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In-Flight Icing and How Airlines Are Coping

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ABSTRACT

The hazards posed by in-flight icing are an important issue in commercial aviation. Extensive research into methods for coping with in-flight icing has been continuing for many years. This paper addresses the issues pertaining to in-flight icing including causes, impact on commercial aviation, and initiatives undertaken to avoid in-flight icing mishaps today and in the future.

INTRODUCTION

"During 20 minutes of cruise flying in icing conditions, the airplane's speed decreased from about 200 knots to 158 knots. Just three seconds after the captain uttered 'severe icing,' the airplane's stall protection system activated. The radar track of its flight showed the airplane falling with the dead weight of a brick at a rate of more than 22,000 feet per minute. The circumstances are similar to those of other events involving various airplane types in cruise, hold, climb or even descent"(Dow, 2003, p.1). The crash of TranAsia Airways Flight GE791 is under investigation by the Aviation Safety Council (ASC) of Taiwan. Recently, the ASC issued a bulletin calling upon French manufacturer Avions de Transport Regional (ATR), and on regulatory authorities in Taiwan, France and Canada to emphasize training in crew awareness of icing conditions (Dow, 2003).

The pilots commented they were in severe icing 73 seconds before the abrupt end of the cockpit voice recording. The progression from concern to genuine alarm is all too familiar. They might have recovered with a descent to warmer levels. Not to go for a rapid descent is to invite the classic stall, "roll upset" and spin. Once the airplane starts to auto-rotate into a spin, recovery under the disorienting conditions at night--as in this case--would have been difficult. If crews miss the insidious rearward motion of the elevator trim wheel (or indicator) as speed bleeds off and angle-of-attack increases to compensate for increased drag, maybe yet another warning system is in order (Dow, 2003).

John Dow, a recently retired Federal Aviation Administration (FAA) expert on in-flight icing, said he could wallpaper a room with digital flight data recorder tracings of icing incidents and accidents that look like this crash, based on the details at this early stage in the postmortem--the steady erosion of speed, the increase in nose-up trim by the autopilot, perhaps the final addition of power, and the wrenching roll and departure from controlled flight (Dow, 2003).

Dow has described the nature of icing as one where the insidious trap is set when stall speed increases from ice buildup on the wing, and then the trap is sprung on a surprised crew. With insufficient available thrust, the crew would be unable to accelerate while remaining in level flight and so would need to unload the airplane by applying nose-down elevator. This method of escape increases airspeed and reduces angle-of-attack away from the deadly stalling angle--where lateral control easily can be lost (Dow, 2003).

Where to Expect Icing

Winter weather patterns provide all the right ingredients to produce major problems with icing. Icing can occur in both stratiform and cumuliform clouds, but in winter, it's more likely to be encountered in solid overcast, stratiform clouds, spread over hundreds of miles. Cumuliform clouds, in contrast, can produce more intense icing, but the icing conditions are relatively isolated, especially in winter. Notably, cumuliform buildups, embedded in warm front stratus clouds, can cause serious icing (George, 2003).

Icing typically occurs on the northern side of storm tracks that often ride winter jet streams, according to Ben Bernstein, senior research meteorologist at the National Center for Atmospheric Research in Boulder, Colo. The northern jet over the United States tends to hug the Canadian border in the autumn, and then migrates south toward Texas and Tennessee during winter months, Bernstein explained. Icing also can be expected on the northern, or colder, side of surface lows, especially in areas of widespread clouds (George, 2003).

Icing occurs only if atmospheric moisture is "super cooled," or cooled below freezing while remaining in liquid state. When the liquid impinges upon a surface, it freezes, thereby creating icing. The heaviest icing usually occurs between -10C and 0C, accumulating as clear icing. It's especially insidious because accretion is hard to see, particularly at night. Relatively warm temperatures also are conducive to formation of larger-diameter water droplets. Larger droplets can rapidly form ice horns or ridges on airfoil leading edges that can distort airflow. Any ice buildup on an airfoil increases drag and stall speed (George, 2003).

