Transport Certification

Update

Certification Information for
the Aviation Industry and Designees

Edition 20, Spring 1996

EMBRAER 120 Icing Tests

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From the Directorate Manager . . .

The six months that have passed since the first publication of the ***Transport Certification Update*** has been a busy period for the Transport Airplane Directorate. Certification activity around the world continues at an ever-increasing pace, stressing the need for more and more FAA services to our transport airplane customers. As a result, we have recently completed the hiring of 31 new positions in the Transport Airplane Directorate's technical staff so that we can continue to:

- provide quality services,
- meet our customers needs, and
- be even better prepared to fulfill our on-going aviation safety mission.

Necessary and timely information is dependent upon knowing what the

Ronald T. Wojnar

needs of our customers are. Our goal in the Directorate is to obtain as much information about customer/program plans as early as possible, so as to improve our responsiveness whenever possible. This requires that information flow in *both* directions. With more accurate and timely information from our customers, the Directorate can provide the quality services our customers expect. The key is working together.

We hope that the ***Update*** will be an important source of information for the aviation community. Thank you for the many compliments, comments, and suggestions on the first issue of the ***Update.*** Please continue to express your thoughts and ideas to the Editor. Working together, we can continue to develop this publication into an ever-improving and more relevant source of information.

Ronald T. Wojnar

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Transport Airplane Directorate,
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Certification Information for the Aviation Industry and Designees

Transport Certification **Update**

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In-Flight Icing: FAA's Three-Phase Program

By KATHI ISHIMARU
Flight Test & Systems Branch, Transport Airplane Directorate

In 1994, an accident involving an Aerospatiale Model ATR72 series airplane occurred, in which severe icing conditions outside of the icing certification envelope may have contributed to uncommanded roll.

This prompted the FAA to initiate a three-phase safety review of aircraft operating characteristics during conditions of in-flight icing.

The *first phase* focused on the accident airplane and resulted in an airplane modification to minimize the possibility of similar accidents. The FAA concluded that the uncommanded roll may have been a result of freezing drizzle forming a ridge of ice on the upper surface of the wing aft of the area protected by the ice protection system. This ridge may have caused airflow separation and uncommanded aileron movement.

During the *second phase*, aircraft similar to the accident airplane were evaluated to determine if uncommanded aileron movement and unacceptable control wheel forces would occur if ice accreted aft of the protected area of the wing.

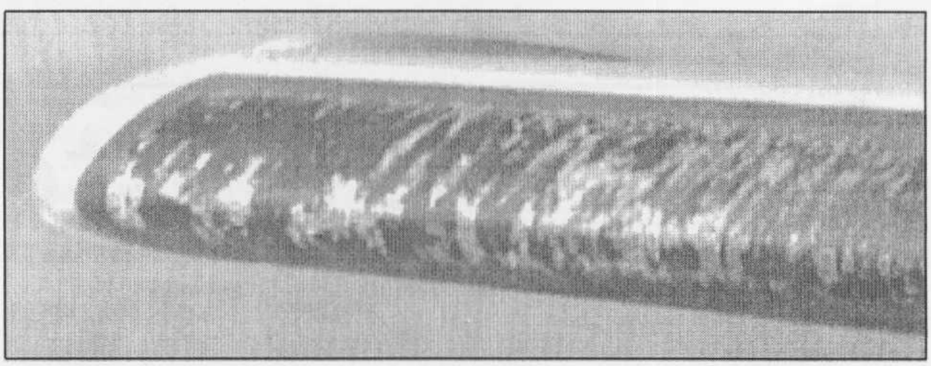
The *third phase* will consist of a review of in-flight aircraft icing safety and the determination of changes that can be made to increase the level of safety.

Phase I

On October 31, 1994, an Aerospatiale Model ATR-72-212 was involved in an accident in which severe icing conditions (believed to be composed of freezing drizzle size droplets) were reported in the area. Freezing drizzle droplets are outside the icing envelope defined in Appendix C of part 25 of the Federal Aviation Regulations (FAR). Consequently, no airplanes have been certificated for operation in these severe icing conditions.

Although the National Transportation Safety Board (NTSB) has not announced the probable cause of the accident, extensive testing by the FAA, Aerospatiale, the French Direction Générale de l'Aviation Civile, Bureau Enquete Accident, National Aeronautics and Space Administration, NTSB, and others has led the FAA to believe that freezing drizzle conditions may have created a ridge of ice aft of the deicing boots and forward of the ailerons, which resulted in uncommanded motion of the ailerons and rapid roll to the right.

