Air Safety Week®

Air Safety & Security Trends, Policy and Regulation

Aerospace Journalist Of The Year – Safety

Corboy & Demetrio Award for Contributions to Improve Aviation Safety

Editorial Excellence Award Winner

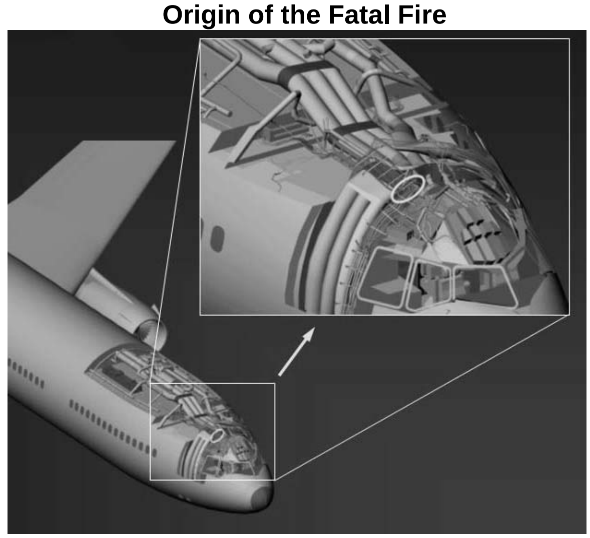
April 7, 2003
Washington, D.C.

Vol. 17 No. 14
www.aviationtoday.com

Canadian Investigators Decry Lack of Preparedness for In-Flight Fire

Swissair MD-11 crash probe reveals flammable materials, inadequate fire defenses

Origin of the Fatal Fire



Through reconstruction of the wreckage, Canadian investigators were able to pinpoint the location (small oval) of the electrical arcing that started the fatal fire in the attic space over the cockpit. This space has neither fire detection nor fire suppression. *Source: TSB*

Already in a dire situation, with one system after another failing, Capt. Urs Zimmermann must have been startled when the ceiling panel over his seat in the cockpit of the **Swissair** MD-11 burned through. The opening unleashed a torrent of hot gas and a dark cloud of charred fiberglass particles released by the insulation blankets whose flammable covering had burned away.

At that moment, with the sudden exclamations from Zimmermann and First Officer Stefan Loew on the radio of "Mayday," the urgency of the intended divert to Halifax became a matter of utter desperation, the planned overnight flight from New York to Geneva now completely forgotten.

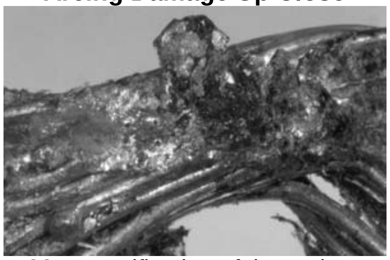
Zimmermann and Loew were in a dark cockpit, filling with smoke and hot gas, gasping futilely for breath when the line supplying emergency oxygen to them was melted by the heat of the inferno in the space above the cockpit. Large red X's appeared on five of their six "glass cockpit" displays showing they were no longer functional, the master caution alarm was sounding insistently, and the runway just 30 miles distant was so close, yet so far away. They didn't make it. The aircraft hit the water nose-down, in a steep bank, at a speed of some 300 knots. The force of deceleration was equivalent to 350 Gs – killing all 229 aboard instantly. Broken bodies and broken aluminum were "commingled," in the delicate euphemism employed by investigators.

The remains of one passenger, a pilot, were found with a life jacket on. Even though smoke from the fire raging overhead never clouded the cabin, he must have known the situation was more serious than the crew's calming assurances.

Capt. Zimmermann was not in his seat at the moment of impact. Most likely he had been driven out by the rain of melted plastic and the sudden downrush of hot gas. The effect perhaps was like that of a match held too close to a strip of celluloid motion picture film. It is a common image – the film darks, then a hole breaks open and the burnt edges of the film melt away, opening the breach. In short order, the film is consumed entirely. *(Cont'd on p. 2)*

- **Arcing Damage Up Close .... Page 2**
- **Two In-Flight Fire Cases Compared .... Page 5**
- **'Long Known Safety Hazards' .... Page 6**
- **Compendium of Complacency .... Page 7**
- **The Investigators Speak .... Page 9**

Arcing Damage Up Close



A 22x magnification of the arcing damage to the wiring powering the in-flight entertainment system on the accident aircraft. This arcing ignited adjacent flammable materials and triggered a cascading sequence of tripped circuit breakers and electrical system failures.
Source: TSB

The accident postmortem

The **Transportation Safety Board** (TSB) of Canada recently concluded its exhaustive investigation into the tragic Sept. 2, 1998, loss of Swissair Flight 111. At a March 27 press conference, TSB chairman Camille Thériault asserted that the report "has changed the face of aviation safety." Investigator in charge Vic Gerden more circumspectly characterized the fire on the Flight 111 jet as "a wake up call to the industry."

