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table of contents

Structural Monitoring Can Pinpoint Impending Failures

A new technology from down under is vacuuming up cracks

A quick head count of airworthiness directives (ADs) discloses that around one-fifth of them are directed at loss of aircraft structural integrity, either through corrosion, cracking or potential overload. This rough figure is probably not representative of the size of the problem, however, as unpublicized Service Information Letters (SILs) or Service Bulletins (SBs) would normally address myriad other minor issues that haven't as yet reached a critical stage requiring a regulatory decree.

Suffice it to say that when airplanes are built, even when overbuilt in terms of robustness for longevity's sake, avoiding the loss of structural integrity over time is a significant cost factor in maintenance, repair and overhaul (MRO). Problems that don't surface visually need to be revealed before they reach significant proportions. The venerable technique is generically referred to as non-destructive inspection (NDI). One case that springs to mind is that of **China Airlines** Flight 611, an aging **Boeing** B747 that suffered catastrophic structural failure over the Taiwan Straits on May 25, 2002.

The **Aviation Safety Council** (ASC) of Taiwan concluded that a 180-centimeter (or 5.9-foot) crack on the under-fuselage had been hidden from view externally by a tailstrike repair doubler for some 25 years *(ASW, March 7, p. 1)*. It was hidden internally by an accumulation of dust and other detritus. When it finally let go, it resulted in an inflight breakup at 35,000 feet, killing 206 passengers and 19 crew. The ASC report included the observation that: "According to the regulations of Boeing's Repair Assessment Program, the aircraft would have undergone inspections of that repair before reaching 22,000 flights. However the accident occurred when the jet had completed its 21,398th flight, a

(See Structural Monitoring on p. 2)

Industry Ill-Prepared for Flying In Severe Icing Conditions

Taiwanese investigators reach conclusion

Pilots need to be more aware of the hazard posed by in-flight icing, while a more sophisticated icing detection system needs to be developed, and a system needs to be implemented to better warn crews when flying in icing with the autopilot engaged. These are perhaps the most significant recommendations to come out of the **Aviation Safety Council** (ASC) of Taiwan's investigation into the Dec. 21, 2002, crash of a **TransAsia Airways** twin-turboprop freighter into the Taiwan Strait on a flight from Taipei to Hong Kong.

The details and circumstances have been previously presented in this publication *(see ASW, Nov. 10, 2003, p. 1, and Feb. 3, 2003, p. 3)*. The two-pilot crew flew into icing conditions, they realized too late they were in severe icing conditions, and lost control of the aircraft, an **Avions de Transport Regional** ATR-72. A passenger version of this aircraft crashed at Roselawn, Ind., in 1974, prompting the retrofit of larger de-icing boots on the wing leading edges. The Taiwanese aircraft was similarly fitted with the larger boots, but they were not, of themselves, sufficient to save the situation.

The airplane was also equipped with ice accretion detectors, which alerted the crew to the need to activate aircraft anti-ice systems. However, the stall protection system is not certified, nor is it required to be, for the freezing drizzle/rain conditions encountered by the accident aircraft. These conditions are outside of Appendix C, which describes

(See Icing on p. 4)

Structural Monitoring *(Cont'd from p. 1)*

few cycles of landing and take-off away from the maintenance program's maximum threshold."

FAA's Aging Aircraft Program

After the explosive decompression and near-crash of a **Boeing** 737 in the Hawaiian Islands in 1987, Congress passed the Aviation Safety Research Act of 1988 (Public Law 100-591). This act increased the scope of the **Federal Aviation Administration** (FAA) mission to include research into the causes, effects, and mitigation of fatigue and environmental degradation of aircraft structures. In response, the FAA developed the National Aging Aircraft Research Program (NAARP).

An Australian company, Perth-based S**tructural Monitoring Systems** (SMS), has devised a patented methodology to reliably detect such unseen defects. It has signed a contract with Airbus for licensed use of its Comparative Vacuum Monitoring (CVM) technology for integration with new and existing Airbus airframes, including the A380. It is also working with Boeing on retrofitting the technology into older aircraft. SMS hopes to be able to roll it out to the U.S. manufacturer's fleet in 2006.

Before looking at how it works and what it can do, what could be the advantages? Firstly designers could re-engineer areas that must be designed to cope with cyclical fatigue (like wing-roots) for weight-savings of around 15 percent. Weight-savings can obviously increase payload or reduce fuel carriage – which in turn can reduce airline fuel bills. The global airline industry spends $12.9 billion annually on structural maintenance.