This scenario is based on high-speed taxi tests and flying the ATR-72 in freezing drizzle conditions produced by the United States Air Force (USAF) NKC-135A icing tanker. Tests conducted in these conditions confirmed that a ridge of ice can form aft of the deicing boots. Subsequent aircraft flight tests in dry air with artificial ice shapes based on the ice shapes formed during the icing tanker tests resulted in roll control anomalies that nearly replicated the accident profile.



Residual ice on a deicing boot of the Model ATR-72 series airplane.

Aerospatiale developed a modification for the ATR-42 and -72 that increased the chord-wise coverage of the active portion of the upper surface of the outer wing deicing boots. By an airworthiness directive (AD), the FAA prohibited flight in icing conditions unless the modified boots were installed. The boot modification provides an increased margin of safety in the event of an encounter with freezing drizzle.

However, even with the improved boots installed, the Aerospatiale airplanes, along with all other airplanes, are not certificated for flight in freezing drizzle conditions or any other conditions outside of the icing certification envelope.

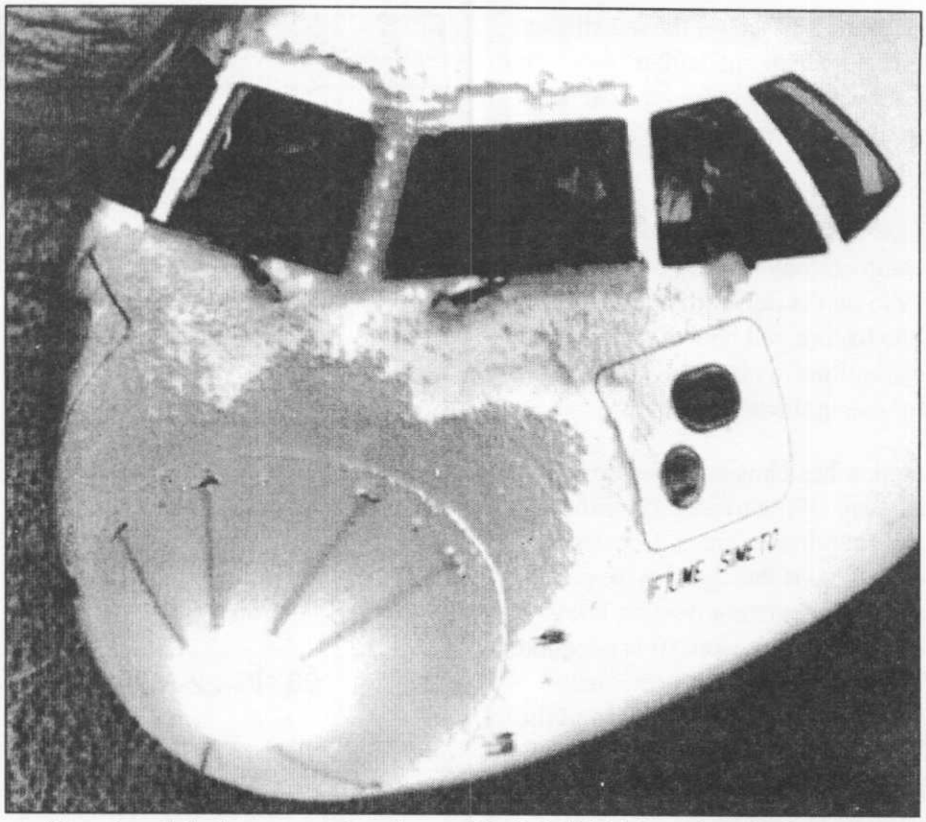
Phase II

In March 1995, the FAA requested other airworthiness authorities and airplane manufacturers to review certain airplanes to determine if other type designs might experience control difficulties should a ridge of ice form aft of the deicing boots and forward of the ailerons.

This investigation addressed part 23 and part 25 airplanes that are equipped with pneumatic deicing boots, non-powered flight control systems, and are used in regularly scheduled passenger service in the United States.

The FAA provided a few suggested means of complying with the requested evaluation which were detailed in the ***Transport Certification Update***, Edition 19, Summer 1995. However, the FAA was open to alternative means of determining that a roll control problem did not exist.