The dry wording of the TSB's 300-page report is an indictment of benign regulatory neglect before the accident, and a "business as usual" attitude since. The final 20 pages of the report, which focus on the actions taken or, more accurately, not taken, repeat the phrase, "The board is concerned that regulatory authorities and the aviation industry have not moved decisively."

Expressions like "The board has yet to see," or "the board remains concerned" appear with depressing frequency. Yet the case deals with one of the greatest hazards in airline operations – fire. The TSB report is a massive case study of the hazard, and a detailed catalog of actions needed but not yet taken *(see compendium of complacency, p. 7).*

In this respect, the TSB report is to fire what the U.S. **National Transportation Safety Board** (NTSB) is to explosions. In addressing the hazard posed by flammable vapors in fuel tanks, the NTSB has said it is not enough to engage in a hopeless pursuit of errant ignition sources – the vapors must be eliminated, thereby removing the potential for catastrophe. What the NTSB has declared about gases, the TSB is now asserting about solids – if the materials used in the airplane are not flammable, then the occurrence of an ignition source does not portend a deadly fire *(see box, p. 4).*

Just as **TWA** Flight 800 was destroyed in 1996 by a tiny electrical spark inside the center wing tank, which started the whole debate about fuel tank safety, the TSB has found that a tiny electrical spark in the attic area over the cockpit of Flight 111 ignited flammable metalized mylar thermal acoustic insulation blankets. The fire spread, feeding on other flammable materials, some supposedly fire-resistant but readily igniting nonetheless as the fire spread with the rapacious speed of a grassfire on the African savannah.

Seduced by smoke

The first telltale sign misled Zimmermann and Loew. They thought the odor and the wisp of smoke entering the cockpit from the center vent overhead was indicating a problem with the air conditioning system. Loew even stood up in his seat to take a sniff. The two pilots had no way of knowing that the power cable for the airplane's interactive in-flight entertainment network (IFEN) had arced, setting off a train of

Air Safety Week
ISSN 1044-727X

Assistant Editor: Eric Grasser, *egrasser@pbimedia.com*
Editor-In-Chief: David Evans *devans@pbimedia.com*
Managing Editor: Fred Donovan *fdonovan@pbimedia.com*
Senior Managing Editor: Jim Rogers
Contributing Editor: Dr. Alex Richman, M.D.
Director of Marketing: Jill Braun *jbraun@pbimedia.com*
Production Manager: Tracey Lilly
Publisher: Diane Schwartz
V.P. & Group Publisher: Heather Farley
President CEO: Don Pazour

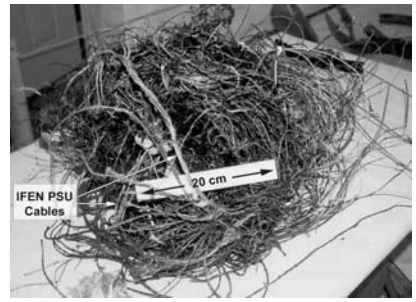
For Advertising Call Jill Braun: +1-301-354-1694

Send press releases to:
Eric Grasser, Assistant Editor
FAX: +1-301-762-4196, *egrasser@pbimedia.com*

arcing events and igniting a hidden fire above and just behind them. Initially, no circuit breakers tripped. The smoke flowed down to the electronics and equipment (E&E) bay, and also back into the attic area over the cabin, following a corkscrew path and finally seeping into the cockpit. When, as part of the troubleshooting checklist for smoke and fire of unknown origin, the ventilation fans for the cabin were turned off, the smoke reversed course. Now, instead of being sucked aft, it flowed toward the cockpit.

About a minute before the fans were turned off, the pilots radioed their intention to divert and land at Halifax's runway 06. At their distance and altitude from the airport, already it was too late by some four minutes. And even if they had been able through a supreme act of airmanship to bring the airplane to touchdown with concrete rather than impact with water, they would not have been able to stop before running out of runway. The ground sensing system was burned through. Without it, auto spoilers and antiskid brakes were inoperative. The electrical circuitry for the leading edge slats was burned through. With slats retracted and only 28º trailing edge flaps, the airplane would have needed at least 9,600 ft. to come to a stop. The runway is 8,800 ft. long.

Fortuitous Find



It was from this jumbled mass of wires that investigators retrieved the arced power service unit (PSU) wiring for the entertainment system. This find was critical in pinpointing the source of the fire. This bundle of entangled wires yielded 9 of the 20 wire segments that were found with arcing damage. *Source: TSB*

Four minutes had elapsed between the time the captain first noticed smoke and said, "Look," to the decision to divert. If they had started to descend at that first instant – well, maybe they would have made it. But remember, the smoke was seductive, showing itself, then disappearing, then showing itself again. What would have helped? Fire detection and suppression in the attic space, not required but part of the TSB's battery of corrective recommendations, would have enabled the pilots to determine if they were facing an air conditioning or electrical system malfunction.