The **National Aeronautics and Space Administration** (NASA) estimates that structural integrity monitoring through embedded devices such as CVM could reduce airframe and maintenance costs by as much as 35 percent. At present, paring weight is not really an option because provisions must be made in load-bearing structures for multiple redundant load-paths. Design standards accommodate the unseen and unforeseen degradation of a primary component due to cracking or corrosion. But even in existing overbuilt structures, the ability to detect cracking and degradation in a timely manner would provide the same sort of safety buffer that modern engines have via the Spectrographic Oil Analysis Program (SOAP). At a certain latter point in its life, thanks to a combination of use, abuse and exposure to the elements, an airframe will transition from fail-safe to fail-sure. NDIs and non-destructive tests (NDTs) can offer only a modicum of reassurance that something isn't failing sight unseen. These kinds of in-depth examinations also occur only periodically. With CVM, airline maintenance personnel shouldn't have to keep their fingers crossed behind their backs in between major overhauls. When something untoward occurs, CVM technology is designed to reveal it without delay.

It's not out of the question that modern aircraft will develop dangerous cracking. Australia's second airline, Ansett, went out of business following two lengthy groundings by the country's regulator. The carrier's maintenance group had totally missed the target dates on two important service bulletins, one involving a potential crack in the tail of its 767s and another addressing engine pylon cracks. Once an audit had picked up these oversights, the carrier was chagrined to find that, yes, it did have dangerous fleet-wide cracks in both areas that were in need

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of repair and, yes, these cracks had been there for quite a while.

SMS is looking to have an offline monitoring system hooked up to the monitoring technology of widebody aircraft some time next year (i.e., a "plug-innable" system with embedded sensors). The following year it hopes to have an online monitorable system interfaced with the aircraft's Health and Usage Monitoring System (i.e., it would be able to provide downloadable data wirelessly). If it proves to be a reliable technology, it may well be incorporated in the Federal Aviation Administration's (FAA) AAR-400 aging aircraft program (see box above).

Traits of Comparative Vacuum Monitoring

Comparative Vacuum Monitoring has special qualities because of its sensing and condition-monitoring capabilities. The sensor can:

- Detect sub-1mm cracks in processed metal surfaces;
- Measure the physical crack;
- Operate successfully on peened, painted or otherwise treated surfaces;
- Monitor welded joints;
- Operate in situ on aircraft;
- Monitor riveted fastenings and sandwiched structure (both external and internal surfaces);
- Operate in varied atmospheric conditions, altitudes and hazardous environments; and
- Measure crack initiation and propagation without stopping the operating equipment for inspection.

Source: SMS

What is CVM?

Retired airline pilot Ken Davey invented Comparative Vacuum Monitoring in 1994 to provide a "Structural Health Monitoring System" for aircraft. In 1968, Davey had been flying a Vickers Viscount the day before its starboard wing catastrophically failed in flight, resulting in the loss of all on board. The cause was an undetected crack through the main wing spar. CVM is a measure of the differential pressure between the "vacuum" side, next to the surface to be checked, and the non-applied side, which has its openings to "atmospheric." If no flaw is present, the vacuum will remain at a stable level. If a flaw develops, air will flow through the passage created from the atmosphere to the vacuum side. A very simple analogy might be trying to get a suction cup to stick to a smooth surface, but traversing a crack. It would stick reliably to glass, but not to a crack in the glass. Sensors may either take the form of self-adhesive polymer "pads" or may form part of the component. A transducer measures the air flow between the passages in the sensor.

A basic system consists of three main components:

✔ An inert sensor that can be adhered to (or embedded within) the structure during manufacture;

✔ A regulated vacuum source to apply and modulate a low vacuum;

✔ A measuring device.

While flat, self-adhesive polymer sensors are most commonly used, sensors can be designed and manufactured to conform to two and three-dimensional surfaces. Sensors can be made in a range of materials to suit even extremely hostile environments.

Sensors can be embedded within the mass of a structure or encased within bonded joints and lap joints to monitor for internal failure. This design can enable significant cost savings when compared to retrospective installations.

Several variations of the basic system are available:

✔ Kits for structural fatigue testing in which multiple test sites can be continuously monitored from a single vacuum source and data acquisition computer.

✔ Unique real-time crack propagation monitoring systems.

✔ Portable systems designed for use on aircraft, where only the passive sensor is installed on the aircraft and the self-contained portable instrument is manually connected for periodic inspections, greatly improving inspection times.

Operator training is fairly easy and covers preparation of the surfaces, installation of the sensors, and the use of the monitoring instrumentation – which is completely automated, according to the manufacturer. The company plans to establish a training program for operators as the commercialization effort progresses.

Of significance, based on damage under doublers found in the wreckage of the China Airlines plane, this technology could detect cracks under doublers. An integral sensor can be sandwiched between the doubler plate and the surface with the cracking problem *(see*

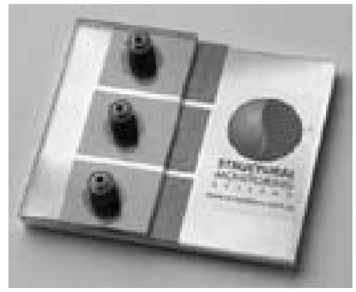
(Continued on p. 4)

Structural Monitoring *(Cont'd from p. 3)*

photograph, right).

