (STI4-5) to TC and the Joint Aviation Authorities (JAA), dealing with CVR duration, independent power supply, and the use of separate electrical buses. A lack of recorded voice and other aural information can inhibit safety investigations, and delay or prevent the identification of safety deficiencies. Given the need for longer periods of recorded sound to capture the initiating events of aviation accidents, and the availability of two-hour CVRs, the TSB believed that such recorders should be mandated by regulatory authorities worldwide. However, it also recognizes that a period of several years may be reasonably required for manufacturers and operators to implement this change. Therefore, for newly manufactured aircraft, the TSB made the following recommendation:

As of 01 January 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 two hours. A99-01 (issued 9 March 1999) (STI4-6)

In addition, the TSB believes that, with appropriate lead time, a retrofit program is warranted for aircraft already in service. Therefore, the TSB made the following recommendation:

As of 01 January 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 two hours. A99-02 (issued 9 March 1999) (STI4-7)

When aircraft power to the SR 111 flight recorders was interrupted at 10 000 feet, the FDR and CVR stopped recording. The aircraft continued to fly for about six minutes with no on-board information being recorded. This lack of recorded information hampered the accident investigation.

With maintenance-free independent power sources, it is now feasible to power new-technology CVRs and the cockpit area microphone (CAM) independently of normal aircraft power for a specific period of time in the event that aircraft power sources to the CVR are interrupted or lost. Therefore, to enhance the capture of CVR information needed for accident investigation purposes, the TSB made the following recommendation:

As of 01 January 2005, for all aircraft equipped with CVRs having a recording capacity of at least two 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 (issued 9 March 1999) (STI4-8)

At the time of the occurrence, FDR and CVR installation in MD-11 aircraft were both powered from AC Generator Bus 3. The Smoke/Fumes of Unknown Origin Checklist (see Appendix C – Swissair Smoke/Fumes of Unknown Origin Checklist) requires the use of the SMOKE ELEC/AIR selector. This switch is used to cut power to each of the three electrical buses in turn in order to isolate the source of the smoke/fumes. The nature of this troubleshooting procedure requires that the switch remain in each position for an indeterminate amount of time, typically at least a few minutes. When the SMOKE ELEC/AIR selector is in the first (3/1 OFF) position, alternating current (AC) Generator Bus 3 is turned off, thereby simultaneously disabling the FDR and the CVR.

With both the CVR and the FDR on the same generator bus, a failure of that bus, or the intentional disabling of the bus (e.g., the result of checklist actions in an emergency), will result in both recorders losing power simultaneously. To enhance the capture of information needed for the identification of safety deficiencies, the TSB made the following recommendation:

Aircraft required to have two flight recorders be required to have those recorders powered from separate generator buses. A99-04 (issued 9 March 1999) (STI4-9)

4.1.2.2 United States National Transportation Safety Board

Coincidently, the NTSB issued recommendations A-99-16 through A-99-18 to the FAA, which contain the same elements as the TSB recommendations. The NTSB also recommended that aircraft be fitted with two combination CVR/digital flight data recorder (DFDR) recording systems. As described in Section 4.1.2.3, the FAA has yet to begin NPRM action in response to the NTSB recommendations. As of 25 July 2001, the NTSB regarded as unacceptable the amount of progress made in the two years since the recommendations were issued. The NTSB continues to urge the FAA to act expeditiously on these recommendations but remains sceptical that the dates for final action can be met.

4.1.2.3 United States Federal Aviation Administration

The FAA agreed with the intent of the NTSB recommendations and indicated that it would initiate NPRM action by the end of summer 1999. By August 1999, the FAA advised the NTSB that because of competing priorities, the NPRM would be delayed until March 2000. Responding to an update request from the NTSB dated June 2000, the FAA announced in April 2001 that rulemaking based on the CVR/FDR recommendations would be further delayed until the end of 2001. As of this writing, the FAA advises that NPRM action will take place in the spring of 2003.

4.1.2.4 Transport Canada

TC responded to the TSB's recommendations with respect to flight recorders and power supply by indicating that it was TC's intention to harmonize its position with the JAA and address the FAA's NPRMs at an appropriate Canadian Aviation Regulation Advisory Council meeting. Therefore, TC's implementation timetable is linked to the FAA schedule.

4.1.2.5 The Boeing Company

Boeing published SB MD11-31-101 on 19 December 2001, which allows MD-11 recorders to be powered by separate buses. Incorporation of the SB will result in the CVR being powered by the right emergency bus, and the digital flight data acquisition unit/DFDR by the Engine 1 AC generator bus.

4.1.3 Thermal Acoustic Insulation Materials

4.1.3.1 Transportation Safety Board of Canada

As of August 1999, the SR 111 investigation had revealed fire damage in the ceiling area forward,
and several metres aft, of the cockpit wall. There were clear indications that a significant source of the combustible materials that sustained the fire was thermal acoustic insulation blanket (insulation blanket) materials. Burnt remnants of this material, caused by the in-flight fire, were found in the wreckage; the fire was extinguished upon impact with the water.

Shortcomings related to the in-service fire resistance of some thermal acoustic insulation materials, and weaknesses in the test criteria used to certify those materials, have been identified during this and other recent aircraft occurrence investigations. Subsequently, the TSB issued recommendations (A99-07 and A99-08) dealing with the risks associated with the flammability of metallized polyethylene terephthalate (MPET)–covered insulation blankets and the test criteria that certified this material for aircraft use.

The in-service history; the demonstrated flammability of the MPET cover material; and the discovery, in the SR 111 wreckage, of remnants of insulation blankets with burnt cover material suggest that MPET cover material was a significant source of the combustible materials that propagated the fire. It is the TSB's view that the operation of aircraft outfitted with insulation blankets incorporating MPET cover material constitutes an unnecessary risk. Therefore, the TSB made the following recommendation:

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 (issued 11 August 1999) (STI4-10)

A review of incidents involving cover materials other than those involving MPET (e.g., non-metallized polyethylene terephthalate) polyester film revealed that the limitations of *Federal Aviation Regulation* (FAR) 25.853, Appendix F, test criteria may not be confined to its inability to accurately and reliably identify the flammability characteristics of MPET-type cover material.

On 14 October 1998, the FAA stated that the test criteria used to certify the flammability characteristics of thermal acoustic insulation materials were inadequate, and committed itself to conduct the research necessary to establish a more comprehensive test standard. At the same time, the FAA indicated that because materials containing polyimide film have performed well in preliminary flammability tests, these materials would be considered compliant under the new regulation. Until adequate flammability test criteria are available, it is not possible to determine whether polyimide film, or other materials, provide adequate protection against fire propagation. Thermal acoustic insulation materials are installed in aircraft as a system, including such related components as tape, fasteners, and breathers. The TSB believed that thermal acoustic insulation materials for use in aircraft must be judged against more valid flammability test criteria—not as individual components, but as a system. Therefore, the TSB made the following recommendation:

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 (issued 11 August 1999) (STI4-11)

4.1.3.2 United States Federal Aviation Administration

The FAA responded to TSB recommendation A99-07 by issuing two NPRMs (99-NM-161-AD and 99-NM-162-AD). The NPRMs proposed the removal of MPET-covered insulation blankets from all US-registered aircraft. The final rule regarding these proposals came in May 2000 when the FAA issued two ADs (AD 2000-11-01 and AD 2000-11-02 available at www.faa.gov), which required the removal of all MPET-covered insulation blankets. These ADs were based on existing McDonnell Douglas (MD) SBs, which call for the replacement of the MPET-covered insulation blankets.

In response to TSB recommendation A99-08, the FAA accelerated a project to develop an improved certification flammability test for all thermal acoustic insulation materials. An NPRM (Docket FAA-2000-7909; Notice 00-09) was issued in September 2000 and the final rule is on hold pending a plain language review and rewrite. In the interim, the FAA issued Flight Standards Information Bulletin for Airworthiness 00-09 to ensure that 14 *Code of Federal Regulations* (CFR) Parts 121 and 125 operators have established procedures for the inspection of thermal acoustic insulation materials for any contamination during heavy maintenance checks.

4.1.3.3 Transport Canada

Although there are currently no aircraft in the Canadian register built with MPET-covered insulation blankets, TC conducted a survey to confirm that no Canadian-registered aircraft had used MPET-covered insulation blankets during a wholesale replacement program. Additionally, they worked with Bombardier Inc. to remove MPET-type tape from their RJ Series 700 specification.

4.1.3.4 Swissair

Prior to issuing the FAA ADs regarding MPET-covered insulation material, Swissair worked with Boeing to identify the high-risk areas of the MD-11 aircraft and by March 2001 had voluntarily replaced selected MPET-covered insulation blankets. Upon receipt of the FAA's

AD 2000-11-02, Swissair began a complete MPET-covered insulation blankets replacement program on their MD-11 fleet. As of January 2003, the AD had been accomplished on 11 MD-11s previously owned by Swissair.

4.1.3.5 Swiss Federal Office for Civil Aviation

The Swiss FOCA reviewed and reissued AD 2000-11-02 as a Swiss AD 2000-414.

4.1.4 MD-11 Flight Crew Reading Light (Map Light)

4.1.4.1 Transportation Safety Board of Canada

During an MD-11 wiring inspection carried out as part of an insulation blanket replacement program, it was noted that an insulation blanket was in contact with the upper part of the recessed map light installed on the right side of the cockpit ceiling. The MPET-covered insulation material had been imprinted and mechanically damaged by the back of the map light fixture, which houses a halogen lamp. Also, one of the ring terminal insulators attached to a wire lead that was attached to the map light, exhibited heat damage. Examination of the left map light found similar but lesser damage. No damage was reported for the observer station map light installations.

This discovery prompted an inspection of 12 additional MD-11 aircraft, which revealed various discrepancies, including cracked protective covers, repairs not in accordance with the component maintenance manual, heat deformation, evidence of arcing, and heat discolouration. In light of the identified flammability risks associated with MPET-covered insulation blankets, the TSB forwarded an ASA (A000008-1) (STI4-12) to the NTSB so that it could review these preliminary findings and forward them to the FAA.