As part of its Modification Plus program, with fire detection, suppression, and closed-circuit television retrofitted by Swissair (now **Swiss**) into the attic space of at least nine of the accident MD-11's sister ships, those crews at least have a means of detection, remote surveillance and a means to fight fire *(see ASW, March 12, 2001, p. 1, and July 30, 2001, p. 1).* The Modification Plus aircraft also feature increased wire/bundle separation, more fire-resistant end caps on the ducting and oxygen line, and include a state-of-the-art standby flight display. For the attic space, the rest of the world's airline fleet remains naked in the face of fire.

Raising the safety bar – but not high enough

The actions taken with respect to improved circuit breakers and more fire-resistant tests of insulation blankets also fall short, according to the TSB. The **Federal Aviation Administration** (FAA) is placing great

> **The Bottom Line of the Swissair Flight 111 Tragedy**
>
> 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.
>
> *Source: TSB, SR 111 final report, p. 280*

faith in arc-fault circuit breaker (AFCB) technology as a means of preventing dangerous arcing events from frayed, chafed or damaged wiring. However, circuit breakers work “upstream” of a wire fault, acting after the insulation has been breached to prevent further damage. Moreover, the TSB noted that the vaunted AFCB technology the FAA is pursuing might not limit the energy of even a fleeting arc to an intensity below the ignition temperature of adjacent materials. The same AFCB technology for residential use must meet this standard.

The FAA also is advertising its new radiant panel test, developed in the wake of the Flight 111 tragedy, as a means of subjecting thermal acoustic insulation blankets to a more rigorous test of fire resistance *(see ASW, Aug. 16, 1999, p. 10).* On this front, too, the TSB found that the new standard for materials could be more challenging:

- ✔ The test sample is oriented horizontally, not vertically. An upright position would be a more demanding test.
- ✔ The test sample is not pre-heated. Even though the radiant panel test is derived from an **American Society for Testing and Materials** (ASTM) protocol, it does not include that procedure’s pre-heat condition.
- ✔ The radiant panel test does not indicate how the flammability characteristics of tape, scrim, attachment fittings and so forth will be assessed in various combinations and installations when only three specimens of the insulation must be tested.
- ✔ The radiant panel test uses a flame. TSB investigators found that insulation blanket material is far more likely to be ignited by the higher heat of an electrical arc.

Reporters at the TSB’s press conference suggested that if the IFEN had not been installed improperly, or at all, Flight 111 might not have been downed by fire. To be sure, the system was connected to a flight essential power bus, the installers having discovered that the IFEN drew too much current to be connected to the non-essential cabin bus. The evidence suggests that the IFEN power circuit arced first. The whole sordid breakdown of FAA oversight of the system’s approval and installation is embarrassing enough, a sloppy legacy which FAA officials belatedly have conceded *(see ASW, Sept. 13, 1999, p. 1)*. But TSB investigators counter that the IFEN’s potential for electrical mayhem is a secondary issue. If arcing cannot ignite the surrounding materials, the arcing danger is blunted. It is the same argument the NTSB has been propounding for inerting flammable vapors as the best means of outflanking the hazard of ignition sources in fuel tanks.

It will take years, if not eventual consignment into retirement of the entire current fleet, before newer aircraft with fire-resistant if not fireproof materials are doing most of the flying. For those new-design airplanes, such as the coming **Airbus** A380, capable of carrying 550+ passengers on two decks, the TSB report serves as a checklist of fire protection features that can be incorporated to guard against that monster aircraft ever suffering the fate of the Swissair MD-11.

Meanwhile, fires continue to occur in the air and on the ground. The video display unit of the IFEN on an **Air Canada** A330 twinjet burst into flames Jan. 17, 2002, while the aircraft was parked at Vancouver. The system was being reset before boarding passengers. Pulling the circuit breaker had no effect and a Halon fire extinguisher was used. The video unit was removed and the aircraft departed 37 minutes late (see Cadors Number 2002P0033).

The NTSB last week released a detailed account of a Nov. 29, 2000, in-flight arcing fire on an **AirTran** DC-9. As shown in a comparison to the Swissair catastrophe, the AirTran jet was at one-tenth the altitude and the pilot was able to make a hasty return to the departure airport within minutes *(see box, p. 5)*.

Take action today

The TSB report, although expressing its frustration with the glacial pace of progress, takes the long view. Many of the deficiencies it cites will take years to correct and for training to be institutionalized. Can anything be done in the short term?

Yes. For one thing, the Flight 111 crew was faced with dense, continuous smoke, which was obscuring their ability to see even the standby instruments, much less out of the cockpit. Note the TSB reports that in the simulator training the smoke was stopped, when it doesn’t always cease in a real crisis.