Mark Vellacott, chief executive officer of the company, is bullish on the technology, and its potential to significantly reduce the cost of structural maintenance inspection programs. "We are well advanced in the process of qualifying CVM systems for use by both civil and military operators," he says. The company already has installed 120 sensors in the A380 full-scale fatigue test rig in Germany, and it hopes to have inspection applications for aircraft fleets in 2006.

>>*Contact: Vellacot, e-mail m.vellacott@ smsystems.com.au; see also www.smsystems.com.au*<< ✈



An integral sensor developed with Airbus and used by the manufacturer to detect cracks around rivet holes in repair schemes for GLARE, the aluminum-fiberglass composite used on the upper fuselage of the A380.

Photo: SMS

Icing *(Cont'd from p. 1)*

the icing conditions that systems must protect against.

Among the ASC's findings:

✔ "The accident flight encountered severe icing conditions. The liquid water content and maximum droplet size were beyond the icing certification envelope [of] Appendix C."

✔ "[The carrier's] training … has not been effective and the pilots have not developed a familiarity with [warnings] set forth in the Flight Crew Operating Manual and the Airplane Flight Manual to adequately perform their duties."

✔ "The flight crew was too late in detecting the severe icing conditions. After detection, they did not change altitude immediately, nor take other steps required in the Severe Icing Emergency Procedures."

✔ "During [the time] the airframe de-icing system was intermittently switched off, it is highly probable that residual ice covered … the wings of the aircraft."

✔ "The icing detection system was operating normally … However, currently there is no … on board system which is able to identify the severe icing condition [encountered] and provide proactively sufficient information related to ice accretion and associated effects to the flight crews." (See box)

✔ "The stall warning system was operating as designed. The Safety Council believes under severe icing condition[s] … the stall warning system could not provide adequate warning."

To TransAsia Airways, the ASC recommended improved training for better situational awareness. Specifically, the ASC said, "Enhance pilots of the ATR fleet with their training and rating on areas such as awareness, observing indications of severe icing, briefings and workload sharing, emergency procedures, and unusual attitude recovery."

To the manufacturer, and to the **Direction Generale d'Aviation Civile** (DGAC), the French regulatory authority, the ASC recommended:

> "Proactively develop a more sophisticated icing detection system to enhance flight crews' understanding and awareness of icing condition[s]. Evaluate a new system to provide flight crews additional warning when [an] aircraft operates in icing environment with autopilot engaged to reduce the potential risk of pilot's failure of monitoring and maintaining airspeed."

That failure was the principal cause of the crash.

The ASC's recommendations are virtually a mirror-image of the National Transportation Safety Board (NTSB) recommendations to the Federal Aviation Administration (FAA). Reducing the dangers from in-flight icing are on the NTSB's "Most Wanted" list of safety improvements. The NTSB has characterized as "unacceptable" the FAA's response to its two recommendations:

> "Use current research on freezing rain and large water droplets to revise the way aircraft are designed and approved for flight in icing conditions,"
>
> and
>
> "Give flight crews accurate information to quickly recognize dangers of all types of icing and maintain airspeeds to avoid loss of aircraft control."

(The ASC report, in English, may be viewed at www.asc.gov.tw/acd_files/ge791_1e.pdf. For the NTSB position, see ASW, Nov. 15, 2004, p. 1, "Safety Board Wants Action on In-Flight Icing Threat.") ✈

Inadequacies Of The Existing Ice Detection System

From the Aviation Safety Council of Taiwan's final report on TransAsia Airways Flight 791 (extract):

"The airframe de-icing system was activated for 2 minutes and 52 seconds then was turned off at time 01:37:21. Because the primary mode of detection remains visual detection of ice formation by the flight crews, when the flight crews judged no more ice the pilots will take further action such as turning off the airframe de-icing system. The CVR [cockpit voice recorder] recording at 01:37:24, CM1 [the captain] mentioned, 'It's gone again.' The Safety Council believes the flight crews perceived that icing condition no longer existed at time 01:37:21, then the airframe de-icing system was switched off.

"When the airframe de-icing system was switched off no single chime was recorded in [the] CVR. At this moment there might be no icing … or there might be ice accreted that [the] icing detection system was not able to detect. The … performance analysis concludes that there was residual ice on the wings after the airframe de-icing system switched off at time 01:37:21. Four minutes later, at time 01:41:21, the single chime sounded again.

"The airframe de-icing system was activated again at time 01:41:25. The Safety Council believes the single chime at 01:41:21 was triggered by the icing detection system. From 01:37:21, when the airframe de-icing system switched off, until 01:41:21, when the icing detection system generated [the] aural alert, within four minutes there was no icing alert, however, residual ice remained on [the] wings.

"Even the primary mode of detection remains visual detection of ice formation still by the flight crews. From the flight operations viewpoint … Section 2.1.2 concludes, 'in adverse weather conditions and night time, it's very difficult to judge the icing condition according to the Flight Operations Manual.'