Subsequently, the SR 111 investigation revealed additional failure modes associated with the map light installation. On 29 December 2000, the TSB issued an ASIL (A000061-1) (STI4-13) apprising stakeholders of these developments.

4.1.4.2 United States National Transportation Safety Board

The NTSB agreed that more should be done to determine the extent of the problem and sent a letter to the FAA encouraging it to take whatever action necessary to alleviate the problems outlined in TSB’s ASA A000008-1.

4.1.4.3 United States Federal Aviation Administration

Based on Boeing’s Alert Service Bulletin (MD-11 33A069), the FAA issued AD 2000-07-02, which mandated a recurring inspection for the affected lights in the MD-11 cockpit. In January 2001, this AD was superseded by AD 2000-26-15, which required operators of affected aircraft equipped with map lights, as part of their aircraft’s “Skybunk” installations, to include these as part of the original recurring inspection requirement. On 15 May 2001, the FAA approved the Hella SB 2LA005916-33-003 as an alternate means of compliance. While incorporating this SB does not terminate the AD, it changes the inspection cycle from every 700 hours to once a year. The AD will remain in force until such time as the unsafe condition related to the map light has been eliminated.

4.1.4.4 Hella Aerospace

Hella Aerospace is working with Boeing to develop various design improvements to address the map light failure modes discovered during the SR 111 investigation. Proposed design changes include reinforced contact spring protective covers to minimize possibility of cracking and breakage, use of protective covers on the carrier frame to avoid metal-to-metal contact, relocation of spare bulb holder to avoid contact with the ON/OFF switch, and reforming of support brackets to reduce possibility of contact with terminal lugs. As an interim measure, Hella issued SB 2LA005916-33-003 dated 12 December 2000, which incorporates some of these changes. Hella advises that a successful design review, in cooperation with Boeing Engineering, took place in August 2002. Documentation regarding the final flight crew reading light (FCRL) redesign has been forwarded to Boeing and production of the new map light series, based on these product improvements, began in November 2002.

4.1.4.5 Swiss Federal Office for Civil Aviation

The Swiss FOCA reviewed and reissued AD 2000-07-02 as Swiss AD 2000-246 and AD 2000-26-15 as Swiss AD 2001-109.

4.1.4.6 Swissair

In June 2001, SR Technics issued engineering order (EO) 217609.01 to incorporate Hella's SB 2LA005916-33-003. The EO modifies the FCRL (map light) to improve its short-circuit protection.

This is accomplished in a variety of ways, including the replacement of the 11.5 watt (W) halogen lamp with a 7.0 W incandescent bulb. SR Technics advises that the EO was fully implemented as of March 2002.

4.1.5 In-Flight Firefighting

4.1.5.1 Transportation Safety Board of Canada

The SR 111 investigation identified safety deficiencies associated with in-flight firefighting measures. Subsequently, the TSB issued five ASRs (A00-16 through A00-20) (STI4-14) (STI4-15) (STI4-16) (STI4-17) (STI4-18) that identified safety deficiencies with respect to in-flight firefighting. The identified safety deficiencies increase the time required to assess and gain control of what could be a rapidly deteriorating situation and reflect a weakness in the efforts of governments and industry to recognize the need for dealing with in-flight fire in a systematic and effective way.

The TSB believes that the risk to the flying public can be reduced by re-examining fire-zone designations in order to identify additional areas of the aircraft that should be equipped with enhanced smoke/fire detection and suppression systems. Therefore, the TSB made the following recommendation:

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 (issued 4 December 2000) (STI4-19)

Along with initiating the other elements of a comprehensive firefighting plan, it is essential that flight crews give attention, without delay, to preparing the aircraft for a possible landing at the nearest suitable airport. Therefore, the TSB made the following recommendation:

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 (issued 4 December 2000) (STI4-20)

Aircraft accident data indicate that a self-propagating fire can develop quickly. Therefore, odour/smoke checklists must be designed to ensure that the appropriate troubleshooting procedures are completed quickly and effectively. The TSB is concerned that this is not the case, and made the following recommendation:

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 time frame that will minimize the possibility of an in-flight fire being ignited or sustained. A00-19 (issued 4 December 2000) (STI4-21)

An uncontrollable in-flight fire constitutes a serious and complicated emergency. A fire may originate from a variety of sources, and can propagate rapidly. Time is critical. Aircraft crews must be knowledgeable about the aircraft and its systems, and be trained to combat any fire quickly and effectively in all areas, including those that may not be readily accessible. The TSB believes that the lack of comprehensive in-flight firefighting procedures, and coordinated aircraft crew training to use such procedures, constitutes a safety deficiency. Therefore, the TSB made the following recommendation:

Appropriate regulatory authorities review current in-flight 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 in-flight fire. A00-20 (issued 4 December 2000) (STI4-22)

In-flight firefighting "systems" should include all procedures and equipment necessary to prevent, detect, control, and eliminate fires in aircraft. This systems approach would include material flammability standards, accessibility, smoke/fire detection and suppression equipment, emergency procedures and training. All of these components should be examined together and the inter-relationships between individual firefighting measures should be reassessed with a view to developing improved, comprehensive firefighting measures. The TSB believes that an in-flight firefighting system, developed according to a systematic approach and consisting of complementary elements, would result in the most effective in-flight firefighting system; therefore, the TSB made the following recommendation:

Appropriate regulatory authorities, in conjunction with the aviation community, review the adequacy of in-flight 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 in-flight fire. A00-16 (issued 4 December 2000) (STI4-23)

4.1.5.2 United States Federal Aviation Administration/Transport Canada

Both the FAA and TC concurred with the TSB's position with respect to in-flight firefighting, and have advised that a review of existing programs is underway. Upon completion of the review, both regulators, in conjunction with the JAA, will take a harmonized approach to improving the in-flight firefighting system. As of March 2002, the program review involved the following activities:

- Developing fire tests for materials in inaccessible areas;
- Developing the most effective means to gain access to hidden areas for the firefighting purposes;
- Determining the feasibility of fire detection and suppression systems in inaccessible areas;
- Exploring the feasibility of water spray and nitrogen suppression systems;
- Developing improved fire/smoke detection systems;
- Developing ultra fire-resistant interior materials;
- Enhancing tools to allow for accurate risk assessment of aircraft wiring system threats;
- Developing new CB technology to prevent the harmful effects of arcing and arc tracking; and
- Developing certification criteria for new fire detector sensor technology.

4.1.5.3 The Boeing Company

Boeing issued a Flight Operations Bulletin (MD-11-99-04) to all MD-11 operators that discussed various options for dealing with smoke in the cockpit. Boeing also established a Boeing Smoke/Fire Committee to study the operational impact of smoke and fire events on each Boeing-manufactured aircraft.

4.1.5.4 Swissair

4.1.5.4.1 MD-11 Checklists

Swissair issued an *Aircraft Operations Manual* (AOM) Bulletin (90/99) advising its MD-11 flight crews of a revision to the Smoke/Fumes of Unknown Origin Checklist (see Appendix C – Swissair Smoke/Fumes of Unknown Origin Checklist). Swissair decided to change the checklist to ensure that the EMER LT switch is selected before the CABIN BUS switch is selected. This change was based on an incident on a flight from Singapore to Zurich, during which the cabin crew had to deal with a "dark cabin" after the CABIN BUS switch had been selected. By design, the emergency lights in the cabin do not come on by selecting the CABIN BUS switch to the OFF position, even if the emergency lights are armed.

To save time when following this checklist, Swissair also instructed its MD-11 flight crews to proceed directly to the SMOKE ELEC/AIR selector checklist item, thereby eliminating the requirement to evaluate the results of de-powering the cabin bus and the need to restore power to the cabin bus.

In March 1999, after intensive discussion with the aircraft manufacturer on the new revision, Swissair conducted a test flight in aircraft HB-IWR to validate the new checklist procedure.

Swissair issued an AOM Bulletin (94/99) to advise its MD-11 flight crews about supplemental information on in-flight smoke/fire. The AOM Bulletin describes the Boeing Flight Operations Bulletin MD-11-99-04, "Supplemental Information to MD-11 Flight Crews on Inflight Smoke/Fire Procedures."

In 1993, the MD-11 manufacturer had decided to eliminate the Air Conditioning Smoke Checklist (see Appendix B – Swissair Air Conditioning Smoke Checklist) because all items covered in this checklist were included in the Smoke/Fumes of Unknown Origin Checklist. However, at this time, Swissair decided to keep the Air Conditioning Smoke Checklist because that checklist would provide a faster method of isolating the specific source of smoke/fumes when they were known to be coming from the air conditioning system. Swissair considered the use of this Air Conditioning Smoke Checklist to be less disruptive to aircraft systems, such as flight displays, communications and navigation systems, than the use of the Smoke/Fumes of Unknown Origin Checklist, which requires the generator buses to be turned off sequentially.

In AOM Bulletin (94/99), Swissair also advised its MD-11 flight crews about a revision to its emergency procedures with respect to dealing with smoke and fumes. Swissair indicated that "under certain circumstances the identification of a smoke source could be very difficult and that in some scenarios, where the air conditioning system acts as transportation media but does not represent the smoke source itself, this could lead to misinterpretation of the smoke origin." To standardize with the manufacturer, as well as to clarify and expedite the smoke source identification process, Swissair decided to use the Smoke/Fumes of Unknown Origin Checklist in any given smoke/fumes situation. Swissair cautioned its flight crews that the Smoke/Fumes of Unknown Origin Checklist "will lead to a shutdown of essential aircraft systems."[121] In addition, Swissair amended the Smoke/Fumes of Unknown Origin Checklist to advise flight crews—at the beginning of the checklist rather than at the end—to consider emergency landing, ditching, and fuel dumping.

[121] The Boeing Company describes those systems affected by the use the Smoke/Fumes of Unknown Origin Checklist as aircraft subsystems rather than "essential" systems.