Most manufacturers chose to perform high-speed taxi tests with 1-inch quarter round shapes located aft of the deicing boots and forward of one aileron, to simulate a worst case freezing drizzle build up. The



Freezing drizzle accumulated on a Model ATR-72 series airplane during icing tanker testing.

control wheel forces obtained during these tests were then extrapolated to forces that would occur at holding speeds.

The the high-speed taxi tests were performed on the following list of airplanes.

- **Beech 99, 200, 1900-C/D**
- **British Aerospace ATP/ HS 748**
- **de Havilland DHC-8-100, -200, 300, DHC-7**
- **Dornier 328**
- **EMBRAER EMB-110**
- **Fairchild SA 226/227**
- **Jetstream 31/32, 4101**
- **Saab 340**
- **Shorts SD3-30/-60**

As a result of the testing, these airplanes were found to have acceptable roll control forces [less than the 60-pound limit specified in section 23.142 (Amdt. 23-45) and section 25.143 (Amdt. 25-42),of the Federal Aviation Regulations].

The EMB-120 Brasilia was flight-tested with the 1-inch quarter round shapes, which resulted in control wheel forces higher than the FAA acceptance criteria. EMBRAER then conducted additional tests to determine more realistic ice shapes that could accrete in freezing drizzle conditions. The definition of these more realistic ice shapes was determined by flying the airplane in simulated freezing drizzle conditions produced by the USAF icing tanker. *(See cover photograph.)*

EMBRAER then performed airplane flight tests in dry air with artificial ice shapes based on the ice shapes formed during the tanker tests. The tests with these more realistic ice shapes resulted in acceptable roll control forces.

Taxi tests were planned to be completed by the end of February 1996 on the deHavilland DHC-6. The testing had been delayed due to difficulties in obtaining an airplane for use in the tests.

Fokker has chosen to perform an analysis of the trajectory of the freezing drizzle sized droplets to determine if the-chord-wise coverage of the existing deicing boots on the F-27 and Fokker 50 is adequate. This method has not previously been used for this purpose, and the FAA is awaiting the results of the analysis and the data that will validate the analysis.

Four turboprop airplanes that do not meet all the criteria of a "Phase II airplane" were voluntarily evaluated by their manufacturers. These four airplanes all performed the high speed taxi tests.

- **The CASA C212 and the Cessna 208 were found to have acceptable roll control forces.**
- **The CASA CN235 test results are under review.**
- **The Saab 2000 had unacceptable control wheel forces and the manufacturer, in conjunction with the Swedish Civil Aviation Authority, is performing additional tests and analyses to fully understand the airplane's susceptibility to roll control anomalies.**

AD Docket Number	Airplane Model
96-NM-13-AD	British Aerospace ATP
96-NM-14-AD	Jetstream 4101
96-NM-15-AD	British Aerospace HS 748
96-NM-16-AD	Saab SF340A, 340B, 2000
96-NM-17-AD	CASA C-212, CN-235
96-NM-18-AD	Dornier 328-100
96-NM-19-AD	EMBRAER EMB-120
96-NM-20-AD	de Havilland DHC-7, DHC-8
96-NM-21-AD	Fokker F27 Mark 100, 200, 300, 400, 500, 600, 700, and F27 Mark 050
96-NM-22-AD	Short Brothers SD3-30, SD3-60, SD3-SHERPA
95-NM-146-AD (Supplemental NPRM)	Aerospatiale ATR-42, ATR-72
96-CE-01-AD	deHavilland DHC-6
96-CE-02-AD	EMBRAER EMB-110P1, EMB-110P2
96-CE-03-AD	Beech 99, 99A, A99A, B99, C99, B200, B200C, 1900, 1900C,1900D
96-CE-04-AD	Dornier 228
96-CE-05-AD	Cessna 208, 208B
96-CE-06-AD	Fairchild SA226, SA227
96-CE-07-AD	Jetstream 3101, 3201

Phase III

The objective of this phase is to review current certification requirements, applicable operating regulations, ice detection/protection technologies, and forecast methodologies associated with aircraft icing under varying environmental conditions. This will occur at an FAA International Conference on Aircraft In-Flight Icing planned for May 6-8, 1996, in the Washington DC area.