"The Safety Council concludes that the existing ice detection system and the visual detection of ice formation neither ... provide sufficient information related to ice accretion to the flight crews nor provide a capability of [determining] the icing severity." *Source: ASC final report, p. 168-169, see www.asc.gov.tw/acd_files/ge791_1e.pdf*

BRIEFS

● **Computational fluid dynamics includes gasses.** A computer model is being developed by Sandia National Laboratories that will enable designers of smoke and fire detection systems for cargo bays to minimize the potential for false alarms *(see ASW, July 4, p. 1)*. We asked Sandia a few relevant questions, to which their responses are provided for information:

✔ How does the model assist in reducing the false alarm rate of a system that's going to be installed?

"The computational fluid dynamics (CFD) model has the potential to reduce false alarms by improving the design and certification of all cargo compartment smoke detection systems. New systems will likely be multi-criteria detectors which alarm only when two fire signatures, such as heat and particulate, are present. Designers of systems using these detectors can use the CFD model to optimize the use of these new detectors. The model provides information on temperatures, gas concentrations, and particulate concentrations in the compartment with time. This information is needed to optimally place the sensors within the compartment and set the alarm thresholds to meet the **Federal Aviation Administration** (FAA) certification requirements. All systems will then be tested on the ground and in-flight to ensure the requirements are met.

✔ Translate this phrase into plain English: "The CFD model couples heat, mass, and momentum transfer phenomena in cargo compartment fires."

"The CFD model provides detailed information on the temperature and the flow of smoke (gas concentrations and particulate) with time resulting from cargo compartment fires. The user can specify the aircraft size, shape and ventilation."

✔ If the current false alarm rate is one in 100, what is the expected reduction in the false alarm rate using this system?

"Although the potential to reduce the false alarm ratio is present, quantifying the improvement would be merely speculation at this time."

✔ As a result of the development of this model, what are you learning about cargo compartment fires that wasn't known (or fully appreciated) before?

"The most significant progress to date is the model validation efforts that showed the difference in optical properties of various 'smoke' sources used for testing and the effect of this on light scattering photoelectric detectors. These differences are important in using the model.

✔ What have you learned regarding location of the smoke/fire detectors?

"The model is just starting to be used. As it is applied to actual compartment certification projects, it will provide specific conclusions about detector locations."

(Continued on p. 6)

Briefs *(Cont'd from p. 5)*

In other words, the model is in its infancy, and it is being verified by doing test burns in aircraft cargo holds on the ground, the results of which are compared to what the model says (for example, a DC-10 test hold at the **Federal Aviation Administration Technical Center**). To discriminate between real and false alarms, it will be necessary to discriminate not only between what's burning and not, but also between various types of cargo. For example, condensation from live frogs and pigs have caused the fire systems to alarm. On April 10, an Emirates A340 enroute to Zurich returned to Dubai after 20 minutes after reports of smoke in the passenger cabin. The smoke and the smell was coming from 800 kilograms of fish being shipped in the cargo hold.

Aircraft flying out of Thailand with a load of Durians, a pungent fruit, have also activated the smoke alarms.

Clearly, to reduce the false alarm rate dramatically, the alarms caused by various flora and fauna will have to be accounted for; more than comparing two "fire signatures" will be needed.

The National Aeronautics and Space Administration (NASA) is also pursuing cargo hold fire detection technology, with the goal of reducing the false alarm rate some 80 percent. A smoke sensor originally designed for the International Space Station has been tested *(see www.fire.tc.faa.gov/pdf/systems/Jun05SystemsMin.pdf)*. ■

● **Clarify cracks policy.** The FAA's fatigue and damage tolerance policy should cover all older aircraft, according to the **Aircraft Owners and Pilots Association** (AOPA). The organization was responding to an FAA draft advisory circular (AC) on fatigue and damage tolerance issued to the industry for comment *(see ASW, May 9, p. 7)*.

The new AC would set guidelines for allowing aircraft to continue flying with known structural cracks, if the cracks are not in the primary structure and the airframe can still withstand the ultimate design load.

"The FAA left out the majority of older general aviation (GA) aircraft from this guidance document," said Luis Gutierrez, AOPA's director of regulation and certification policy. "As drafted, it only applies to Part 23-certificated aircraft, but most aircraft flying today were certificated under the old CAR 3 standards."

He argues that the CAR 3 standards should be included. As AOPA said in its comments to the FAA, "The FAA has previously applied this policy to CAR 3 airplanes."

Of concern to AOPA is the elimination of analysis and test options for flying with known cracks. "The FAA's 1996 policy memorandum allows for various combinations of analysis and test," the AOPA submission to the docket says. "The removal of those options would eliminate viable alternative methods to substantiate the ability to sustain ultimate load with known cracks." ■

● **Checkered history of airspace modernization.** Detailed information about the impact of planned funding cuts to national airspace system (NAS) modernization should be provided to **Congress** by the FAA, according to a new **Government Accountability Office** (GAO) report. The report found that the FAA's performance-based Air Traffic Organization (ATO), created in February 2004, has met its 2004 acquisition goal, but no details of funding cuts in coming years have been provided, and without this information, legislators lack "important details when considering FAA's annual budget submissions."