Swissair issued an AOM Bulletin (111/00) to advise its MD-11 flight crews about a revision to its Smoke/Fumes of Unknown Origin Checklist. OXYGEN MASKS was added as the first item in the Smoke/Fumes of Unknown Origin Checklist. This addition did not represent a change to Swissair practices, as donning an oxygen mask had always been the first memory item when dealing with smoke situations in simulator training. Subsequently, in AOM Bulletin (122/01) Swissair explained the reasons behind the dramatic changes in the presentation of the

Smoke/Fumes of Unknown Origin Checklist procedure. This same bulletin informed the MD-11 flight crews that Airbus has combined three “smoke” procedures into one checklist procedure similar to the MD-11 Smoke/Fumes of Unknown Origin Checklist.

4.1.5.4.2 Training

Swissair continued to educate its MD-11 flight crews through AOM Bulletins and *Info Flashes* (an internal newsletter) on its CB reset policies, checklist revisions, and incidents that involve smoke or odours. Flight crews were informed about increased inspections of map lights owing to heat damage discovered during maintenance.

In recent years, Swissair has revised its ground school refresher training to include briefings based, in part, on the SR 111 experience. The briefings were meant to emphasize the need for effective communications and timely decision making when dealing with smoke of unknown origin.

Swissair revised the part of its cockpit (or crew) resource management training program dealing with smoke emergencies. The program, attended by both pilots and cabin crew, consists of a day of lectures and reaffirmed the company’s policies with regard to the new policies and procedures.

4.1.5.4.3 MD-11 Modification Plus Program

In the post-accident environment, Swissair and its maintenance provider, SR Technics, undertook a joint study to analyze all potential factors that may have contributed to the accident. The study focused on exploiting opportunities to minimize the vulnerability of the MD-11 aircraft to an in-flight fire by developing an early warning smoke detection system. The stated intention was to enhance the firefighting and emergency response capability of the MD-11 and not to call into question the type certification of the aircraft. The study resulted in the adoption of the “MD-11 Modification Plus” program.

The program consists of the following enhancements:

- **Miscellaneous Smoke Detector System:** This modification installs smoke detectors in the avionics compartment, the cockpit overhead area, and the first-class galley overhead zone of the MD-11. The system consists of a dual-loop smoke detector system, which illuminates an amber MISC SMOKE warning light on the glareshield control panel, together with an aural warning. An emergency checklist entitled MISC SMOKE was created and introduced to the MD-11 crews via AOM Bulletin (123/01).
- **Video Camera Monitoring System:** This system installs cameras in the avionics compartment, the cockpit overhead area, and the first-class galley overhead zone to provide a visual confirmation of the presence of smoke. The camera installation includes a dedicated display screen, located on the centre pedestal, to allow the pilots to view the area of interest.
- **Halon Distribution System:** This system consists of three fixed Halon bottles connected to a distribution system. The HDS can direct a fire-suppressing agent to the cockpit overhead area, and the first-class galley overhead zone. As these areas are not readily accessible, this modification optimizes the aircraft crew’s fire-suppression capabilities.
- **Wire Routing:** This part of the program includes a wiring modification designed to enhance separation and increase survivability of flight-critical systems. The modification physically separates the left and right power wires to opposite sides of the cockpit.
- **Oxygen System/Air Conditioning System Improvements:** As a fire-hardening measure for its crew oxygen system, Swissair incorporated Boeing’s SB MD11-35-021, which replaces aluminium components with steel. Additionally, Swissair has replaced the end caps used in the air conditioning system ducting with a more fire-resistant

version.

• **Standby Flight Instruments:** This unit is a "mini" primary flight display. It combines all necessary flight-relevant information including standby horizon, speed, altitude, and heading indications. This unit also includes an automatic back-up battery power supply.

To reduce aircraft downtime the "MD-11 Modification Plus" program is being coordinated with the MPET-covered insulation blanket replacement program as required in accordance with FAA AD 2000-11-02.

All modifications have been approved by the appropriate airworthiness authorities and as of January 2003, nine MD-11s previously owned by Swissair, have been modified in accordance with the "MD-11 Modification Plus" program.

4.1.5.5 United States National Transportation Safety Board

On 4 January 2002, the NTSB released five recommendations (A01-83 through A01-87) dealing with recent in-flight fires. Although not directly related to the circumstances of the SR 111 accident, NTSB's efforts reflect a common concern with the provisions currently in place for in-flight firefighting. That is, the TSB recommendations took a systems approach in identifying deficiencies in such areas as detection and suppression, crew coordination, checklist procedures, equipment, and accessibility. The NTSB recommendations focused primarily on deficiencies associated with the actions of aircraft crews in dealing with in-flight fires. The NTSB recommendations complement those of the TSB by highlighting inadequacies in aircraft crew awareness and training that limit their ability to execute effective in-flight firefighting.

4.1.6 Overhead Aisle and Emergency Lights

4.1.6.1 Transportation Safety Board of Canada

The interest in the MD-11 aisle and emergency light assemblies stems from analysis of heat-damaged ceiling panels recovered from the SR 111 aircraft. This damage was associated with overheating of the light assembly. During subsequent aircraft inspections, conducted as part of the SR 111 investigation, the TSB became aware of additional examples of overheating conditions in the overhead aisle and emergency light fixture used on the MD-11. Subsequently, on 29 December 2000 the TSB issued ASIL (A000062-1 (STI4-24) and A000062-2 (STI4-25)), which detailed this information to both the NTSB and the manufacturer of the fixture.

4.1.6.2 United States Federal Aviation Administration

The FAA reviewed the MD-11 industry in-service data pertaining to the overhead aisle and emergency lights, and determined that there was insufficient information to confirm the existence of an unsafe condition that would warrant safety action.

4.1.6.3 The Boeing Company

In response to the TSB's findings, Boeing requested that the aisle and emergency light assembly manufacturer conduct testing. The results of this testing did not reveal any anomalies and confirmed that the fixture met existing certification standards.

4.1.7 In-Flight Entertainment Network/Supplemental Type Certificate

4.1.7.1 Transportation Safety Board of Canada

Early in the SR 111 investigation, it was discovered that the Swissair MD-11 in-flight entertainment network (IFEN) was connected to aircraft power in such a way that was not compatible with the emergency electrical load-shedding design philosophy of the MD-11 aircraft. The IFEN was powered from AC Bus 2, a bus that is not deactivated when the CABIN BUS switch is selected. Use of the CABIN BUS switch, which was the first item in Swissair's Smoke/Fumes of Unknown Origin Checklist at the time of the occurrence, is intended to remove most electrical power from the aircraft cabin.

The TSB alerted all stakeholders of this situation while continuing to investigate the circumstances surrounding the Supplemental Type Certificate (STC) process that approved this installation.

4.1.7.2 Swissair

As a precautionary measure, on 29 October 1998, Swissair reacted to the TSB discovery by disabling the IFEN in both its MD-11 and Boeing 747 fleets. Eventually, Swissair removed the IFEN entirely.

4.1.7.3 Federal Office for Civil Aviation

On 13 November 1998, the FOCA issued FOCA Order 220.99 cancelling the validations of IFEN STC ST00236LA-D (MD-11) and ST00431LA-D (B-747).

4.1.7.4 United States Federal Aviation Administration

The FAA launched an internal Special Certification Review (SCR) of Santa Barbara Aerospace's STC ST00236LA-D, which ultimately resulted in the withdrawal of the IFEN certification. Subsequent to this review, the FAA has acted on several fronts as described in the following sections.

4.1.7.4.1 AD 99-20-08

Effective 13 October 1999, the FAA issued an AD that prevented the use of STC ST00236LA-D. The purpose of the AD was to prevent possible confusion, with respect to flight crew expectations, when performing their duties in response to a smoke/fumes emergency. Any confusion could impair their ability to correctly identify the source of the smoke/fumes and, therefore, affect the continued safe flight and landing of the aircraft.

4.1.7.4.2 Passenger Entertainment System STC Survey

The FAA conducted a survey of other passenger entertainment system STCs in an effort to quantify the extent of the problems identified during the SCR of STC ST00236LA-D. The survey identified unsafe conditions associated with various STCs, which resulted in the issuance of 18 ADs requiring changes to various passenger entertainment system design types. An extensive review revealed that these systems could remain powered despite flight crew procedures. Typically, these ADs required that operators deactivate or modify the entertainment system, revise crew procedures for removing power from the system, or remove the entertainment system from the aircraft entirely.

4.1.7.4.3 Aircraft Certification Service Policy Change

Based on the FAA SCR issued 14 June 1999, the FAA implemented the following corrective actions:

1. A memorandum entitled "Follow-on Corrective Actions Pertaining to Aircraft Certification Systems Evaluation Program Findings at Delegated Facilities," dated 2 July 1999. The memorandum

    - reminded all Aircraft Certification Offices (ACO) to adhere to procedures that ensure Aircraft Certification Systems Evaluation Program (ACSEP) findings that require corrective action are addressed by the managing ACO; and

[122] FAA Order 8100.9 DOA, DAS, SFAR 36 Authorization Procedures was signed on 7 August 2002.

• directed the ACOs to immediately implement the intent of Draft Order 8100.XX (Designated Alteration Station (DAS), Delegation Option Authorization (DOA)), and *Special Federal Aviation Regulation* (SFAR) 36 Authorization Procedures), as well as Notice 8100.13, "The ACSEP Criteria for Delegated Facilities."[122]

2. A memorandum entitled "AIR-100 Policy Memorandum # 00-01, Proper DAS Program Notification (Letter of Intent) Content and FAA Response," dated 10 March 2000. The memorandum

• prescribed a policy addressing what should be contained in DAS-submitted program notifications and ACO response guidelines; and

• ensured that the DAS program notification and ACO response is standardized.