At colder temperatures, rime ice is more likely to form, appearing similar to frost buildup in an old freezer. Rime ice is typically encountered at temperatures between -20C and -10C. It usually doesn't build up as fast as clear ice because clouds typically have less liquid water content and smaller droplets at colder temperatures. Below -20C, for instance, the probability of encountering ice drops steeply, although icing has been known to occur at temperatures as cold as -40C. Below that temperature, all the moisture within the cloud freezes, thereby eliminating the potential for icing. Types of aircraft icing are summarized in table 1 (George, 2003).

Table 1. Summary of types of aircraft icing

Icing Type	Temperature Range	Associated w/ Type Cloud	Relative to the Aircraft	Distorts the Airfoil
Clear	0°C and -10°C	Cumulus	Adheres firmly	Less
Rime	-10°and -20°C	Stratus	Easily removed	More

Any weather phenomena producing gradual lift can generate super-cooled water droplets if sufficient moisture is present. But if the lift is too gentle, then only clouds develop. If the lift is too rapid, large droplets tend to form, falling as rain or hail. Sometimes, the droplets will fall as freezing rain or drizzle below the cloud, an especially formidable type of icing hazard. Surface weather observations or forecasts of freezing rain or drizzle, or ice pellets, indicate a high probability of encountering significant, if not extreme, icing in the skies or clouds above (George, 2003).

Effects of Ice

Ice in-flight is always bad news. It destroys the smooth flow of air, increasing drag while decreasing the ability of the airfoil to lift. The actual weight of the ice on the airplane is secondary to the airflow disruption it causes. As power is added to compensate for the additional drag and the nose is lifted to maintain altitude, the angle of attack is increased, allowing the undersides of the wings and fuselage to accumulate ice. Ice accumulates on every exposed part of the airplane--not just on the wings, propeller, and windscreen, but also on the antennas, vents, intakes, and cowlings. It builds in flight where no heat, boots, or deicing fluid can reach it. It can cause antennas to vibrate so severely that they break. In moderate to severe conditions, smaller aircraft can become so iced up that continued flight is impossible. The airplane may stall at much higher speeds and lower angles of attack than normal. It can roll or pitch uncontrollably, and recovery may be impossible (Brown, 1999).

In order to provide a standard for reporting and describing icing, the aviation community has classified icing into intensities according to the rate of accumulation. Categories of icing are summarized in table 2 (Dow, 1999).

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Table 2. Summary of categories of icing

Icing Category	Rate of Accumulation
Trace	Slightly greater than the rate of sublimation
Light	May require occasional use of ice protection systems to remove
Moderate	Frequent use of ice protection systems is necessary
Severe	Ice protection systems fail to remove the accumulation of ice

Impact of Icing on Commercial Aviation

According to recent FAA surveys, aircraft crashes due to icing claim about 30 lives, injure 14 others, and result in $96 million in property damage annually in the United States (McGehan, 2002). Cancellations and delays due to icy weather can cost airlines millions of dollars in a single day. On March 20, 2000, icing conditions at Denver International Airport forced Air Wisconsin to cancel 152 flights. United cancelled 159 outbound and 140 inbound flights the same day, mostly because of weather ("Airlines Get New Tools to Avoid In-Flight Icing," 2002).

As David Hinson, then FAA administrator, explained the agency's position: "Technology has not advanced to the point of providing a reliable means to assess in-flight icing conditions with that degree of accuracy or specificity"(Cole, 1997, B1). By contrast, the National Transportation Safety Board had urged the FAA to require installation of new equipment that can "positively determine" when airplanes are in hazardous icing conditions (Cole, 1997).

Manufacturers and some pilots also have called for such upgrades. James Bettcher, a pilot for Delta Air Lines who serves on the Air Line Pilots Association's special icing study team, says that ice remains a serious hazard. "If everyone who flies knew how bad the situation really is, they wouldn't stand for it," he says (Cole, 1997, p.1).