The GAO report contains a penultimate history of NAS modernization:

> "The ATO met its acquisition goal for fiscal year 2004. However, prior to the establishment of the ATO, FAA had experienced more than two decades of cost, schedule, and/or performance shortfalls in acquiring major systems under its ATC [air traffic control] modernization program. For example, 13 of the 16 major system acquisitions that we reviewed in detail have experienced cost, schedule, and/or performance shortfalls when assessed against their original milestones.
>
> "These 13 system acquisitions experienced total cost growth from $1.1 million to about $1.5 billion; schedule extensions ranging from 1 to 13 years; and performance shortfalls, including safety problems.
>
> "We found that one or more of four factors – funding, requirements growth and/or unplanned work, stakeholder involvement, and software complexity – have contributed to these legacy challenges.
>
> "While FAA met its recent acquisition goal, it is important to note that this goal is based on updated program milestones and cost targets for system acquisitions, not those set at their inception. Consequently, they do not provide a consistent benchmark for assessing progress over time. Also, as indicators of annual progress, they cannot be used in isolation to measure progress over the life of an acquisition." (*For the full GAO report, see www.gao.gov/cgi-bin/getrpt?GAO-05-331*) ■

● **Determining fuel tank vulnerability.** In its discussion of fuel tank safety for the **Airbus** A380, the

European Aviation Safety Agency (EASA) commented on the use of the Monte Carlo method of assessing fuel storage system safety. That comment was not central to our discussion of the A380 situation *(see ASW, July 11, p. 1)*. However, the Monte Carlo method is central to the special conditions announced for the inerting system proposed for **Boeing** 747 and 737 jets *(see ASW, March 14, p. 1 and June 20, p. 7)*. Basically, the Monte Carlo method provides an estimation of fleetwide average vulnerability to flammable vapors. Aircraft on specific flights may experience higher or lower vulnerability.

EASA said: "Regarding the Monte Carlo assessment, it appears it was a very useful methodology for research purposes, but has some inherent limitations as a certification tool. Hence, the EASA considers that the Monte Carlo method is not the most adequate tool to establish if a tank belongs to either the low or high flammability categories."

The FAA told EASA the Monte Carlo method was used "for the last seven years" to assess the impact of design changes on fuel tank flammability. ■

● **NASA scraps inspections of aging wiring.** NASA is abandoning the development of state-of-the-art tools to inspect aging Space Shuttle wiring, which is susceptible to electrical shorts.

As a consequence, the agency's inspector general says, NASA is putting astronauts at risk and failing to comply with a recommendation made by the **Columbia Accident Investigation Board** (CAIB).

"Without new evaluation technology, the inability to detect unseen wiring problems will continue to be a safety risk for the orbiter and any next-generation space vehicles," the NASA inspector general said in a summary of the agency's response to CAIB recommendations *(see box)*.

In July 1999, an electrical short knocked out two main engine computers, leaving the crew one failure away from an unprecedented emergency-landing attempt. Investigators determined that the frayed wire arced to a nearby metal screw head, triggering the failure of the main engine computers. The shuttle fleet was grounded for five months for extensive inspections and repair of the wiring as a result of this incident.

At the time of the original CAIB recommendation to develop state-of-the-art wire inspection techniques, NASA planned to keep the shuttles flying until 2020. However, they now will be retired in 2010 under a new directive to develop a replacement space ship. As a consequence, NASA managers concluded that improved inspection techniques would not be ready or cost effective before the shuttle program's 2010 retirement.

The inspector general thinks otherwise, that NASA should continue to develop advanced inspection techniques.

The shuttle is outfitted with aromatic polyimide (Kapton) as the general purpose wiring. Kapton is known to age in service and suffer insulation breaches over time, and wire in inaccessible spaces or buried in a bundle is not amenable to visual inspection.

Contrast the NASA attitude with that of **Federal Express,** which concluded that complete rewiring of DC-10s to MD-10s was necessary to ensure their continued safety. The details are contained in a paper prepared for the March 2004 symposium on cargo operations hosted by the **National Transportation Safety Board** (NTSB). In their paper on "Fleet Supportability and Aging Aircraft," Captains Michael Bender and David Wells of the **Air Line Pilots Association** (ALPA) wrote:

> "Polyimide wire insulation has been identified as becoming brittle over time. Brittle polyimide has the potential for arcing which can lead to an on board fire. While work is being accomplished to identify a replacement, the potential for fire on an older cargo aircraft increases every day. Accident statistics show that the time between the onset of a fire and its resulting in a catastrophic failure can be as little as 20 minutes, so the ability to rapidly and positively extinguish a fire on board is critical.
>
> "Wiring deterioration in older aircraft has proven to be a continuing problem and the cause of numerous serious electrical problems and airborne emergencies. One cargo airline that is converting thirty-plus year old three-cockpit crew aircraft into two pilot aircraft has found that instead of repairing the old wiring, it is actually quicker and ultimately safer to replace all wiring during the aircraft modification program." *(See www.ntsb.gov/events/symp_air_cargo/papers/backup_aging_aircraft.pdf)*

Thus, MD-10 cargo pilots will fly with new wiring, while shuttle pilots will fly for another five years with existing wiring. ■

'Kapton Wiring Will Continue To Be a Safety Risk'

Summary of the Office of Inspector General's Reviews on Aspects of NASA's Response to the Columbia Accident Investigation Board Report, May 13, 2005, extracts:

"NASA plans to proceed with the inspection and detection process in place since August 1999 and fund the development of Destructive Evaluation Age Life Testing.