3. A memorandum entitled "AIR-100 Policy Memorandum # 00-02, Designated Alteration Station Certification Activities Performed on Foreign-Registered Test Articles, and/or at Off-Site Locations," dated 13 March 2000. The memorandum

• prescribed a policy addressing foreign-registered test articles and off-site activities of the DASs, including activities in other countries;

• addressed a DAS providing certification services without performing actual engineering design or installation work;

• stated that the DASs must specify who will perform the design and installation work, and the scope of each party's involvement; and

• required a description of how the DAS will manage the other parties' activities to ensure that all certification requirements, including those performed at a location other than the DAS's, are met.

4. A memorandum entitled "Interim Policy Guidance for Certification of In-Flight Entertainment Systems on Title 14 CFR Part 25 Aircraft," dated 18 September 2000. The memorandum provided information to FAA personnel resulting from the SCR of STC ST00236LA-D and a review of in-flight entertainment (IFE) systems certified by the STCs that

• ensured a standardized approach to IFE system certification across all ACOs and DASs;

• highlighted several unsafe conditions discovered during the STC reviews;

• listed certification guidelines to prevent similar designs from obtaining FAA approval such as the following:

– The IFE system should not be connected to an electrical bus that also supplies electrical power to systems that are necessary for continued safe flight and landing;

– A means should be provided to remove power from the IFE;

– CBs should not be used as a sole means to remove power from the system;

– IFE wiring must be protected by appropriately rated and coordinated Cbs;

– Design and installation of an IFE should minimize any impact on aircraft operation; and

– The STC applicant is accountable for certification of the entire IFE system, including the seat-mounted equipment.

Additional points resulting from the STC review included

• insufficient certification data;

• inadequate or missing requirements for maintaining IFE system separation from other systems;

• failure to produce Instructions for Continued Airworthiness;

• inadequate consideration for aircraft manufacturer's design philosophy; and

• failure to prepare an adequate electrical load analysis.

4.1.7.4.4 DDS Program

Initiated in 1997, the FAA's DAS, the DOA, and SFAR 36 (DDS) Program satisfied the requirement to establish standard procedures, guidance, and limitations of authority for organizations (the DAS, DOA holder, and SFAR 36 holder) that the FAA appointed to act on its behalf. Prior to this initiative, the FAA had no directives that dealt with such delegations to organizations.

The first step in establishing this program was to draft an FAA order guiding the organizations and providing a common understanding of their authorized functions and the procedures they should follow when exercising their authority.

Expected outcomes of this program include the following:

- Standardized election, appointment, and management procedures;
- Certification processes that result in compliance with all regulations and FAA directives;
- The understanding that a Memorandum of Understanding between an organization and the FAA is a prerequisite to appointment;
- The program notification letter, formerly known as a Letter of Intent, should include both certification and conformity plans;
- Increased FAA supervision of delegated organizations;
- Increased project oversight;
- Additional training requirements for the delegation;
- Self-evaluations by delegations; and
- The standardization, in both format and content, of the DDS procedures manual.

4.1.7.4.5 Organizational Designation Authorization

Supplemental to the DDS program, the FAA intends to consolidate all of its delegation authorization, applicable to organizations, into a single FAR Part 183. This consolidation would terminate DAS, DOA, and SFAR 36 authorizations. The focus of the Organizational Designation Authorization (ODA) will be on system processes and an organizational model, and not on individual staff members. The FAA will approve the ODA administrator, organizational model, and procedures manual. The goal is to prohibit eligibility of applicants that have little or no experience with FAA certification procedures.

4.1.7.4.6 Policy Statement ANM-01-04

The FAA released a notification entitled "System Wiring Policy for Certification of Part 25 Airplanes" on 2 July 2001. The notice announced the FAA's policy with respect to the type design data needed for the certification of wiring installed on transport category aircraft. The FAA stated that the policy is necessary to correct deficiencies associated with the submission of design data and instructions for continuing airworthiness involving aeroplane system wiring for type design, amended design, and supplemental design changes. The policy advised applicants for type certificates, amended type certificates, STCs, or type design changes of the range and quality of type design data considered acceptable to the FAA, as part of any certification project submission. The policy does not establish any new rules, but provides the applicant with advisory material on how existing rules (currently contained in 14 CFR, Part 21) are to be interpreted.

4.1.7.5 The Boeing Company

Boeing, as a supplier of factory-installed IFE systems, conducted a design review of its installations to confirm that no unsafe conditions existed. The review resulted in production changes (to several aircraft models) designed to isolate the IFE system from the cockpit.

4.1.8 Circuit Breaker Reset Philosophy

4.1.8.1 General

As the SR 111 investigation progressed, it became evident that CB reset philosophies for the pilot, cabin crew, and maintenance communities were inconsistent across the aviation industry. A lack of a single approach created widely different interpretations regarding the best course of action in this regard.

4.1.8.2 Airbus

Airbus issued CB reset policies that do not allow CB reset in flight except in emergency conditions, and then only when authorized by the pilot-in-command.

4.1.8.3 The Boeing Company

Boeing issued essentially the same policy as Airbus, except that it stipulated that no resets for fuel pump circuits were to be carried out under any circumstances.

4.1.8.4 Transport Canada

In an effort to raise awareness on several issues surrounding the use of CBs, TC published an article in the 1/2001 issue of its *Aviation Safety Letter*.

4.1.8.5 United States Federal Aviation Administration

On 21 August 2000, the FAA issued a Joint Flight Standards Information Bulletin for Airworthiness, Air Transportation, and General Aviation (Flight Standards Information Bulletin for Air Transportation 00-07A) to summarize the FAA's position on the issue of resetting tripped CBs. The overriding message is one of caution. In-flight resets are not allowed unless such action is consistent with the approved *Flight Crew Operating Manual* and is deemed necessary for safe flight and landing. A logbook entry is necessary to provide effective troubleshooting and corrective action by maintenance crews on the ground. Additionally, CB resets on the ground are only permitted after maintenance staff have determined the cause of the trip.

4.1.8.6 Swissair

Swissair issued an AOM Bulletin (93/99) advising its MD-11 flight crews about a revision to CB reset procedures. The decision was made to allow a single reset during aircraft preparation prior to the aircraft moving under its own power. However, aircrews are not authorized to reset a tripped CB during taxi or in flight. The procedure to reboot a computer by cycling a CB, when stipulated by the manufacturer, will continue.

SR Technics, Swissair's maintenance provider, also reviewed its CB reset policy. Subsequently, the maintenance provider released Continuation Training Letter 041, which states that SR Technics expects that its technicians will use all available troubleshooting techniques to determine the cause of the electrical overload before any attempt is made to reset the CB. Additionally, SR Technics requires that all CB trips and resets are to be recorded as part of the maintenance log.

4.1.9 Standby Instrumentation

4.1.9.1 Transportation Safety Board of Canada

The investigation revealed that, as the SR 111 emergency progressed, various systems-related failures occurred that affected primary instrument displays and that standby instruments were being used. Given the substantially increased pilot workload during the emergency, the investigation became interested in the adequacy of the standby instrumentation. The results of TSB's inquiry indicated that when pilots have been forced to rely on standby instruments in emergency situations, they have noted deficiencies, including poor instrument location, small displays, difficulty in transition from primary flight instruments, and lack of adequate training.

It was determined that, while the Swissair MD-11 standby instruments meet regulatory requirements, their functionality may not be optimized. Limitations with respect to location, powering, and pilot training resulted in the TSB issuing two ASAs (A010042-1 (STI4-26) and A010042-2 (STI4-27)) on 28 September 2001. The advisories suggested that authorities consider reviewing the existing requirements for standby instrumentation, including related issues such as standby communication and navigation capabilities. The advisories also called for a review of present regulations and practices to ensure that flight crews receive adequate training in the use of standby flight instruments and that design standards be adequate to ensure that standby instruments are grouped adjacent to one another, and have a layout similar to the primary flight instruments.

4.1.9.2 Swissair

As part of its "MD-11 Modification Plus" program, Swissair chose to install a secondary flight display system that has a layout similar to the primary flight display in the MD-11 aircraft. The display system includes attitude, airspeed, altitude, and heading in a single integrated display. In addition, in the event of a loss of primary aircraft electrical power to the unit, the display has an auxiliary battery that can supply power for a minimum of 45 minutes.

4.1.9.3 United States Federal Aviation Administration

The FAA plans to address the emergency instrumentation issues raised by the TSB at the appropriate Aviation Rulemaking Advisory Committee (ARAC). This forum will compare the issues raised by the TSB with current safety issues and will decide upon a course of action.

4.1.9.4 The Boeing Company

Boeing advises that they have reviewed their current standby instrumentation equipment in an effort to identify any areas that could be optimized. As part of its ongoing product improvement effort to its customers, Boeing offers standby instrument systems, such as their Integrated Standby Instrument System used on the B-717, that combine several standby instrumentation requirements in a single display.

4.1.10 Material Flammability Standards

4.1.10.1 Transportation Safety Board of Canada

The investigation's continued research into material flammability standards has revealed several safety deficiencies that pose unacceptable risks to the flying public. On 28 August 2001, the TSB issued ASRs (A01-02 through A01-04) (STI4-28) (STI4-29) (STI4-30) detailing its concerns regarding inadequacies that exist with respect to flammability standards for certain materials; testing and certification of aircraft wiring; and the requirements when conducting system safety analyses, which should also include the analysis of potential system failures that could be created by on-board fires.

The TSB believes that the use of a material, regardless of its location, type, or quantity that sustains or propagates fire when subjected to realistic ignition scenarios, constitutes an unacceptable risk, and that, as a minimum, material used in the manufacture of any aeronautical product should not propagate or sustain a fire in any realistic operating environment. Therefore, the TSB made the following recommendation:

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 (issued 28 August 2001) (STI4-31)

Regardless of efforts to design, install, and maintain an aircraft's wiring system to a high standard, deficiencies with wires will likely persist and present the potential for wire failures.

While all wires will arc under certain circumstances, the dynamics of how a particular wire fails during an arcing event is highly dependent on the composition of the wire insulation. Understanding the dynamics of how a wire will fail under realistic conditions would be valuable, given the known consequences of the failure of an energized wire. While the FAA endorses several failure tests (e.g., the dry arc-tracking test procedure), it does not require any failure tests as a basis for wire certification.