PREVENTING ICING-RELATED MISHAPS

Pilot Training

The coefficient of lift for a clean wing might be 1.60. But with ice contamination it can drop 40% or more to 0.9. As a consequence, stall speed can increase from 110 knots, in this case, to 140 knots. The airplane may give no warning to the pilot of the new, higher stall speed. At 130 knots or less in this hypothetical example, there is adequate power to overcome drag. But with the contaminated stall speed of 140 knots, the airplane loses lift before speed decreases to 130 knots. Additionally, ice contamination can cause propeller efficiency to degrade 15% or more. The pilot does not have the power to accelerate to a higher speed or maintain altitude. The result is the airplane must descend. The question is whether it will descend under the control of the pilot or Mother Nature (Dow, 2003).

The following is a simple warning system for severe icing. At top of the climb, set the airspeed on cruise speed. When the speed drops 20 knots below that, a warbler sounds and the pilots are either in a steep turn with power set or experiencing the onset of severe icing. The 20-kt band accommodates a speed variance that might be seen in the turn as a turboprop executes the reversals of direction in a lightly iced holding pattern. Dozens of roll upset events show that pilots are maintaining or attempting to increase pitch attitude while applying power. This has resulted in failure to recover from the stall and protracted roll oscillations with altitude loss in excess of 3,000 feet with several accidents resulting in altitude losses in excess of 10,000 feet (Dow, 2003).

Pilots are being trained to recover using this technique at first sign of stall, usually stick shaker in lieu of reducing angle of attack by pitch attitude change or flap extension if ground contact is imminent or airplane pitch response is degraded. Stall protection systems may not have sufficient margin to protect against contaminated stall so that the stick shaker does not fire or fires at stall onset, instead of activating in the approach to stall. Insufficient thrust is available to accelerate airplane out of stall, so stall upset is protracted and total loss of control may occur (Dow, 2003).

Pilots do not experience this type of event in training and are not trained to recover. Very few regional turboprop operators have simulators, which can realistically present these events for pilot training. At first sign of a stall, which may be stick shaker, uncommanded roll, buffet or other aerodynamic cues, apply nose down pitch control and level the wings while advancing RPM and torque until sufficient increase in airspeed for type. If unable to lower nose, extend flaps from the cruise configuration. Recover, maintaining higher airspeed than at upset. Retract flaps if extended for the recovery (Dow, 2003).

The NTSB recently identified its 2003 "Most Wanted" aviation safety recommendations, and airframe structural icing was also included on this year's most wanted. The board had described the FAA's icing certification process as "inadequate, and the FAA had not adopted a systematic and reactive approach to the certification and operational issues of turboprop-driven airplane icing."(Fiorino, 2003)

Aviation Directive 97-20-14 currently requires incorporating information into the Airplane Flight Manual that would mandate pilot training before flight into known or forecast icing conditions after a certain date. AD 97-20-14 was the result of the FAA's analysis that the training level of the pilots of the MU-2B series airplanes made it difficult for pilots to recognize adverse operating conditions and operate safely while flying in icing conditions. Since issuance of AD 97-20-14, a new training video has been developed that includes information that is critical to safety of the MU-2B series airplanes. This proposed AD would require this new video as the mandatory pilot training. The actions specified by this AD are intended to decrease the chance of icing-related incidents or accidents of the MU-2B series airplanes due to pilot error. FAA estimates that this proposed AD affects 300 airplanes on the U. S. Registry. The pilot can view the training video in eight hours (Airworthiness Directives, 2003).

The aviation simulation and training business is expanding. In addition, the FAA is proposing sweeping changes that will affect the simulation industry. Innovative techniques and procedures are evolving to train pilots of general aviation and air transport aircraft that take advantage of the increased simulation capabilities available. As part of the process, the FAA's Flight Standards Division officials are meeting with simulator manufacturers and end users to learn more about new technologies. For example, one area under discussion is icing (Phillips, 2002)

FAA Aviation Weather Research Program

Since 2002, airlines have a new tool for avoiding in-flight icing, which can threaten smaller commuter planes and delay larger commercial aircraft as they land or take off. Current Icing Potential (CIP) is an online display that offers high-precision maps and plots, updated hourly, to identify areas of potential aircraft icing produced by cloud drops, freezing rain, and drizzle. Researchers at the National Center for Atmospheric Research, with funding from the FAA, developed new methods and software for detecting and forecasting icing potential in the atmosphere. They then applied these methods to produce CIP, a web-based display describing current icing conditions. CIP is for use by meteorologists and airline dispatchers. Its use by pilots and air traffic controllers is pending FAA approval. A companion tool, called FIP (Forecast Icing Potential), which forecasts potential icing up to 12 hours ahead, is still in development at NCAR and classified as experimental by the FAA (Airlines Get New Tools to Avoid In-Flight Icing, 2002).