The conference will include a review of all aspects of airworthiness when operating in icing conditions and the conference working groups will make recommendations regarding changes or modifications that can be made to provide an increased level of safety.

The emphasis at the conference will be on supercooled large droplets (freezing rain and freezing drizzle) which are outside the FAA icing certification envelope, but will not be strictly limited to large droplet icing. Based on the factual information obtained at the conference the FAA will develop an icing plan with short- and long-term goals.

Recent Icing-Related Rulemaking Actions:

Flightcrews are not currently provided with the information necessary to determine:

- **when the airplane is operating in icing conditions, which has been shown to be unsafe and for which the airplane is not certificated; or**

- **what action to take when such conditions are encountered.**

Therefore, the FAA has determined that flightcrews must be provided with such information, and must be made aware of certain visual cues that may indicate when the airplane is operating in atmospheric conditions that are outside the icing envelope.

In support of this finding, the FAA recently issued 17 notices of proposed rulemaking (NPRM) that propose new airworthiness directives (AD) applicable to 27 different models of part 23 and part 25 airplanes. The NPRM's propose to require that the flightcrews must immediately exit freezing rain and freezing drizzle conditions when these conditions are encountered.

The FAA concurrently issued a supplemental NPRM for the ATR-42 and -72, which proposes to require that these airplanes have the same prohibition in freezing rain and freezing drizzle as the airplanes addressed in the other NPRM's. The Supplemental NPRM also proposes to delete the existing prohibition of operating the ATR-42 and -72 in known freezing rain and freezing drizzle.

The table on the preceding page lists these recently issued icing-related NPRM's by their AD docket number and model. All 17 NPRM's were published in the ***Federal Register*** on January 25, 1996. The period for public comment closed March 7, 1996.

The FAA recognizes that the flightcrew of any airplane that is certificated for flight in icing conditions may not have adequate information concerning flight in icing conditions outside the icing envelope.

The FAA may consider additional action for other types of airplanes.

For additional information on this subject, please contact John Dow, Sr., of the Small Airplane Directorate, at telephone (816) 426-6932; or Kathi Ishimaru of the Transport Airplane Directorate, at telephone (206) 227-2674.

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For Your Information...

Parts Definition Policy On Hold

The last edition of the ***Transport Certification Update*** carried an article entitled, "**Standard and Commercial Parts Definitions**," which provided interim policy and guidance relevant to definitions of standard parts and commercial parts. It also provided interim guidance on how to apply these definitions, and interim procedures for Federal Aviation Administration personnel.

Since release of the ***Transport Certification Update***, the Federal Aviation Administration has retracted that policy, and is currently reviewing and reconsidering it.

Once this review is completed, new policy and guidance may be issued.

The material that appeared in the article in the last ***Transport Certification Update*** (Edition 19, Summer 1995) should ***NOT*** be considered as "Federal Aviation Administration policy," and should ***NOT*** be applied by any person in any certification activity as "Federal Aviation Administration policy."

The ***Transport Certification Update*** will provide any new material or guidance on this subject as it becomes available.

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The New Boeing Model 777

General News

Roll Upset in Severe Icing

By JOHN DOW
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Overview

This article is intended to provide pilots current information about the background, preventative measures, symptoms, and corrective measures on the hazards of uncommanded and uncontrolled roll excursion, referred to as roll upset, associated with severe in-flight icing. It should be of special interest to pilots flying airplanes certificated for flight in icing conditions since it describes icing conditions outside the airplane certification icing envelope.

Roll upset may be caused by airflow separation (aerodynamic stall) inducing self deflection of the ailerons, loss, or degradation of roll handling characteristics. It is a little known and infrequently occurring flight hazard potentially affecting airplanes of all sizes.

Roll upset can result from severe icing conditions without the usual symptoms of ice or perceived aerodynamic stall.

The Aeronautical (formerly Airman's) Information Manual (AIM) defines severe icing as:

> *"The rate of accumulation is such that the deicing/anti-icing equipment fails to control the hazard. Immediate flight diversion is necessary."*

Severity in the context of the AIM is associated with rapid growth of visible ice shapes most often produced in conditions of high liquid water content and other combinations of environment and flight conditions. This kind of severe ice is often accompanied by aerodynamic degradation such as high drag, aerodynamic buffet, and premature stall.