Therefore, given the incidence of aircraft wire failures and their role as potential ignition sources, the absence of a certification requirement that measures a wire's failure characteristics, and that specifies performance standards under realistic operating conditions, constitutes a risk. Therefore, the TSB made the following recommendation:

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 (issued 28 August 2001) (STI4-32)

All aircraft systems are subject to a system safety analysis as part of their certification process. Notwithstanding, for most systems this analysis does not ascertain how the system will perform in a fire-in-progress situation. Systems, such as oxygen, conditioned air, and hydraulic systems can exacerbate such a situation. The TSB believes that a fire-induced material failure in some aircraft systems has the potential to augment the combustion process and exacerbate the consequences of an in-flight fire. Therefore, the TSB made the following recommendation:

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 (issued 28 August 2001) (STI4-33)

4.1.10.2 Transport Canada

TC agrees with the TSB's recommendations and agrees that more must be done to ensure appropriate regulations with respect to material flammability standards. TC intends to coordinate its actions with both the FAA and JAA in order to harmonize their respective regulatory environments.

4.1.10.3 United States Federal Aviation Administration

The FAA agrees with the thrust of the TSB's recommendations that material flammability standards must be improved. The FAA is confident that its previously announced Flammability of Materials in Inaccessible Areas and Improved Flammability Requirements for Thermal/Acoustic Insulation programs, in addition to its Test Methods for Evaluation of Low Heat Release Materials program, will address the concerns raised in TSB Recommendation A01-02.

With respect to the issue raised in A01-03, the FAA feels the arc fault circuit breaker (AFCB) program enhances the protection of aircraft wiring. In addition, the FAA has given the Wire Systems Harmonization Working Group the task of revising the standards for wiring performance and test requirements. The FAA advises that this effort may result in the development of a technical standard order for wiring. This group is also reviewing FAR 25.1309 in order to develop recommendations for the new Wire Systems Rule to address potential wire failures and in-service conditions.

Finally, the FAA believes that the existing regulations dealing with fire protection and prevention of critical systems (e.g., oxygen) are sufficient to deal with the system fire-hardening concerns raised in A01-04. The FAA's position is that current regulations, coupled with the results of FAA initiatives, such as the AFCB program, will mitigate the risks of fire-induced failures.

4.1.10.4 The Boeing Company

On 18 May 2001, Boeing issued SB MD11-35-021 entitled "OXYGEN - Control and Distribution -
Modify Crew Oxygen Supply Line Installation." The purpose of the SB was to inform MD-11 operators of an FAA-approved modification procedure that replaces the aluminium components of the crew oxygen supply line system with steel components as a fire-hardening measure.

4.1.11 Air Traffic Controller Training

4.1.11.1 Transportation Safety Board of Canada

The investigation found that two air traffic controllers involved in this occurrence believed that flight crews, for safety reasons, might turn off some aircraft electrical and radio systems during fuel dumping operations. This perception was used by the air traffic controllers to explain the cessation of radio communications and secondary radar information, which occurred immediately after the SR 111 flight crew had indicated that they were starting to dump fuel.

In emergency situations, the potential to minimize undesirable outcomes and enhance the service provided to flight crews could depend, in part, on the controller's awareness of the ramifications of special or emergency procedures conducted by those flight crews. Controller knowledge of flight crew expectations, and basic familiarity with the capabilities of commercial aircraft, could enhance their awareness of flight crews' operational needs.

Currently, there is no regulatory requirement for controllers in Canada to receive special training in the handling of aircraft emergencies, either during *ab initio* or refresher training. Consequently, on 14 August 2001, the TSB issued an ASA (A010020-1) to TC suggesting that it review controller training requirements. Consideration should be given to the need for additional training regarding aircraft emergency scenarios prior to the initial issuance of a licence to air traffic controllers under the *Canadian Aviation Regulations* (CARs). Specifically, further training may be warranted that provides the requisite knowledge and skills so that controllers are better able to provide safe and expeditious air traffic control (ATC) services to aircraft experiencing emergency or distress conditions. The need for regular continuation training and refresher exercises regarding emergency scenarios should also be considered.

4.1.11.2 Transport Canada

TC advised the TSB that it was liaising with the ATC service providers, Nav Canada and SERCO Aviation Services, to ensure the concerns noted in the TSB ASA are addressed.

4.1.11.3 Nav Canada

Nav Canada developed and delivered a refresher training module during 1999–2000 and 2000–2001 training years for controllers, which included familiarization with an in-flight smoke or fire emergency. The training familiarized the controllers with the expectations and operational needs of pilots, and the capabilities of a commercial aircraft, during such an emergency situation.

In addition, on 11 July 2002, Nav Canada issued an amendment to its *Air Traffic Control Manual of Operations* to provide controllers with new direction regarding fuel dumping operations and, in particular, the following information. "It has been determined some aircraft may be incapable of making radio transmissions during a fuel dump however, all are capable of maintaining a listening watch on the frequency. As well, some aircraft must also turn off their transponders during the fuel dump procedure."

4.2 Action Required

4.2.1 Thermal Acoustic Insulation Materials

4.2.1.1 Other Thermal Acoustic Insulation Materials at Risk

Since the beginning of this investigation, the aviation industry's understanding of the flammability characteristics of thermal acoustic insulation materials has advanced considerably. The recognition that MPET-covered insulation blankets are flammable and provided the main source of fuel in the SR 111 in-flight fire was significant. Extensive flammability testing determined that such blankets are susceptible to being ignited by small ignition sources, such as electrical arcing or sparking and will propagate a fire. Consequently, the FAA required that these blankets be removed from US-registered aircraft, and accelerated work to develop an improved flammability test for the certification of all thermal acoustic insulation materials.

Occurrence data confirms that some thermal acoustic insulation materials, other than MPET-covered insulation blankets, have been involved in aircraft fires that were ignited by electrical sources. FAA research revealed that these other thermal acoustic insulation materials, although more difficult to ignite, exhibit similar flammability characteristics once ignited. The flammability test that was used to certify all such materials (i.e., the vertical Bunsen burner test) was designed to determine whether the material would ignite from a small ignition source, such as an electrical arcing event, and extinguish within a predetermined flame time and burn length. All such materials were approved for use in aircraft because, once ignited, they self-extinguished within a predetermined flame time and burn length. The FAA's Radiant Panel Test (RPT) certifies materials using similar, albeit much more stringent, criteria.

The FAA has tested a representative sample of thermal acoustic insulation materials currently in use in the aviation industry and has determined that approximately two-thirds failed the RPT. Because the RPT effectively fails materials that could be ignited from a small ignition source, including an arc or spark, then potentially, these failed materials could exhibit such inappropriate characteristics while in-service. If the RPT is ultimately approved, any materials that fail the RPT would not be acceptable for use in any future aircraft manufacture or repair. However, unlike the case with MPET-covered insulation blankets, there is no indication that regulatory authorities will mandate a wholesale removal, from existing aircraft, of those other in-service thermal acoustic insulation materials that failed the RPT.

Additionally, since smoke generation and toxicity limits have never been established for thermal acoustic insulation materials, the associated risks have not been quantified. Such risks would likely be a factor if these flammable materials become involved in an in-flight fire. It has been suggested that, once the RPT is adopted, the "zero burn" feature of the RPT will result in the eventual elimination of flammable thermal acoustic insulation material in aircraft, and therefore, measuring a material's smoke generation and toxicity levels, as part of the certification process, is unnecessary. However, under the present approach, mitigation of the risks associated with these flammable materials will not be accomplished until the existing fleet of aircraft is replaced. Therefore, known flammable materials will exist for decades in thousands of aircraft worldwide.

The in-flight fire risks associated with MPET-covered insulation blankets have largely been mitigated. However, there are other thermal acoustic insulation materials that once ignited, exhibit similar flammability characteristics to MPET-covered insulation blankets, and have failed the RPT. Although these materials exist in many aircraft, as of this report's publication date, no mitigation strategy has been undertaken to address the known associated risks. Therefore, the Board recommends that

Regulatory authorities quantify and mitigate the risks associated with in-service thermal acoustic insulation materials that have failed the Radiant Panel Test.

A03-01

4.2.1.2 Proposed Certification Standard for Thermal Acoustic Insulation Materials

The FAA has proposed a rule that would replace the existing vertical Bunsen burner test with the RPT to evaluate fire ignition and propagation characteristics of all thermal acoustic insulation materials. During its validation of the RPT, the FAA reported that only 25 to 35 per cent of the various insulation blanket cover materials would pass the RPT. The proposed test has been widely accepted as a major improvement over the previous test in that it effectively imposes a "zero burn" criterion for all thermal acoustic insulation materials. Although the test would be required for all thermal acoustic insulation materials, and appears to be a better discriminator of materials that exhibit inappropriate flammability characteristics, the design of the RPT contains some inherent limitations.

The RPT is designed to expose the test specimen to a small fire-in-progress scenario that sets higher ignition and propagation threshold "pass" requirements. However, there are concerns about whether the current RPT suitably addresses the following key issues:

- Although the FAA believes that a test specimen's orientation is an important factor in determining its propensity to be ignited and propagate a fire, the RPT only requires that a specimen be oriented horizontally;
- The RPT has its origins in the American Society for Testing and Materials E648 test, which requires that the test specimen be pre-heated prior to the application of the flame. Although the FAA recognizes the benefits of pre-heating test specimens because of the deleterious effects on the thin-film covered thermal acoustic insulation materials, the RPT does not impose this pre-heat condition; and
- The RPT requires the testing of three specimens that include all those materials used in the construction of insulation blankets (including batting, film, scrim, tape, etc.). However, it does not indicate how the flammability characteristics of the component materials are to be tested in the various permutations and combinations while only requiring that three specimens be tested.