NASA Research Program (Intelligent Flight Control System)

National Aeronautics and Space Administration (NASA) researchers are flying the first set of tests aimed at creating "smart" flight control software they hope will someday allow battle-damaged military jets and commercial jetliners with severe icing to land safely. Researchers at the NASA Dryden Flight Research Center have started a series of six to 10 flight tests of the Intelligent Flight Control System (IFSC). The tests are in support of a NASA effort to develop neural "network" software that would discover patterns in the data it receives and modify its behavior accordingly (Skeen, 2002).

The goal is to develop software that would sense when an aircraft is damaged and then automatically manipulate control surfaces -- like flaps, rudders or ailerons -- to compensate, restoring control to the pilot. The first set of flight tests involve a "nonlearning" preliminary version of the neural network software that is pre-trained to the aerodynamic database of the research aircraft, a highly modified F-15B fighter. The first of three objectives is to make sure that the nonlearning parts of the system are functioning correctly. These tests will look at the stability and control of the aircraft. The test aircraft will have two flight control systems: its regular system to bring the aircraft up to test altitudes and speeds, and the test software (Skeen, 2002). "We are going to attempt to determine the best maneuvers for online parameter identification -- the aerodynamic data, stability and control, and handling qualities," John Bosworth, the project's chief engineer, said of the second objective. "In addition, for the third objective, we will be performing handling qualities studies with the nonlearning system for comparison to the learning system in order to get more baseline data to compare with simulation and aerodynamic models" (Skeen, 2002, p. 3).

Neural network software is distinguished by its ability to observe patterns in the data it receives and processes and then performs different tasks in response to new patterns. NASA estimates it will spend about $10

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million over three years on the program, called the Intelligent Flight Control System. Flight tests of a "self-learning" version of the IFCS software are tentatively planned for 2003, and an upgraded version is targeted for evaluation on a U.S. Air Force C-17 transport in 2005. The C-17 was chosen because it most closely resembles a jet airliner. The system is very early in its development. Military applications of the system are at least five years away. Civilian applications are at least 10 years away (Skeen, 2002).

In-Flight Icing Simulation

FENSAP-ICE is an in-flight icing simulation system consisting of four modules that can calculate with great precision and detailed airflow, ice droplets impingement and ice accretion shapes, as well as estimate the handling qualities degradation of an iced aircraft. The system is literally a "Virtual Icing Research Tunnel" at an engineer's desk, significantly reducing the need for expensive wind tunnel, icing tunnel and flight-testing. Its modern technology allows designers to explore and venture safely even beyond the limits of the certification regulations. The increase in aircraft safety is considered significant. Many airframe and engine manufacturers, flight simulation companies, aircraft accident investigators and aircraft insurance groups have already adopted this software system. Both the Joint Aviation Administration (JAA) and the FAA have also readily accepted its results in certification (Duns, 2002).

The Kawasaki contract is estimated at $250 000 and is the first contract in Japan. Fred Habashi, President of Newmercial Technologies International, says: "FENSAP-ICE has broken the sound of silence in the icing field not only by being the first commercially available in-flight icing software unprotected by national secrecy, but by also introducing very modern approaches to this field. We have had considerable success with European and American companies that have adopted our software over the freely available software from their National Laboratories, but this is significant as it is our first contract in Japan and it opens the doors to other countries barred from accessing American and European technology" (Duns, 2002, p.1).