(Continued on p. 8)

NASA has cancelled plans to continue developing and testing state-of-the-art technology for evaluating orbiter wiring based on their conclusion that the new technology would not be cost effective or ready before the planned 2010 shuttle retirement and funding constraints.

"In our March 16, 2005, discussion draft report, 'Review of Orbiter Wiring,' we disagreed with the closing of this recommendation. We concluded that without new evaluation technology, inaccessible Kapton wiring will continue to be a safety risk for the space shuttle and future space vehicles. NASA should establish a formal procedure that will transmit lessons learned from the canceled technology development plans to facilitate development of new evaluation technology for wiring inspection of the next-generation space vehicle. NASA should also formally assess the risk of aging and damaged orbiter wiring and develop a risk mitigation plan based on that risk assessment."

Source: www.hq.nasa.gov/office/oig/hq/audits/reports/FY05/ig-05-015.pdf

● **When it has to be done right.** In aviation, having a second set of eyeballs to verify a procedure is an article of faith. To its credit, NASA has done the same, as evidenced by this extract from the NASA IG's May 13 status of recommendations:

"R4.2-3 – Closeout Inspections

"**Recommendation:** Require that at least two employees attend all final closeouts and intertank area hand-spraying procedures. [Note: deals with the spraying of foam insulation, a piece of which broke off during the launch of Shuttle Columbia and punched a hole in the reinforced carbon carbon (RCC) tiles in the wing leading edge, leading to catastrophic overheating during re-entry.]

"**Status of Recommendation:** NASA not only revised the procedures for intertank closeout inspections but also expanded the concept to all flight hardware projects. A program audit of all final closeouts was performed to ensure compliance with the existing guidelines that a minimum of two persons witness final flight hardware closures for both quality assurance and security purposes. Program level requirements documents have been revised to strengthen and more thoroughly document the two-person closeout rule." *(From www.hq.nasa.gov/office/oig/hq/audits/reports/FY05/ig-05-015.pdf)* ■

● **Protecting the shuttle.** It is obvious that there are continued and unresolved ice shedding problems on the Space Shuttle, as evidenced by this recommendation in the NASA IG report: Initiate a program designed to "increase the Orbiter's ability to sustain minor debris damage by measures such as improved impact resistant RCC [reinforced carbon carbon wing leading edge] and acreage tiles. This program should determine the actual impact resistance and the effect of likely debris strikes."

However, NASA has already conceded (and demonstrated) that brittle RCC wing leading edge tiles don't have any impact resistance at all. That explains the effort to ensure the integrity of external tank insulating foam and ice debris avoidance.

Note that Shuttle Discovery already sustained debris damage on the launch pad from a falling window cover that damaged tiles on the tailfin. It may be time to reconsider, again, the notion of the sacrificial glove propounded in this publication as a probable solution for ice and foam hits *(see ASW, Mar 2, p. 8)*. A one-inch thick conformal coating of RTV (room temperature vulcanizing) silicone, which would burn off on reentry, would be sufficient to soak up a hit that would otherwise create massive damage. NASA officials have freely admitted that a leading edge crack the width of the thickness of four pieces of paper would be sufficient to doom the crew on reentry (a 0.020 inch by two-inch crack is the critical size) – yet they admit that:

1. The ability to detect such a fine crack in orbit (or via cameras) is problematic, and

2. If such a crack were detected, it could be repaired (they think).

Under the heading of Leading Edge Damage in the report, NASA claims, "As a result of Shuttle design and the material characteristics of RCC, NASA can do little to change the actual material characteristics." Yes, but the sacrificial glove offers a way to protect and avoid damage to those immutable properties of RCC. The sacrificial glove would also resolve in part their other major concern, "Launch-pad leaching of zinc primer onto RCC components." Similarly, in orbit protection for critical areas against micrometeoroid and orbital debris would be facilitated.

It would seem that being unable to repair any sizeable crack would put the emphasis on a necessary RCC leading edge tile damage avoidance policy. No piece of ice is going to damage the wing or tailfin leading edge with a direct or glancing blow if that leading edge is protected by a one inch thick layer of resilient RTV silicone. Carrying a whole set of RCC tiles to the International Space Station for bolt-on repairs is logistically cumbersome, weight prohibitive, and requires astronauts to exit the vehicle.