Also, the Board is aware of initiatives by the FAA to design the RPT to account for potential degradation in the flammability characteristics of materials after they are exposed to their intended operating environment. The FAA has recognized that most aircraft in-service have insulation blankets with varying degrees of surface contamination, and that experience has shown that such contamination cannot be fully avoided. Therefore, one goal of the testing is to develop an appropriate evaluation procedure that can account for realistic in-service conditions. Because the issues listed above are not addressed, it is unclear how the RPT would effectively identify all thermal acoustic insulation materials that may exhibit inappropriate flammability characteristics. Rather, it appears that the RPT is a single certification test for thermal acoustic insulation materials, which under certain conditions (such as conditions that do not involve pre-heating), results in an effective flammability test for thin-film-covered insulation blanket materials.

By developing the RPT, the FAA has successfully designed a single certification test that, while a major improvement over the vertical Bunsen burner test, may not successfully evaluate the performance of all types of thermal acoustic insulation materials under representative conditions. Given these limitations of the FAA's proposed RPT, the Board recommends that Regulatory authorities develop a test regime that will effectively prevent the certification of any thermal acoustic insulation materials that, based on realistic ignition scenarios, would sustain or propagate a fire.

A03-02

4.2.2 Interpretation of Material Flammability Test Requirements

As a result of the investigation, the TSB previously issued three recommendations on the subject of Material Flammability Standards. Reaction to the content of these recommendations has been positive. Regulatory authorities have largely embraced the need for regulatory changes that would result in no materials being certified that would sustain or propagate a fire, as recommended in A01-02. The FAA is leading a research and development effort as part of the International Aircraft Materials Fire Test Working Group that is developing new flammability tests for materials, including wires and cables, found in "hidden areas." The Board believes that imposing more realistic and thus more severe flammability test requirements will serve to decrease the likelihood of flammable materials being approved for use in the manufacture or repair of aircraft. However, variations still remain in the interpretation and application of the regulations and guidance material.

Throughout this investigation, in an effort to determine the ignition and propagation scenario for the in-flight fire, various materials used in the manufacture of the MD-11 were tested in accordance with the applicable regulatory requirements. In some cases, materials such as silicone elastomeric end caps and hook-and-loop fasteners, demonstrated inappropriate flammability characteristics. Neither the aircraft manufacturer nor the regulatory authority were able to effectively explain whether these or other such materials had been required to be tested and, if so, could not produce a record of the resultant certification test data. It appears that varying interpretations of the same regulations may explain why some materials that were certified for use in aircraft met the flammability standards while others did not. As explained in the TSB's Material Flammability Standards recommendation package (issued August 2001), except for the most obvious and common materials, it was difficult to determine with certainty which flammability test(s) applied to which material. The applicable FARs could be misinterpreted so as to minimize the amount and level of testing required for certification of any particular material.

The certification of a newly manufactured aircraft is a complex endeavour, which includes the certification of many types of materials. The Board expected that as a result of its previous recommendations, regulatory authorities would not only develop improved testing but also simplify the interpretation of the regulations and guidance material so as to prevent the approval of flammable materials. Without such a concerted and focused effort, manufacturers and those responsible for the certification of aircraft materials will continue to operate in an environment where it is possible to misinterpret the regulatory requirements. In such circumstances, materials that exhibit inappropriate flammability characteristics can continue to be approved for use in aircraft. Therefore, the Board recommends that

Regulatory authorities take action to ensure the accurate and consistent interpretation of the regulations governing material flammability requirements for aircraft materials so as to prevent the use of any material with inappropriate flammability characteristics.

A03-03

4.2.3 IFEN – Supplemental Type Certificate Process

Based on information highlighted by this accident, the FAA has initiated many positive changes to its type certification process. However, there is one area that the Board feels requires additional consideration.

The purpose of FAR 25.1309 is to confirm that a system's design does not adversely affect the original aircraft type certificate. This investigation identified a deficiency with the provisions of FAR 25.1309, which allowed the IFEN STC ST00236LA-D system-to-aircraft integration design to be approved without confirmation that it was compliant with the aircraft's original type certificate. The Board is aware that there were other STC designs, certified in accordance with FAR 25.1309, in which the system-to-aircraft integration design introduced latent unsafe conditions with the potential to adversely impact the operation of the aircraft during emergency procedures. In some instances, the STC process allowed the intended function of certain checklist procedures during abnormal or emergency situations, to be altered without issuing an

Airplane Flight Manual (AFM) supplement to advise the pilots. Although FAR 25.1309 applies to all aircraft systems, it would appear that STC designs that have been typically viewed as "non-essential, non-required"and that can be approved based on a qualitative assessment, are especially susceptible to improper integration.

The Board believes that, as currently written, FAR 25.1309 can be interpreted to allow STC approval of system-to-aircraft integration designs that are not compliant with the original type certification. Therefore, the Board recommends that

Regulatory authorities require that every system installed through the STC process, undergo a level of quantitative analysis to ensure that it is properly integrated with aircraft type-certified procedures, such as emergency load-shedding.

A03-04

4.2.4 Circuit Breaker Reset Philosophy

In recent years, aircraft manufacturers and operators have identified improper CB reset procedures. Consequently, they have taken positive steps to determine the most appropriate philosophy governing the resetting of CBs and to communicate that philosophy to pilots and technicians. The FAA 's Flight Standards Information Bulletin has also served to normalize the approach to the resetting of CBs taken by operators and their personnel, specifically flight crews, maintenance personnel, and ground servicing personnel.

TC relayed its position on the resetting of CBs in an issue of the *Aviation Safety Letter*, whose distribution is limited to Canadian licensed pilots. Awareness about such "best practices" appears to be increasing; however, the regulatory environment remains unchanged. At this time, requirements and guidance material do not include a clear and unambiguous message stipulating the acceptable CB reset philosophy, and the consequences of an inappropriate CB reset.

The Board believes that despite these initiatives, if the existing regulatory environment is not amended to reflect the acceptable CB reset philosophy, such "best practices" will not be universally applied across the aviation industry and ultimately, the positive changes currently established may not be maintained. Therefore, the Board recommends that

Regulatory authorities establish the requirements and industry standard for circuit breaker resetting.

A03-05

4.2.5 Accident Investigation Issues

4.2.5.1 Quality of CVR Recording

Frequently, the CVR recording of cockpit conversations are of poor quality, particularly when the conversations are recorded through the CAM. The voice quality on CVR recordings is dramatically improved when voices are recorded through boom microphones. However, pilots are not required to wear headsets with boom microphones at cruising altitudes.

Various national regulations differ concerning the maximum altitudes below which flight crews are required to wear boom microphones. For example, the CARs require the use of boom microphones below 10 000 feet, the FARs below 18 000 feet and the Joint Aviation Requirements do not have any requirement that they be used. Swissair required their pilots to use boom microphones when flying below 15 000 feet. The present requirements were developed before modern technology allowed headsets with boom microphones to be designed for comfort over long periods of time, such as during cruise flight.

When the SR 111 pilots first noted an odour in the cockpit, they were in cruise flight and were not wearing boom microphones. Although the internal communications between the pilots were recorded through the CAM, the conversations were difficult to hear and decipher. There was a marked improvement in recording quality after the pilots donned their oxygen masks, which have built-in microphones.

Even though the boom or oxygen mask microphones are recorded on a different channel than the CAM, the recordings of internal communications on the microphone channels are still frequently masked by incoming radio transmissions because internal, as well as external, communications are recorded on the same CVR channels but at different amplitudes. For example, the recorded incoming radio communications for SR 111 were of significantly higher amplitude than the internal communication from the mask microphone, making it difficult and occasionally impossible to discern internal communications. The relative amplitude of the incoming radio calls to that of the internal communications is pre-set at equipment installation and is not affected by crew adjustment of audio volume. Therefore, even if the pilots can hear each other readily through their headsets, the CVR recording of internal communications may be masked substantially by incoming radio communications. Significant difficulties in extracting such “masked” internal communications from CVR recordings have been experienced by the TSB and by safety investigation agencies from other nations.

The ability to decipher internal conversations between flight crew members is an important element of effective accident investigation. Therefore, the Board recommends that

Regulatory authorities, in concert with the aviation industry, take measures to enhance the quality and intelligibility of CVR recordings.

A03-06

4.2.5.2 Quick Access Recorder Data

Quick access recorders (QAR) are voluntarily installed in many transport aircraft and routinely record far more data than the mandatory FDR. For example, the FDR installed on SR 111 was a solid state unit that recorded approximately 250 parameters, whereas the QAR used a tape-based cartridge, which recorded approximately 1 500 parameters. That is, the optional QAR recorded six times the amount of data recorded on the mandatory FDR. The additional data recorded on the QAR included numerous inputs from line replaceable units (LRU) that would have been extremely valuable in determining aircraft systems status, as well as temperatures at a number of locations in the fire-damaged area.

Many airlines are developing Flight Operational Quality Assurance (FOQA) or Flight Data Monitoring (FDM) programs; such programs require that increased data sets be recorded. The use of QARs is voluntary; therefore, the operating environment allows operators to change the QAR data-set according to their operational requirements. Conversely, changing the data-set on an FDR is currently an expensive process, largely due to the associated re-certification issues. As modern-day versions of both types of recorders employ solid state memory technologies, these modern FDRs effectively have as much capacity to record data as QARs. The Board believes that there is no technical reason why safety investigations should not benefit from the FOQA/FDM trend, and that all data voluntarily collected for any operational purpose should also be available for accident investigation. To achieve this, regulatory authorities need to develop regulations that protect the core parameters required for all FDRs, while also allowing FDRs to be easily augmented with additional parameters, higher sample rates, and higher resolutions without requiring re-certification of the FDR and without requiring validation/calibration of parameters that are not dedicated to the FDR. Operators would need ready access to these FOQA/FDM parameters and might choose to use only the FDR unit to meet the mandatory FDR parameter list, as well as their optional FOQA/FDM data needs.