DeIcers/Anti-Icing Equipment

Anti-icing equipment is turned on before the flight enters icing conditions. Typically this includes carburetor heat, prop heat, pitot heat, fuel vent heat, and windscreen heat. Ice often forms on the propeller before it is visible on the wing. Props are treated with deicing fluid applied by slinger rings on the prop hub or with electrically heated elements on the leading edges. Ice prevention on props is preferable to deicing because the ice may not come off the blades evenly and the unbalanced prop may vibrate badly (Aircraft Icing,1998)

Deicing equipment is used after ice has built up to an appreciable amount. There are presently three major types of wing deicers: boots, weeping wing systems (fluid deice systems), and heated wings. For the most part, general aviation aircraft equipped to fly in icing conditions use boots and, to a lesser extent, weeping wings (Aircraft Icing, 1998). Boots are strips of rubber that run along the front edges of the wings and the tail surfaces. When ice adheres to those surfaces, the pilot flips a switch that inflates the boots with air. As they inflate, the boots expand and the ice breaks away. The technology is found on most turboprop planes. Although boots of various designs have been used successfully for decades, they are not without their flaws. The boot does not work equally well for ice of all thicknesses (Paula, 1997).

Years ago, deicers had large, widely spaced inflation tubes that were slow to inflate. It was necessary to wait until one-quarter to one-half inch of ice built up on the boot prior to actuation to prevent the chance of ice bridging, an arch of ice formed over the top of the inflated tubes. The bridge could not be broken because its base remained suspended above the fully inflated boot. Modern deicers, though, have much narrower inflation tubes and considerably faster inflation rates. No longer is it necessary to wait for measurable ice accretion before actuating the boots. Most approved flight manuals now recommend actuating the boots at the first sign of ice accretion. But deicer use instructions vary by make and model of aircraft. And deicers don't protect all surfaces on the aircraft. Only a few critical surfaces, such as airfoil, and in some cases strut and leading edges are protected. Unprotected surfaces can still accrete ice, thereby increasing drag. For instance, NASA claims that some aircraft can suffer a 36 percent increase in drag due to icing, even though the deicers are functioning properly. The only ways to rid the aircraft of such ice accretion is to climb to cold, dry air where the ice can sublimate or descend into warmer air where it can melt (George, 2003). BFGoodrich, presently the only supplier of boots in the United States, has introduced a new system that incorporates ice detection and deicing into one package. Called "Smartboot," it advises the pilot when to cycle, confirms boot inflation, and detects any residual ice, making Smartboot easier to use and more effective than conventional boots. The sensor's principal component is a 4-

inch-diameter probe that protrudes about 2 inches through the strut on the ice detector. Inside the strut are two coils, one of which vibrates ultrasonically at 40,000 hertz. As ice builds up on the probe, the probe's vibrational frequency decreases. The second coil senses the change in frequency. At a specified frequency shift, which is related to the ice mass on the probe, an output signal is generated to instruct the pilots to activate the deicing system. "Being able to read icing conditions across the 3-foot length of the deicer provides a whole new level of detection," said Dick McMurry, ice protection-systems general manager. "It's a great alternative to single-point ice sensors, where localized detection may not be sufficient" (Paula, 1997, p.75).

The weeping wing system is a patented alcohol deicer system that pumps fluid from a reservoir through a mesh screen embedded in the leading edges of the wing and tail. Activated by a switch in the cockpit, the liquid flows all over the wing and tail surfaces, deicing as it flows (Aircraft Icing, 1998).

Many aircraft are now fitted with ice detectors--small probes that vibrate at a specific frequency. When ice builds up on the probe, it slows the vibration, activating an ice alert message in the cockpit. Periodically, the probe is heated for a few moments, melting the ice so it can detect subsequent ice accretion (George, 2003).

Jets, with more powerful engines to keep crucial surfaces free of ice in flight, usually have heated metal leading edges instead of boots and rarely have icing difficulties (Hedges, 1998). Furthermore, the cruising altitudes of these aircraft are generally well above any precipitation, so ice would only be a potential concern during takeoffs and landings (Paula, 1997).

THE BUREAUCRACY AND DELAYS

The FAA provides oversight for the largest, busiest and most complex aviation system in the world. As part of its mission, the FAA and its staff of 49,000 operate and maintain our nation's air traffic system, orchestrating the take-off, landing and routing of 93,000 aircraft a day. The FAA also regulates aviation safety and security, which entails standard setting for, and oversight of, commercial airlines, private aircraft, aircraft manufacturers and the air traffic system (U.S. Newswire, 2000).