Physically displacing the smoke with an emergency vision assurance system (EVAS) is one means of coping with continuous smoke, by means of a clear inflatable 'bag' tailored to fit the cockpit. Although not required by regulation, FAA-certified EVAS technology is finding its way onto more transport category aircraft *(see ASW, Oct. 21, 2002, p. 1 and Dec. 21, 1998, p. 8)*.

Two additional ideas can be borrowed from a new approach to cockpit and cabin fire safety propounded in 1999 by Capt. Ken Adams *(see ASW, Nov. 1, 1999, p. 3)*. Now retired, at the time Adams was an MD-11 pilot with **Delta Air Lines** [DAL]. Adams cited an in-flight fire aboard a **Federal Express** DC-10 freighter in 1996 as the aircraft was cruising at 33,000 feet, the same altitude as the Swissair trijet almost to the day two years later. The crew landed the airplane in 20 minutes and evacuated before the airplane was consumed by fire. Note the 20 minutes – pretty close to the same time between the initial appearance of smoke and the loss of Flight 111. Early detection prompted the captain's decision to land immediately.

Cases Compared
Characteristics in common – different outcomes

Item	Swissair Flight 111, Sept. 2, 1998	AirTran Flight 956, Nov. 29, 2000
Aircraft model	MD-11 widebody	DC-9 narrowbody
Altitude at beginning	Cruise at 33,000 ft.	Climbing through 3,800 feet
Time of day	Night	Day
Pilot flying	First officer	Captain
First symptom(s)	Unusual odor, temporary wisps of smoke out of cockpit center air vent.	Popped circuit breakers, Master Caution and other warning lights illuminate, smoke emanates from left sidewall in forward cabin.
Immediate actions	Advise ATC of intent to divert to Boston. Cabin bus switched off.	Emergency power selected; generators taken off line; cabin pressurization to manual.
Plan of action	Divert to Halifax, closer than Boston.	Immediate return to Atlanta.
Further symptoms during descent	Smoke in cockpit. Circuit breakers pop. Loss of most primary instruments and displays. FDR records multiple system failures. Loss of FDR/CVR & radar transponder.	Left attitude direction indicator (ADI) fails intermittently; cockpit lights flicker; captain fears all cockpit instruments will fail. Loss of CVR & radar transponder. Smoke in forward cabin.
Elapsed time	20 min., 40 seconds	7 min., 50 seconds
Outcome	Fatal. Loss of control; nose down impact with water at 300 knots. Wires and cables recovered with clear evidence of arcing/fire damage.	Successful emergency landing and evacuation via slides with minor injuries. Fire and soot damage to electrical bundles.

Sources: TSB, NTSB

In his concept, Adams suggested placing smoke detectors in each of the ducts supplying air to the cabin and cockpit. Locate the detectors right where the ducts exit the air conditioning packs. Better yet, evenly space additional smoke detectors close to electrical wire and bundle routings. Had such detectors been installed on the Swissair jet, the pilots would have been able to more quickly determine if they had an air conditioning system malfunction or a more threatening electrical system problem.

In addition, apertures could be placed in the cabin and cockpit at hidden fire zones – areas with a high concentration of electrical wiring/equipment and/or flammable material. With such ports, cabin crew could use their hand held fire extinguishers to quickly apply agent into these concealed areas. Duct detectors and access apertures could be installed in a low cost effort that might well prevent a repeat of the Swissair Flight 111 tragedy. Against the day of the strategic fire protection improvements called for by the TSB, this minimalist approach could be done quicker and cheaper than the effort undertaken after the 1996 crash of a **ValuJet** DC-9. A belly hold fire downed the jet, killing all 110 aboard, and within three years the entire airline fleet was retrofitted with fire detection and suppression in these previously unprotected holds. Where there is a will, the industry finds a way. >> *The TSB's full report of the SR 111 accident may be viewed at www.tsb.gc.ca/en/reports/air/1998/a98h0003/eReport/SR111_200303.pdf* << ✈

'Long Known Safety Hazards'

Lyn Romano, chair of the International Aviation Safety Association, reacted to the TSB's final report on the Swissair Flight 111 crash:

I was in Halifax to attend the **Transportation Safety Board** (TSB) of Canada's March 27 release of the **Swissair** Flight111 report and was impressed with the exhaustive efforts and expertise that went into the investigation of this crash of an MD-11 trijet.

For those who have not followed this investigation closely, the TSB's findings and recommendations might come as a surprise. The crash of Flight 111 was due to issues I, as chairman of the **International Aviation Safety Association**, and my colleagues and counterparts have been aggressively pursuing with the **Federal Aviation Administration** (FAA) and other regulatory agencies around the world. Due to the lack of appropriate regulatory attention to safety issues that have plagued the aviation industry for years 229 lives were lost.