The Board recognizes that the US convened a Future Flight Data Collection Committee to address these issues, and that in Europe, the European Organisation for Civil Aviation Equipment (EUROCAE) Working Group 50 is updating its international Minimum Operational Performance Specifications. The Board supports FOQA and FDM programs and believes that they contribute significantly toward improving aviation safety. The Board also believes that all

FOQA and FDM data routinely collected should be available for safety investigations. Therefore, the Board recommends that Regulatory authorities require, for all aircraft manufactured after 1 January 2007 which require an FDR, that in addition to the existing minimum mandatory parameter lists for FDRs, all optional flight data collected for non-mandatory programs such as FOQA/FDM, be recorded on the FDR.
A03-07

4.2.5.3 Image (Video) Recording

Only recently has it become economically feasible to record cockpit images in a crash-protected memory device. New "immersive" technology provides for camera systems that can capture panoramic, wide-angle views necessary to record the cockpit environment. Image recordings can capture other aspects of the cockpit environment that would otherwise be impractical or impossible to record. Special playback software allows investigators to "immerse" themselves in the cockpit and view virtually the entire flight deck.

Vital information regarding the cockpit environment, non-verbal crew communications, crew workload, instrument display selections and status have not been available on traditional data and voice recorders. This has limited the scope of many investigations, but more importantly, has hindered the identification of safety issues and consequently the corrective action needed to prevent future occurrences.

Some operators are installing video cameras for operational purposes. These systems provide the flight crew with images, such as the external views of the undercarriage area, wings and engines, or internal views of cargo and cabin areas. Since these video images have the potential to influence critical operational decisions, the images presented to the flight crew should be stored in crash-protected memory to facilitate safety investigations.

The Board believes that image recording in the cockpit will substantially benefit safety investigations. It will provide investigators with a reliable and objective means of expeditiously determining what happened. This will assist safety investigators in focusing on why events took the course they did, what risks exist in the system, and how best to eliminate those risks in the future.

The Board endorses the NTSB recommendations issued in April 2000 (A-00-30 and A-00-31), and advocates the development of international Minimum Operational Performance Specifications for image recording systems by EUROCAE Working Group 50. Therefore, the Board recommends that Regulatory authorities develop harmonized requirements to fit aircraft with image recording systems that would include imaging within the cockpit.
A03-08

The Board is acutely aware of the concerns expressed by industry associations that sensitive recordings will be inappropriately released to the public or used for purposes other than safety investigation. While Canada treats these recordings as privileged, all nations do not. If image recordings are to be universally accepted, worldwide protections need to be put in place for all cockpit voice and image recordings. These protections would allow investigation authorities to use the recordings for safety purposes while preventing them from being aired for other purposes. Therefore, the Board recommends that Regulatory authorities harmonize international rules and processes for the protection of cockpit voice and image recordings used for safety investigations.
A03-09

4.3 Safety Concern

4.3.1 In-Flight Firefighting Measures

In December 2000, the TSB issued five recommendations that identified deficiencies associated with in-flight firefighting measures. Although the Board recognizes that improved material flammability certification tests will eventually result in a decreased threat, flammable materials will remain in many aircraft for decades. In addition, initiatives aimed at reducing potential ignition sources, such as improved CB, wire inspection methods, and maintenance procedures, while encouraging, will not eliminate all potential ignition sources. Consequently, the Board believes that continuing emphasis must be placed on ensuring that aircraft crews are adequately prepared and equipped to quickly detect, analyze and suppress any in-flight fire, including those that may occur in areas such as cockpits, avionics compartments, and hidden spaces.

The Board is encouraged that the deficiencies identified in its recommendation package of December 2000 are being assessed and acted upon at various levels by manufacturers, operators, and regulatory authorities. Such activity will lead to enhanced safety, and some positive changes have already been achieved as indicated in Section 4.1 of this report. However, industry-wide progress appears to be unnecessarily slow. For example, although some airline operators have made improvements, the Board remains concerned with the pace of progress in mandating that all aircraft crews have a comprehensive firefighting plan that starts with the assumption that any smoke situation must be considered to be an out-of-control fire until proven otherwise, and that an immediate response based on that assumption is required. Regulatory authorities have not taken substantive measures to ensure that aircraft crews are provided with all necessary firefighting procedures, equipment, and training to prevent, detect, control, and suppress fires in aircraft.

In addition, there are specific aspects that remain problematic. In the recommendation package dealing with in-flight firefighting measures, the TSB expressed concern with the lack of built-in smoke/fire detection and suppression equipment in hidden areas of aircraft. For the most part, smoke/fire detection is reliant on human sensory perception, and fire suppression is dependent on direct human intervention. As shown by this accident, human sensory perception cannot be relied on to consistently detect or locate an in-flight fire. Furthermore, it is unrealistic to rely on human intervention for firefighting in areas that are not readily accessible. The Board believes that the industry, led by regulatory authorities, needs to do more to provide a higher degree of safety by enhancing smoke/fire detection and suppression capabilities.

The TSB expressed concern that there was a lack of awareness in the industry about the potential seriousness of odour and smoke events. The TSB recommended that 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. Although the tragic events of SR 111 have served to alert the industry to the threat from in-flight fire, the Board believes that the potential for complacency may increase with the passage of time. The Board believes that regulatory authorities need to do more to enhance the regulatory environment (i.e., regulations, advisory material, etc.) to ensure that awareness remains high in the long term and appropriate plans, procedures, and training are in place industry wide.

The TSB has observed that personnel involved with maintaining and operating aircraft remain unaware of the potential existence of flammable materials in their aircraft. In general, the predominant misconception remains as it was before SR 111; that is, that the materials used in aircraft construction are “certified,” and therefore are not flammable. As highlighted by this investigation, existing certification criteria do not ensure that materials used in the manufacture or repair of aircraft are not flammable. This lack of awareness continues to lead to circumstances where potential ignition sources, such as electrical anomalies, are viewed as reliability or maintenance issues, and not as potential safety issues and fire threats.

As the threat from an in-flight fire will continue to exist in many in-service aircraft, the Board believes that as a minimum, aircraft crews need to be provided with a comprehensive firefighting plan that is based on the philosophy that the presence of any unusual odour or smoke in an aircraft should be considered to be a potential fire threat until proven otherwise.

The Board has yet to see significant industry-wide improvements in certain important areas, and is concerned that regulatory authorities and the aviation industry have not moved decisively to ensure that aircraft crews have adequate means to mitigate the risks posed by in-flight fire, by way of a comprehensive firefighting plan that includes procedures, equipment, and training.

4.3.2 Aircraft System Evaluation: Fire-Hardening Considerations

In its material flammability standards recommendation package issued in August 2001, the TSB identified a deficiency regarding the certification of certain aircraft systems. In its recommendation A01-04, the TSB stated that more validation needed to be done prior to the certification of aircraft systems to ensure that a fire-induced material failure would not exacerbate the consequences of an in-flight fire. The response from the regulatory authorities supported the status quo by declaring that the regulations governing the certification of critical systems, such as hydraulic, oxygen, and flight controls were comprehensive enough to address a system's fire protection and prevention requirements. For other aircraft systems, regulatory authorities have indicated that the combined effect of increasing the material flammability standards, introducing new technologies like the AFCBs, and implementing the recommendations of the Wire Systems Harmonization Working Group will mitigate the risk of initiating or sustaining an in-flight fire.

Testing during the investigation demonstrated that the flight crew oxygen system in the MD-11 could fail in a high heat environment, and exacerbate a fire. The regulatory authorities have not addressed the issue of how the existing regulations allowed for the certification of this oxygen system, which was constructed using dissimilar metals, while providing for the "fire protection and prevention" certification requirement. The design of the oxygen system met the requirements of existing regulations, otherwise, it would not have been approved for use in an aircraft. The same holds true for other materials that failed and exacerbated the SR 111 fire, such as the silicon elastomeric end caps on the air conditioning ducts.

The Board disagrees that the eventual reduction or elimination of flammable materials, and anticipated technological advances, adequately deal with the near-term risk. Therefore, the Board is concerned that regulatory authorities have not taken sufficient action to mitigate the risks identified in the TSB's recommendation A01-04, issued in August 2001, which recommended that as a prerequisite to certification, all aircraft systems in the pressurized portion of an aircraft, including their subsystems, 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.

4.3.3 Aircraft Wiring Issues

4.3.3.1 Material Flammability Test Requirements for Aircraft Wiring

In one of its recommendations regarding Material Flammability Standards (A01-03), the TSB explained the need to augment the certification test regime used in the approval of aircraft wires. Specifically, the certification criteria need to be expanded to include the determination of wire failure characteristics, using realistic operating conditions and specified performance criteria. The goal of such certification requirements would be to establish standards that would prevent the approval of any wire whose in-service failure could ignite a fire and minimize further collateral wire damage.

Regulatory authorities have advised the TSB that this issue is to be dealt with under the auspices of the FAA's Aging Transport Systems Rulemaking Advisory Committee (ASTRAC). The Board is aware that a Wire Systems Harmonization Working Group has been established to review the certification standards related to aircraft wiring systems. However, in evaluating the assignments of this working group, the Board was unable to identify a specific task that would initiate a review, based on the deficiency described in A01-03.

The Board appreciates that regulatory authorities are dealing with the larger issue of in-flight fires on several fronts, including improved material flammability standards and AFCB technology. While such activities have been beneficial and necessary, the Board is concerned that the deficiency identified in its A01-03 recommendation will not be corrected unless a specific regulatory review of certification requirements is undertaken to ensure the proper evaluation of aircraft electrical wire failure characteristics.

4.3.3.2 Limitations of FAR 25.1353 Electrical Equipment and Installations

During this investigation, the TSB found that there are limitations associated with the interpretation and application of FAR 25.1353(b). In aircraft design, it is not always possible to maintain physical separation between wires, especially in the cockpit area where, typically, space available for installations is confined. The guidance material does not specify what measures or criteria would be acceptable to meet the requirements of FAR 25.1353(b).