Why does it sometimes take disaster or the passage of years for the FAA to take significant action? It is embedded in the conflicted nature of the FAA. Serving two masters, the agency not only is charged with nurturing the aviation industry but also must ensure the safety of the flying public. Whenever the FAA considers changes in safety and equipment regulations, the agency must balance safety against the cost to airlines. According to records and interviews, the result can be delays in addressing safety problems and more accidents related to them. Deadly delays have occurred in part because a law requires the FAA to justify the cost of implementing proposed safety measures by showing that enough lives will be saved (Brazil, 1994).

Despite recommendations from one of its own safety specialists, the FAA failed to require changes to a popular commuter aircraft a full year before one of those planes crashed near Detroit, killing all 29 people on board. The recommendations in a January 1996 internal FAA memo called for measures that would allow pilots flying the 30-seat Embraer Brasilia 120 to better detect ice building up on the wings of their planes, known as EMB-120s (Hedges, 1998).

In-flight icing is the suspected cause in the Jan. 9, 1997, crash of Comair-Delta Connection Flight 3272 near Detroit. Several aviation experts and the Airline Pilots Association, the nation's largest pilot union, contend that the fixes would have prevented the crash of Flight 3272. A Tribune examination shows the FAA did not adopt the recommendations until last January, two years after the memo and a year after the Comair crash (Hedges, 1998).

John Dow, a FAA icing expert, wrote a memo after discovering a trend. There had been six previous cases involving the EMB-120 since 1989, all of them similar to the Flight 3272 accident. None resulted in a loss of life, but each occurred in icy rain which can adhere to the wings and disrupt airflow (Hedges, 1998).

FAA and Embraer officials refused to discuss their actions regarding the EMB-120. Six U.S. airlines fly a total of 220 EMB-120s. United Express and Comair fly the plane in service to O'Hare International and Midway Airports. In addition to Dow's recommendations, wind tunnel tests conducted by NASA after the Flight 3272 crash showed that ice can form on the underside of the EMB-120's wing, behind deicing devices. According to the pilots union, this causes drag on the wings, slowing the airplane so much that it cannot fly. Embraer knew about ice forming behind the deicers as early as 1980, the pilots union argues, when BFGoodrich Aerospace, which makes the deicing equipment, predicted it in a study. "ALPA believes that this accident was avoidable and was caused by the actions (or inactions) of many organizations," the union report contends. "There were several significant warnings during the history of EMB-120 operations that should have resulted in proactive actions to preclude an accident" (Hedges,

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1998).

The crash of Flight 3272 came as the plane was descending at the end of a 76-minute hop from Cincinnati to Detroit. Pilots Dann Carlsen and Ken Reece had no indication that something was going wrong. Trouble began just after Detroit air controllers ordered the pilots to slow the plane and then to turn left. As the plane began to turn, it dramatically lost speed. "Looks like your speed indicator," Carlsen told his first officer with professional calm. The engine power was increased, but the EMB- 120's turn kept getting steeper, its airspeed lower. "Power," Carlsen commanded. The plane's bank angle reached 45 degrees, and then the autopilot disconnected. Suddenly, Flight 3272 flipped onto its back. The plane swung back and forth as the pilots tried to regain control, but just 29 seconds after the first hint of trouble, Flight 3272 hurtled into the wet ground near Monroe, Mich. In less than a half-minute, 29 lives were ended (Hedges, 1998).

Finally, Dow recommended that if pilots were not getting enough warning about ice, the EMB-120 should have "a reliable means" to assess the danger of ice and to fly out of it. Icing experts say that would mean installation of an ice detector, which is one of the fixes the FAA finally adopted, at a cost of about $16,000 per plane. The improvement came after the Flight 3272 crash (Hedges, 1998). Embraer and FAA took additional actions after this event. Embraer recommended that deice boots be activated at a higher rate, the autopilot was to be deactivated in icing conditions until a low speed-alarm had been installed and they released a revised training video related to flight icing conditions. Embraer also started to improve the stall-warning computer icing operations (A History of Disturbing Icing Accidents, 2003).