As in the case of the fatal 1996 loss of 230 lives on **TWA** Flight 800, electrical wiring once again is called into focus. The TSB concluded that the fire started from arcing associated with the wiring in the Swissair jet's in-flight entertainment network (IFEN), or "other aircraft wiring" in proximity to the IFEN circuitry. The intense if even momentary heat of the arcing ignited the metalized polyethylene terephthalate (MPET) covering material on the thermal acoustic insulation blankets. In the confined attic area above the cockpit and area above the forward cabin galley, wiring was run closely, if not in physical contact, with the flammable acoustic insulation blankets. The covering on those blankets was the fuel that enabled the fire to grow. As the fire spread, it fed on other flammable materials allowed on this aircraft, resulting in the pilot's inability to retain control.

The dangerous characteristics of aromatic polyimide (trade name Kapton) wiring, which constituted more than 95 percent of the wiring in the area where the fire occurred, is known for its explosive characteristics under arcing conditions and for its carbonized insulation's ability to conduct electricity, thereby spreading the effect of an arcing event. The dangers of polyimide wiring have been known by the FAA and industry for years – as evidenced by efforts to use other wire types with polyimide's weight saving benefits but without its attendant hazards. When polyimide wiring is handled incorrectly or placed in close proximity to a softer wire type, such as the IFEN's Tefzel wiring, the stage is set for the two wire types to rub together in a sandpaper effect. The harder insulation wears away that of its softer neighbor, exposing conductor and opening a pathway door for catastrophic arcing. Unfortunately, in the question of the "lead event' (i.e. was the polyimide wiring the catalyst or was it the IFEN wiring?), nothing could be stated categorically by the TSB. But of this there is no doubt – the arcing was the match and the MPET insulation material was the equivalent of dry tinder. This enabled the fire to spread voraciously.

The certification of the IFEN system by Santa Barbara Aerospace (the Designated Alteration Station, or DAS, acting with FAA approval) was justifiably criticized by the TSB. The DAS did not employ personnel with "sufficient aircraft-specific knowledge to appropriately assess the integration of the IFEN power supply with aircraft power before granting certification," according to the dry wording of the TSB judgment. More bluntly, this was a case of negligence in action, considering the authority the DAS was granted to oversee the IFEN installation.

I have highlighted just a couple of the long known safety hazards that figured in the crash of Swissair Flight 111. How do we know that the hazards were known? By the fact that some 50 airworthiness directives (ADs) were issued by the FAA after the crash correcting deficiencies in the MD-11 electrical system. Those deficiencies were separate from the IFEN's installation. In light of the landslide of ADs issued after the crash, it is apparent that this aircraft type was not actually airworthy prior to the Swissair event. Moreover, electrical and wiring standards for certification had not kept pace with the exponential increase in wiring and electrical systems. In-flight procedures and provisions for dealing with electrical fire and smoke have not kept pace, either. 'Land as soon as possible' remains an instinctively primitive last-ditch recourse and reflects the prevailing lack of electrical redundancy.

I call upon the **General Accounting Office** (GAO), the investigative arm of Congress, or the **Department of Justice**, to conduct a further investigation now that the TSB has delivered its findings. I'm only one of many who believe that the gross lack of oversight by the regulators responsible for the safety of the flying public points to their culpability in this tragedy. Flying involves risks. Life involves risks. But risks can be mitigated and preventable crashes can be avoided. Swissair Flight 111 was a preventable aviation disaster. It is a case study in the breakdown of oversight.

I believe the time has come to demand an independent office be established to provide more focused oversight of the FAA. If that's construed as policing the regulator, then so be it. The Department of Transportation's Inspector General has too shallow a remit – and the GAO too broad. Considering the concerns expressed by some senior FAA officials about their agency's lack of funding and shortage of people, they might be grateful for the outside assistance and moral support.

There is a larger lesson. Every aviation disaster that can be prevented is one less tombstone in the cemetery of 'accident' causation – one less stone signifying lives needlessly cut short. That's why the TSB's recommendations must be acted upon immediately.

Byline: Romano's husband, Ray, was a passenger on Swissair Flight 111. She established the International Aviation Safety Association to further the cause of aviation safety. ■

Compendium of Complacency

Page numbers are those in the TSB's SR 111 report

✈ What was not being done or required before the accident:

✔ There was no regulatory requirement to install smoke barriers in passenger aircraft, or for such a barrier to meet a fire rating or fire blocking standard *(p. 13)*.

✔ The MD-11 was not certified to conduct back-course approaches using the flight management system, FMS *(p. 30)*.

✔ The flight data recorder (FDR) did not record individual air duct or zone temperatures, cabin smoke, lavatory smoke, parameters related to the in-flight entertainment system, or any system cues displayed on the system display control panel, or SDCP *(p. 31 & 73)*.

✔ The cockpit voice recorder (CVR) had a 30-min. capacity. It met regulatory requirements based on 1960s technology *(p. 75)*.

✔ Both recorders (FDR/CVR) were powered by the same source *(p. 74)*.