The Board has not issued a safety communication on this subject as it is aware that the FAA's ASTRAC (includes the JAA and TC) has been tasked with identifying the requirements for wire separation as they pertain to electrical equipment and installations. Specifically, the ASTRAC is to determine whether a comprehensive wire separation regulation needs to be included in a new wire system rule.

The ASTRAC's final recommendations on this matter have yet to be published; however, the Board is aware that Working Group 6 has declared to the FAA that the creation of separation standards is well beyond the scope of its tasking. Given this situation, it is unlikely that substantive change on the matter of wire separation will result from the current round of ASTRAC assignments. The Board remains concerned about the limitations regarding the interpretation of FAR 25.1353(b) and encourages the regulatory authorities to take follow-up action to research and resolve this matter.

4.3.3.3 Potential Limitations of MIL-W-22759/16 Wire

The primary wire type selected for the IFEN system installation was MIL-W-22759/16. This wire is commonly used by aircraft modifiers and the general aviation industry, although the wire is not used by major aircraft manufacturers, such as Bombardier and Boeing. The wire type is certified and used successfully without any record of inherent problems or adverse service history.

The Board is aware that on 22 March 2002, the United Kingdom Civil Aviation Authority issued Appendix 64 to its Airworthiness Notice 12, entitled Experience from Incidents. Appendix 64 deals specifically with MIL-W-22759/16 Electrical Cable and states, in part:

[P]articular care must be taken when selecting this cable type to ensure that it meets all installation requirements and is fit for its intended application.

The appendix lists several areas that must be addressed prior to the approval of MIL-W-22759/16 wire usage in the United Kingdom.

While the Board has not determined that this wire type is problematic, it remains concerned that, based on the Airworthiness Notice 12, the in-service performance of MIL-W-22759/16 wire may not be fully known.

4.3.4 Flight Crew Reading Light (Map Light)

The Board appreciates that improvements to the FCRL design and to the installations in MD-11s, have been undertaken since its ASA A000008-1 was issued. While it was appropriate that such improvements focused on the MD-11 FCRL and its installation, the Board believes that some of the same design limitations may exist in variants of this FCRL that are installed in other types of aircraft. The Board is concerned that there is not enough being done to apply the lessons learned from the deficiencies of the FCRL installation in the MD-11 to other aircraft installations involving the variants of this FCRL.

4.3.5 Standby Instrumentation

The Board recognizes that TC has committed to reviewing the requirements for standby instrumentation, including related issues such as standby communication and navigation capabilities. TC has indicated that the appropriate approach would be to address these issues in harmony with the FAA and the JAA, and that this objective could be achieved through current and future ARAC activities. The Board remains concerned with the lack of substantive progress in mitigating the risks identified in the TSB ASA A010042-1 (issued 28 September 2001) and encourages TC to work with the FAA and the JAA to expedite the required safety action.

TC indicated that during the certification process, the suitability of the standby instrumentation display(s) and placement are evaluated. TC also indicated that the installation of digital integrated standby instrument systems appears to improve the displayed information. The Board believes that standby instruments should be in a standard grouping layout similar to the primary flight instruments, and that the instruments should be positioned in the normal line of vision of the flight crew. The Board encourages TC to coordinate with the FAA and the JAA to address this issue without further delay.

The Board notes that TC is reviewing training scenarios developed by airline operators. The Board believes that TC should ensure that realistic training scenarios, involving the use of standby instruments, are incorporated in training programs, and that the scenarios include complicating factors, such as loss of additional systems, wearing of oxygen masks and goggles, and smoke in the cockpit.

The Board remains concerned that regulations do not require that standby instruments are capable of remaining powered by an independent power supply that is separate from the aircraft electrical system and battery. The Board believes that with current technology, providing independent standby instrumentation for secondary navigation and communication is feasible. The Board encourages TC to coordinate with the FAA and the JAA to address this issue without further delay.

4.3.6 Contamination Effects

Although the Board determined that contamination was not a factor in the initiation of the fire in SR 111, it remains concerned that the role of contamination in an in-flight fire is not well known. The Board believes that more needs to be done to quantify the risks. The Board is presently investigating the role of contamination in the context of another in-flight fire accident. TSB Investigation Report A02O0123 will address the safety deficiencies associated with contamination of aircraft.

4.3.7 Arc-Fault Circuit Breaker Certification

Significant research and development has been done in recent years to quantify and address the inherent limitations of existing aircraft CB design. This work has resulted in a new type of CB known as the AFCB, capable of reacting to a wider range of arc fault situations. The AFCB will prevent an arc fault from developing into a more serious situation that could damage other nearby wires and will limit the energy available to ignite flammable materials. While the AFCB trip characteristics will provide major improvements over the traditional aircraft CB design, these devices will not be certified to a standard that will require that the AFCB trips prior to the ignition of nearby flammable material. The Board is concerned that unless this aspect of the design specifications is addressed, AFCBs certified for use on aircraft will be capable of remaining energized long enough to ignite nearby flammable material.

4.3.8 Role of the FAA's Aircraft Evaluation Group

Title 49 United States Code section 44702(d) provides the FAA Administrator with the authority to delegate matters related to the examination, testing, and inspection necessary to issue certificates as part of its type certification process. The Administrator has determined that there exist certain aspects that are not to be delegated. One such function is the role of the FAA's Aircraft Evaluation Group (AEG), which is responsible for providing operations and maintenance input to all facets of the type certification process. For STCs, the FAA has determined that no delegate may make determinations regarding operations and maintenance issues; that role is reserved for the AEG.

For STC ST00236LA-D, the impact on the operations and maintenance of the MD-11 was determined by the STC applicant without direct AEG involvement. A survey of similar "non-essential, non-required" IFE system STCs revealed that approximately 10 per cent had been designed, installed, and certified in such a way that the flight crew could not remove electrical power from the IFE system without also interfering with essential aircraft systems. The survey results indicate that the operational review conducted as part of the STC ST00236LA-D approval process, was not unique in not detecting operational shortfalls.

The Board is concerned that a *de facto* delegation of the AEG's role has evolved with respect to the type certification process, which has resulted in less-than-adequate assessments of the operations and maintenance impact of some STCs, particularly those STCs designated as "non-essential, non-required."

4.3.9 Checklist Modifications

Checklists are designed by aircraft manufacturers and approved by regulatory authorities as part of the original evaluation and approval of aircraft-type design data. As airline operators decide to modify checklists to meet changing operational requirements, there is a need for modified checklists to follow the original design concepts contained in the AFM or other documents associated with the certificate of airworthiness.

In the absence of regulations requiring the approval of checklists that have been modified by airline operators, guidance material should be provided to operations inspectors. The guidance material, as a minimum, should contain methods of checklist design; checklist content; checklist format utilizing human factors principles; immediate action items; and sequencing of checklist items.

The Board is concerned that, given the lack of checklist modification and approval standardization within the aviation industry, airline operators may unknowingly introduce latent unsafe conditions, particularly to emergency checklists.

4.3.10 Accident Investigation Issues

4.3.10.1 Flight Recorder Duration and Power Supply

TSB Recommendations A99-01 through A99-04 were sent to the Minister of Transport in Canada and to the JAA in the Netherlands. The TSB also sent copies of its recommendations to the Swiss Aircraft Accident Investigation Bureau, the United Kingdom Air Accidents Investigation Branch and the French Bureau d'Enquêtes et d'Analyse. Concurrently, the NTSB issued similar recommendations A99-16 through A99-18 to the FAA.

TC has agreed with the recommendations and advises that it is taking measures to amend its regulations by the dates stipulated by the TSB. However, TC also advises that because the FAA is dealing with similar issues raised by the NTSB, it intends to harmonize its actions with those of the FAA. In this regard, the NTSB has expressed its apprehension that, although the FAA has indicated the intention to implement the recommended actions, the dates for final action may not be met.

The Board recognizes that TC has started its consultative process with the Canadian aviation industry, and understands the value of a harmonized approach with US authorities. However, the Board is concerned that TC will also not meet its commitment to implement the required changes in a timely fashion.

4.3.10.2 Underwater Locator Beacon

The flight recorders were recovered from the ocean floor by tracking the acoustic waves emitted from their attached underwater locator beacon (ULB). Given the substantial fragmentation of the aircraft wreckage, and the low visibility water conditions, the ULBs minimized the time required to locate the recorders.

While the recorder's internal crash-protected memory modules were intact, the ULB brackets were damaged. The extent of the bracket damage suggests a high probability that one or both of the ULBs could have readily detached during the impact sequence. The issue of the adequacy of ULB attachments has been a concern of the international recorder community for years.

The Board recognizes that EUROCAE Working Group 50 is developing minimum operational performance specifications for crash-protection of airborne recorders. Currently, these specifications include requirements for the application of impact shock tests to ensure the integrity of a flight recorder's ULB attachment. As EUROCAE recommendations are advisory in nature, the Board is concerned that without adoption and harmonization by regulatory authorities worldwide, ULB attachment specifications may not be universally applied.

4.3.10.3 Non-volatile Memory

Modern aircraft are equipped with electronic systems that contain memory devices designed for data storage. Most commonly, such systems contain a type of volatile memory device whose data is lost when power is removed. Frequently, systems contain a memory device known as non-volatile memory (NVM), which is capable of retaining its stored data even though power has been removed. In the case of SR 111, the engines were controlled with the assistance of full-authority digital electronic control (FADEC) engine control units, which contained NVM devices. In the absence of FDR information, data retrieved from the engine FADEC 2 was helpful in providing some information about the final five-and-a-half minutes of the flight. However, as the FADEC memory was designed for engine maintenance troubleshooting purposes, and the "time stamp" indicating when faults occurred versus when they were written to memory, was of poor resolution for accident investigation purposes. In addition, many other NVM devices from other LRUs were extremely difficult and time-consuming to identify as there were no distinctive markings to facilitate identification.

The Board is concerned that manufacturers and designers of equipment containing memory devices may not consider the potential use of such devices for accident investigation purposes. These aspects are best considered at the design stage, when improvements in data quantity, quality, and ease of device recognition can generally be included for relatively low cost.