A four-month Times review of government documents revealed that in some cases years have passed and lives have been lost before the FAA acted on safety problems although the agency had long been aware of the hazards. Congressional officials have suggested that the nation's skies would be safer and more efficient if the day-to-day air traffic control operations were taken away from the FAA so it can focus on airline safety issues. (Brazil, 1994).

CONCLUSION

Icing was a contributing factor in at least eight fatal crashes and many more accidents involving U.S. commercial aircraft in the last decade, including the 1994 crash of an American Eagle ATR-72 turboprop in Roselawn, Indiana, that killed all 68 people on board. Government investigators say ice is among the possible causes of the crash of a Comair twin-engine turboprop that killed 29 people (Cole, 1997).

Despite that history, most aircraft still rely on fairly primitive systems to monitor ice and remove it; the FAA literally advises pilots of commuter planes that the best way to detect hazardous icing is to look out of the window for telltale signs of buildup. New technologies are available to alert pilots when ice is forming and break it up more effectively in flight. This design relies on "smart skin" technology, fiber optics, specialized software and a computer chip no more powerful than those found in ordinary laptops. Genetically, it's called a stress sensor. An L-shaped epoxy-based patch thinner than a credit card is fixed to the upper side of each wing where it joins the fuselage. The size of the patch depends on the aircraft, but a Boeing 747, for example, would require one extending a couple of feet up the fuselage and the same distance out the wing. The patch contains a network of hair-like fiber optic cables, which run through a pencil-size hole in the body of the plane to a cable connected to a digital-analog converter. The converter feeds the information to a computer, and special software interprets the data for the pilot, either on a screen or through a digitized voice alert (Budris, 1995).

But the FAA has declined to mandate such systems, arguing that the technology remains largely untested. Even when the FAA announced a host of proposed new icing rules, officials focus on stepped-up training for pilots, better weather forecasting and more studies of how ice forms, not the installation of new hardware (Cole, 1997).

A successful program to avoid icing-related mishaps must be approved by FAA. Two laws spell potential delay for installation of icing detection systems by our airlines. The FAA is required by law to balance safety against the financial burden to airlines and manufacturers whenever it considers changes in safety and equipment regulations. Cost could cause delay by adversely impacting the smaller airlines in a significant way. Also FAA must justify the cost of implementing proposed safety measures by showing that enough lives will be saved (Brazil, 1994).

Even FAA's harshest critics don't believe that the agency knowingly waits for accidents to happen. But because the FAA must justify changes that require expenditures by the aviation industry, the agency sometimes must use past accidents to help build its case. And once the agency decides to make safety-related changes, it can take years before new rules take effect because the agency must consider the effects on the airline industry. FAA is required by law to justify rules changes that cause financial burdens to government or private industry. Critics say that the FAA, in seeking changes in regulations, depends too heavily on accidents that have already occurred. The reason, they say, is that in an atmosphere of public outrage over a serious accident, it is easier to pass reforms through Congress. Before the FAA can act, the agency must calculate how a proposed safety rule will affect the aviation industry. The agency must consider everything from the public perceptions to the economic impact. Critics feel that sometimes safety is secondary to economic concerns (Brazil, 1994).

The FAA could do more to fund airframe ice-detection technologies to help pilots steer clear of dangerous icing encounters, says Carol Carmody, the former acting chair of the National Transportation Safety Board. Sensor manufacturers like BFGoodrich Aerospace Aircraft Sensors, developer of an ice-detector system that Carmody said could be acceptable for aircraft if made smaller, may be "waiting for a sign from the FAA before proceeding." The agency, however, believes detection technologies have advanced to the point where no further FAA research dollars are needed. Said FAA spokesman Les Dorr: "The information we have from BFGoodrich shows the R&D is at the point where if they submitted [the design] to us, we could certify it." The FAA, instead, is investing in weather forecasting technologies that could help pilots avoid icing altogether (Asker, 2001).

Icing remains a major threat to flight safety and is a paramount concern to the aviation industry. Sophisticated "smart skin" technologies are available to alert pilots when ice is forming and break it up more effectively in flight. The cost of implementing and standardizing this technology for the airlines must be measured by comparing the 30 lives lost in aircraft crashes due to icing annually in the United States. This begs the question---when is it time for action?✈

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