✔ There was no provision for a self-contained, independent electrical power supply for standby communication and navigation, nor was this required by regulation *(p. 31)*.

✔ In 1975, the FAA issued a notice of proposed rulemaking (NPRM) stating that for wire, the … requirement for smoke emission would be a value of 15 (maximum) within 20 minutes of the start of the test. Although expected to be adopted, the NPRM was terminated without affecting the existing rules *(p. 41).*

✔ The crew oxygen masks have a 6-ft. attachment line. Therefore, with the mask on, the first officer would not be able to reach any of the emergency equipment *(p. 60).*

✔ Prior to this occurrence, (air traffic) controllers did not receive basic or continuation training on aircraft in abnormal or emergency situations *(p. 70).*

✔ Quick access recorders (QARs), which capture far more information than FDRs, are not required by regulation. It is technically feasible to capture QAR information within the FDR crash protected environment *(p. 76)*.

✔ The SR 111 cockpit was not equipped with an image recording device, nor was one required by regulation. New technology provides economical single-camera systems that can capture a 360º panoramic view of the cockpit *(p. 76)*.

✔ The underwater locator beacon (ULB) attachments were damaged to the extent that they nearly became detached from the FDR and CVR. There is no requirement that the recorders be tested and certified with the ULBs attached *(p. 78)*.

✔ Materials used in occupied areas had to be self extinguishing. No testing was required for toxicity. Less stringent flammability standards were applied to those materials used within the pressure vessel but outside the occupied areas. No requirement existed for these materials to be self-extinguishing. Therefore, many materials were certified even though they were flammable *(p. 107)*.

✔ Testing during the investigation demonstrated that the flight crew oxygen system could fail in a high heat environment and accelerate a fire. Regulatory authorities have not explained how this oxygen system, using dissimilar metals (steel, aluminum) met the "fire protection and prevention" certification requirement. 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 *(p. 293)*.

✔ Two blanket materials in the accident aircraft are widely used in the aviation industry, metalized polyethylene terephthalate (MPET) and metalized polyvinyl fluoride (MPVF). Both were approved based on FAA certification tests at the time. Between November 1993 and March 1999, seven known occurrences took place in which MPET and MPVF-covered insulation blankets had been ignited and propagated flame *(p. 139)*.

✔ Under regulations in place at the time the MD-11 was certified, no requirement existed to determine whether a failure of any material would exacerbate a fire in progress. A premature breach of a certain system, such as oxygen, hydraulic and conditioned air, could exacerbate an in-flight fire *(p. 144)*.

✔ Typically, the (FAA-required) systems safety analysis does not include an assessment of the system's failure as a result of a fire in progress *(p. 145)*.

✔ Training for use of the Smoke/Fumes of Unknown Origin Checklist was conducted in the simulator. To save simulator time, the simulated smoke was terminated when the pilots selected the first position on the selector. As was the industry norm, there was no simulator training for an ongoing fire *(p. 161)*. Simulator training tended to reinforce a positive outcome to smoke-related events *(p. 215)*.

✔ No specific training was provided for locating and suppressing fires in the cockpit or avionics compartment *(p. 162)*.
✔ No specific training was provided on flying the aircraft using only standby instruments *(p. 162)*.
✔ There was no specific training on the location of potential flammable material in the aircraft, especially in hidden areas *(p. 162)*.
✔ There was no specific training regarding firefighting in the [cockpit] attic area [nor] specific training to the cabin crew about fighting a fire in the cockpit. Government regulations did not require it *(p. 163)*.
✔ Regarding wire separation and routing, the regulation requires that a potential threat be minimized; it does not require that a potential threat be eliminated. The term "minimized" is not defined *(p. 167)*.
✔ The adverse consequences of a circuit breaker (CB) reset may not be well understood. On Aug. 21, 2000, the FAA issued a bulletin on resetting circuit breakers in an attempt to standardize practices. This bulletin was only applicable to air carriers in scheduled operation with aircraft of 10 or more passenger seats or a payload of more than 7,500 lbs., and this bulletin's expiration date was Oct. 31, 2001 *(p. 170)*.
✔ There are no regulatory restrictions on the use of CBs as switches. As certified and installed, the original IFEN system did not incorporate an ON/OFF master switch *(p. 171)*. (*ASW* note: the CB was used for this purpose.)