To be sure, NASA is expending considerable effort ensuring that RCC tiles and their carrier sub-panel frames are up to specification both before and post-flight, but this effort does not deal with a tile taking a direct hit from ice or insulating foam. Nor will myriad sensors fitted to detect hits improve the chance of making a round trip.

Perhaps the sacrificial glove concept should be part of the response to the recommendation dealing with the shuttle's mid-life recertification. Admittedly, NASA does not plan to extend the shuttle beyond 2010 (at which point a new vehicle supposedly will come on line), but once the sacrificial glove is incorporated into that contingency plan, it may gather impetus as a concept worth exploring and exploiting. *(Relevant sections of the 60-page NASA IG report are at page 16-17, the ice shedding problem, p. 37, the difficulty of altering RCC material, p. 38, the problem of zinc primer leaching onto the shuttle on the pad, p. 20, ensuring that the RCC tiles are up to specification, and p. 50, the shuttle mid-life recertification program. The NASA IG report may be viewed at www.hq.nasa.gov/office/oig/hq/audits/reports/FY05/ig-05-015.pdf)*

● **More arcing and blankets.** "While there was no fire, the heat generated during the arcing event resulted in extensive charring to two adjacent insulation blankets," according to a recent report by the **Australian Transport Safety Bureau** (ATSB) of an April 2003 event on a **Qantas** B747-300. During power-up, the "No Smoking/Fasten Seatbelt" sign circuit breaker tripped, and a flash and burning smell were detected on the main deck.

The airplane was evacuated. The sidewall trim and stowage bins in the vicinity of seat 37K were removed, and technicians discovered that the seat belt sign and other wiring was chaffed to the point where arcing occurred *(see photo)*. The wiring had been pinched between the outboard corner of the stowage bin and the adjacent structural frame. The wiring had been routed slightly higher and the bin was installed slightly lower, contributing to the chafing. The pinching most probably occurred when the bins were replaced in the aircraft's last "D" check in October 2002.

The ATSB report noted, "The aircraft maintenance manual and operator's task cards did not contain a requirement to check for clearance between the stowage bin and the adjacent wiring loom and the aircraft structure."

The task cards used by the operator now require inspection to ensure adequate clearance. Manufacturer's documentation has not been changed; **Boeing** said the wire separation requirement is documented in the Standard Wiring Practices Manual. *(For the full report, see www.atsb.gov.au/aviation/occurs/occurs_detail.cfm?ID=594)* ■

Corner of stowage bin (lower right) pushing the wiring into the insulation blanket and the underlying structural frame.

Photo: ATSB

Significant Regulatory Activity

Action & Date Posted on *Federal Register*	Summary of Situation	Action Date & Comments
July 5 Final rule, Stage 4 Aircraft Noise Standards FR Doc 05-13076 Docket No. FAA-2003-16526 Noise pollution	**The Federal Aviation Administration** (FAA) adopts a new noise standard for subsonic transport category airplanes applicable to new aircraft designs submitted on or after Jan. 1, 2006. Proposes a 10-decibel (dB) reduction over Stage 3. This level represents a cumulative reduction over three phases of flight at certification (flyover, lateral, and approach).	Effective Aug. 4. Many commenters expressed the belief that 10 dB is not enough. The **Alliance of Residents Concerning O'Hare** (AReCO) suggested a 23 dB reduction for new airplanes certified after 2015. The FAA disagreed, saying: "AReCO's proposal is based on an entirely new certification framework … (that uses) a complex formula that considers an aircraft's maximum range and takeoff weight to determine its payload, including the amount of fuel it would be allowed to carry. This proposal is well beyond the scope of" the notice of proposed rulemaking.

Source: U.S. Federal Register

ACCIDENTS AND INCIDENTS[1]