✈ **The paucity of progress since the accident:**
✔ Europe's **Joint Aviation Authorities** (JAA) require 2-hour CVR for all aircraft certified after April 1, 1998. The United States and Canada still only require a 30-min. CVR *(p. 209)*.
✔ The FAA has yet to act on the recommendation for two combined FDR/CVR units with an independent back up power supply. Canada's implementation timetable is linked to the FAA schedule (p. 265).
✔ Boom microphones [as opposed to cockpit area microphones] improve the clarity of the CVR information. Currently, there is no regulatory requirement for the use of boom microphones in all phases of flight *(p. 210)*.
✔ There is no regulatory requirement that modern FDRs record QAR data *(p. 210)*.
✔ Although it is technically feasible to do so, regulations do not require the recording of cockpit images *(p. 210)*.
✔ Existing regulations do not require that underwater locator beacon attachments meet the same level of crash protection as other data recorder components *(p. 210)*.
✔ No regulatory requirement exists for transport category aircraft to allow for a checklist procedure that de-powers all but essential electrical equipment for the purpose of eliminating a potential ignition source *(p. 216)*.
✔ No regulatory requirement exists governing the length of time to complete checklists for odor/smoke events. The MD-11 checklist can take 30 minutes or more *(p. 216-217)*.
✔ The proposed arc fault circuit breaker (AFCB) technology will improve arc detection, but the performance criteria do not limit the arc energy to a level below the ignition level of flammable materials. Such testing criteria have been established for residential AFCBs, but the draft requirements for aircraft AFCBs do not include such criteria *(p. 224)*.
✔ Six power feed cables were routed together near the overhead switch panel in the accident aircraft. The regulations are such that minimum separation is needed only when a wire bundle contains essential system wires and heavy current-carrying cables *(p. 225)*.
✔ The FAA still does not require more than the 60º flame test to certify wiring. A wire systems harmonization working group has been tasked to revise performance standards and tests *(p. 281, 282)*.
✔ Controllers in Canada now receive refresher training on in-flight smoke and fire emergencies *(p. 283)*.
✔ There is no indication that regulatory authorities will mandate the wholesale removal from existing aircraft of other flammable acoustic insulation materials that fail the radiant panel test. Therefore, known flammable materials will exist for decades in thousands of aircraft worldwide *(p. 284)*.
✔ The board has yet to see significant industry-wide improvements … 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 *(p. 292)*. ■

The Investigators Speak

‣ *ASW:* In the accident airplane, is there anything in its operational, or electrical or maintenance history that indicated there might have been something in the way of a looming electrical problem?

Vic Gerden

Vic Gerden, (TSB investigator in charge): The short answer is no. We did look at the maintenance history of the aircraft in detail, and there wasn't anything pointing to a discrepancy or problem that would lead to this accident. (*ASW* note: The overall reliability of the MD-11 does not compare favorably with other aircraft, based on service difficulty reports. Although the accident MD-11 was not included, 34 sister aircraft in U.S. service showed a sixfold greater rate of problems with in-flight entertainment systems compared to 197 B757 and B767 aircraft; see box below).

MD-11 Service Difficulty Reporting Over 3-year period, 34 MD-11s compared to 117 B757s and 80 B767s **Greater frequency of reports for MD-11**	
Communications systems	7.3 times
Smoke detection	30 times
Fire detection	6.7 times
Public address & entertainment systems	6.0 times
Engine shutdown	7.3 times
Deactivate system	2.7 times
Source: AlgoPlus Consulting Ltd.	

‣ *ASW:* The photo shown at the press conference of the arcing in the bundle shows evidence of a full-blown arc, not a ticking fault. Did the circuit protector fail to protect?
Gerden: The arc that we showed [at the press conference] was magnified 22 times. In fact, it is barely visible to the naked eye. It was a very small arc site. It did not trip the circuit breaker. The same phase on that power cable arced further downstream, about 50 centimeters or 20 inches.

‣ *ASW:* How many? As the fire is spreading, it's eating into more circuits, so now some of the other breakers might be going off line.
Gerden: Yes, sooting was found on some other breakers. Those trips were caused by thermal tripping from the fire.

Jim Foot

Jim Foot (TSB systems group chairman for the SR 111 investigation): You know the white indicator ring on the end of a circuit breaker? We found some of those that were sooted. So obviously they tripped before impact. They were a variety from the overhead circuit breaker panel.

‣ *ASW:* Vic, you mentioned that the crew lost *most* of their instruments. Could you be more specific? Did they lose all six of the glass-cockpit displays, for example?
Gerden: They lost five for sure. They would have had a red 'X' there. There are indications that they attempted to restore information that would have appeared on DU 2 [display unit #2, the center one in front of the captain]. That would have been partial information. So other than that they had standby instruments. The compass was up on the windshield, between the two front windscreens and had to be pulled down, and it was a pretty basic compass. And the other standby instrumentation was not ideally set up, but it was all they had. By the time the airplane impacted the water, the 'OFF' flag was on the standby indicator.

‣ *ASW:* What are you and your [TSB] colleagues looking at to give an assured power supply to the standby instrument?
Gerden: We issued an advisory in September 2001 dealing with the position, the size and the additional independent power supply for the standby instrument, as well as additional training for the crews.

‣ *ASW:* Has any of that taken root in the industry?
Gerden: Swissair certainly made changes. They put in an integrated display of standby instruments with a backup power supply. Other companies have installed that same integrated standby instrument in their MD-11s.

‣ *ASW:* You mentioned that it was not possible for Capt. Urs Zimmermann and First Officer Stefan Loew to have gotten the airplane down to a landing. Did you explore an emergency descent, not relying on the FMS [flight management system], just raw data, no fuel dump, and accept the fact of an overweight landing?
Gerden: The calculation we did was just that. Under ideal conditions, the minimum descent time and landing, with everything working, and fuel dumping would be immaterial – you could do that if you wanted to – but in terms of the minimum time to descend and land, it would have taken 13 minutes from the ideal 'start of descent' point. That would take them to 10:27 p.m. By 10:24 p.m. the systems already were starting to fall off line and the cockpit environment was deteriorating pretty rapidly after 10:25. So the answer is unfortunately no.

‣ *ASW:* On troubleshooting, in trying to determine whether it is air conditioning or something more serious, what are your thoughts on locating smoke detectors in the air conditioning ducts to at least get

a 'yes' or a 'no' on that as the first order of business?
Gerden: We're not normally in the business of creating the solutions or attempting to go beyond identifying the safety deficiency. We did make recommendations in terms of the requirement for built-in smoke detectors and suppression equipment. A big adjunct to that is what the crews should have in terms of training and procedures and access into areas so they can have an aggressive program in place to locate what the problem is and to deal with it as early as possible, and at the same time to prepare the airplane to land expeditiously. It depends on where they are over the world – they may not be able to land.

‣ *ASW:* The U.S. **National Transportation Safety Board** issued recommendations last year associated with the problems of detection and suppression of fire in inaccessible spaces, and the UK's **Air Accidents Investigation Branch** has cited the problem. When the TSB recommends that we need better coverage in inaccessible areas, how far do you have in mind – all inaccessible areas?
Gerden: This is a function of the design of the aircraft and the risks associated with where the electrical and wiring components are vis-à-vis combustible materials, so it would probably vary from one airplane to the next.

‣ *ASW:* You alluded to deficiencies in circuit breaker design. Could you be more specific?
Foot: The breakers used now are all thermal. They don't catch some of the arc faults, which don't have enough current to drive the circuit breaker to trip. The newer ones can catch a very small arcing event within the first few cycles of it taking place. That's a huge safety advance.

‣ *ASW:* Are you referring to the arc fault circuit interrupter technology?
Foot: Yes.

‣ *ASW:* Have you indicated when you would like to see that sort of technology deployed in commercial aircraft?
Gerden: We haven't put a time frame on that in the recommendation that was issued. As soon as feasible.

‣ *ASW:* It was interesting to hear the TSB's call for a cockpit video recorder. How might that have helped in the investigation?
Gerden: It could capture switch positions, displays, circuit breaker trips, and it could capture the cockpit environment. A picture is worth a thousand words.

‣ *ASW:* What timeline were you looking for regarding installation of cockpit video?
Gerden: The technology is available. It's a matter of getting the will.
Foot: EUROCAE (**European Organization for Civil Aviation Equipment**) has put together a standard. It will be coming out soon.
Gerden: From an accident investigation perspective, having it in sooner rather than later is the objective.

‣ *ASW:* You envision cockpit video recording not only for new production aircraft but also a hard mandate to retrofit into the existing fleet?
Gerden: Our preference would be to have a retrofit.

‣ *ASW:* You indicated a need for a more comprehensive testing standard for the thermal acoustic insulation material. The FAA developed the radiant panel test after the Flight 111 accident. You alluded to the need to go beyond that test. What did you have in mind?
Gerden: That test primarily is designed for a thin film material. There are other materials that are not thin film, that are foams and thicker materials. They may not be appropriately tested by that one single radiant heat panel test. We're suggesting additional tests for all types of materials used for thermal acoustic insulation blankets.

‣ *ASW:* Would you be looking at smokiness, toxicity, what?
Gerden: Our approach is that the material should not sustain or propagate fire. If it doesn't sustain a fire then toxicity or smoke are not a problem.

‣ *ASW:* On the wiring, you referenced the limitation of the 60º vertical flame test on an unpowered wire. What would you like to see in terms of more realistic testing?
Gerden: In our August 2001 recommendations, we called for a test regime that evaluates the wire and its failure characteristics under realistic operating conditions (e.g., powered), so the goal is to prevent the risk of ignition, and the corollary is to minimize damage in adjoining areas.

‣ *ASW:* What additional policies or practices with respect to wire installation, separation and segregation come to mind as a result of this investigation?
Gerden: The safety concern is that the criteria used need to be more specific and clear as to what wire separation is acceptable.

‣ *ASW:* Is it possible to remove all the flammable materials used in the construction of a modern jetliner and install non-flammable materials?
Gerden: It's possible to remove the MPET material. That order has been put out there. But there are other ways of mitigating the risk, by having built in detectors, by having an in-flight firefighting plan. The problem needs to be tackled on many fronts. ■