DATE/SITE	AIRCRAFT & REGN	CIRCUMSTANCES	DEATH & INJURY	PRELIMINARY ANALYSIS2 Imagery at www.iasa.com.au/180705.htm
26 June 1610Z Grand Junction, Colo.	Beech 1900D of Gt. Lakes Avn.	**While standing after boarding with L eng running, N240GL rolled into fence**	Nil	Mounted curb & became enmeshed in a chain link fence. Substantial damage
28 June approx. Mozambique	Caravan C208 of AirServ (UN a/c)	**C208 serial #13 written off in post-accident fire (overturned on landing)**	Nil	On Island of Matemo. N9324F was previously world's highest-time C208
28 June 1550Z Greensboro, N.C.	CL-600-2B19 Reg: N623BR	**Nose-gear collapsed on Independence Air CL-600 while parked at its gate**	1 inj	After deplaning pax on arrival from Chantilly, Va.
01 July 2251Z Atlanta, Ga.	757 of Delta Flt: DAL1171	**Blew tire on t/off Miami. Wing & flap damage was found on landing ATL**	Nil	Raises question mark re: retracting gear & flap & proceeding to destination
01 July 2251Z Amarillo, Texas	Learjet 25 Reg: N345MC	**A/c ran off LHS of runway 04 at midfield during landing roll-out**	Nil / 2 o/b	Minor damage
04 July Manchester, UK	BAe146 of Rock Band U2	**Emergency landing soon after takeoff – with a developing galley fire**	Nil	G-BPNT (operated by Flightline Inc). No Bono onboard
04 Jul Paris CDG A/P	L-1011 of Starjet Reg: A6-BSM	**A6-BSM ret'd to Charles de Gaulle with crew reporting overheated #3 eng**	Nil	Op to Athens for Olympic Awys
05 July Manchester, UK	747 of PIA	**Baggage truck became hard wedged beneath eng nacelle causing a 15" gash**	Nil	Situation worsened by operator then trying to reverse the truck out.
06 July 0145Z Oklahoma City, Okla.	Citation 560 Reg: N511TH	**RH engine caught fire on climb-out. A/c returned and landed w/o incident**	Nil / 2 o/b	Destination: Dallas, Texas
06 July 1730L Thunder Bay, Can.	Metroliner of Bearskin Airlines	**Landed safely on main wheels only after nose-gear doors jammed shut**	Nil / 19 pax	Extensive damage to nose, engines and props
06 July Manchester, UK	737-400 of Jet 2 Reg: TF-ELZ	**Ramp agent removed a GPU from an a/c while it was still connected to it**	Nil	Caused over US$1M damage to hardware and a/c electrics
06 July morning Raleigh Durham, N.C.	A320 of Jet Blue	**A/c made an emergency landing after a smoky odor was detected aboard**	Nil / 153 pax	Headed for West Palm Beach, Fla.
07 July 0900L Paris (CDG A/P)	A330-200 of TAM PT-MVC	**Flt JJ8096 became stuck in the grass after leaving the paved surfaces**	Nil	Undamaged and later headed back to Brazil as JJ8097 (CDG – Sao Paulo)
07 July afternoon Shannon, Ireland	777-200 of American Airlines	**Emergency diversion & landing with electrical fault & smoke in the cockpit**	Nil / 190 pax +12	Still on tarmac at Shannon at press time.
07 July 1100Z Chicago O'Hare	A319 of Air Canada C-GBHR	**Blade of a concrete cutter (working on tarmac) ricocheted off wing and embedded in a UAL cart**	Nil	Would appear blade wasn't properly locked. Minor damage to A319 wing
08 July Papua Niu Gini	Fokker 100 x2 of Air Niugini	**PNG jets grounded (failing to install EGPWS by July 1, 2005 – 5 yrs notice)**	Nil	Joins two Australian regionals who've had a/c grounded due to no EGPWS
08 July early morn Trinidad	767-300 of Air Canada	**AC094 was forced to divert to Port of Spain A/P after pax became disruptive**	Nil	Toronto to Buenos Aires flight. Male pax arrested after landing
08 July 1502Z Denver, Colo.	A320 of United Flt: UA1511	**Returned to land when a fire erupted in #1 eng during climb out of Denver**	Nil	Fire was extinguished before landing
09 July Dan Helder A/P	DC2-142 of Aviodrome	**On landing the left main gear of PH-AJU retracted and wingtip dragged**	Nil	Substantial damage to this historic Netherlands bird
09 July 2350Z JFK New York	A330-200 of LTU (LTU1551)	**Olympic A340 struck LTU A330 that had reported brake problems on taxi**	Nil	A340-300 flt OA412 struck rear of A330's stabilizer & both were u/s'd
10 July ~1030L Delaware Bay	RV-8 and Rutan Long-EZ N78LC	**2/6 formating airplanes collided during oppositional maneuvering & crashed**	2 fatal / 2	2 fatalities also at CFB Moose Jaw Saskatchewan (an airshow collision)
10 July ~1700L Manila, Philippines	A330 of Air France PR106	**Nosewheel malfunctioned during 180˚ turn on runway & a/c became stuck**	Nil / 281 o/b	Incoming flights divtd Clark Intl and all outgoing flights were delayed
11 July Neuquen, Argentina	737-200 of Southern Winds	**Flt A46176 made emerg landing due to a severely overtemping engine enroute**	Nil / 106 pax	Departed Buenos Aires for destination Neuquen
11 July Boston Logan A/P	A330-300 of US Airways	**Flight diverted into Boston with an air-rage passenger who'd been subdued**	Nil	Charlotte, N.C., to Heathrow flight was delayed 3 hrs & male pax was arrested
11 July Gatwick, UK	767 of Nationwide	**Wheel fires developed after a high speed abort following an engine surge**	Nil	Engine and wheel changes required after this takeoff incident
12 July Stansted, UK	737 of Titan	**7 crew hospitalized for checks after a/c diverted due to fumes in the cabin**	Nil / >120 pax	Birmingham to Palma Majorca flight operated on behalf of BMI Baby

1 Air carrier accidents, or other incidents involving serious failures or fatal injuries.

2 DISCLAIMER: These assessments are not intended to assert probable cause or liability, but rather are intended to provide insight pending publication of a final report of investigation. Preliminary analysis by John Sampson - International Aviation Safety Association (IASA).