In addition, ice associated with freezing rain or freezing drizzle accreting beyond the limit of the ice protection system should also be described as severe. This kind of ice may not develop shapes as large, and may not produce familiar aerodynamic degradation such as high drag, but nonetheless, may be potentially hazardous.

Freezing rain and freezing drizzle contains droplets larger than the certification requirements and temperatures near freezing can produce this kind of severe icing.

Background

On October 31, 1994, an Aerospatiale Model ATR 72-212 airplane, operating as American Eagle Flight 4184, suffered a roll upset during descent after holding in what turned out to be severe icing conditions. Full recovery from the upset did not occur and the airplane crashed, resulting in fatal injuries to all 64 passengers and four crew members.

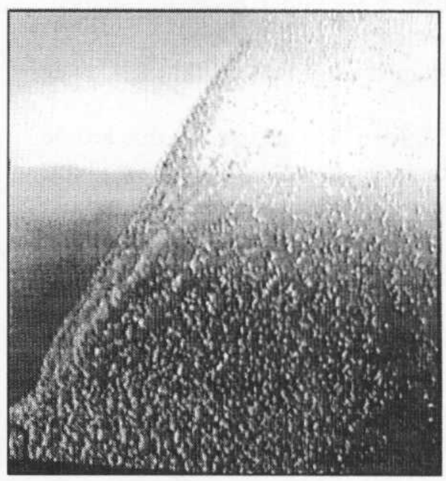
While the National Transportation Safety Board (NTSB) has not announced its finding of probable cause for this accident, a little known form of freezing drizzle aloft — also described as supercooled drizzle drops (SCDD) — appears to have been a factor in the roll upset.

While the physics of formation and altitude vs. temperature profiles differ between freezing drizzle and SCDD, for the purposes of ice accretion only, freezing drizzle and SCDD may be considered synonymous terms. Droplets of liquid water at temperatures below 0° C (supercooled) having diameters of 40 to 400 microns are found in both.

The accident airplane was operating in a complex icing environment that likely contained supercooled droplets having a liquid water content (LWC) estimated to be as high as 0.7 grams per cubic meter and a temperature near freezing. Estimates of the droplet diameter vary significantly depending on the estimating methodology, but the droplets with the most severe adverse consequences appear to be in the range of 100 to 400 microns or up to 10 times larger than normal certification requirements. ***No aircraft is certificated for flight in these conditions!***

Holding with the flaps extended in the severe icing conditions caused ice to form on and aft of the deicing boots. The ice aft of the boots could not be shed even though the ice protection system was functioning normally. When the flaps were retracted at a constant airspeed, the airplane suffered a roll upset.

While the crew of the accident airplane may not have been aware that they were holding in severe icing conditions, the cockpit voice recorder indicates they were aware of ice accretion on their aircraft. Additionally, up to the time of the upset, the autopilot was controlling the airplane, so that the pilot was not sensing changes to control forces.



Side window icing cue; alerts the crew to the presence of freezing drizzle.

Supercooled Large Droplets Include Freezing Rain, Freezing Drizzle, and Supercooled Drizzle Drops

During the investigation surrounding the accident, the FAA uncovered accidents and incidents involving other types of airplanes in freezing rain, freezing drizzle, and supercooled drizzle drops (SCDD). Collectively these icing conditions will be referred to in this article as supercooled large droplets (SLD).

The insidious aspect of SLD conditions is that:

- **they may challenge contemporary understanding of the hazards of icing; and**
- **the airplane may not exhibit the usual symptoms or cues associated with severe icing prior to loss or degradation of performance, stability, or control characteristics.**

What Is Being Done To Reduce The Hazard?

To minimize the hazard to SLD conditions, the FAA has established a three-phase program (*see cover story on this subject in this edition of the __Update__*):

- __Phase I__—remedy the accident airplane type;
- __Phase II__— screen other airplane types similar to the ATR for susceptibility to roll upset in severe icing and correct susceptible airplanes; and
- __Phase III__—reexamine all aspects of icing certification, including the large droplet environment, weather forecasting, training, and operation.

Phase I is essentially complete. All ATR Model 42 and 72 airplanes are now equipped with extended deicing boots that approximately double the coverage on the upper surface of the outer wings. The increased coverage of the ATR boots is intended to minimize the hazard during inadvertent exposure to drizzle size drops while the crew takes steps to exit the icing condition.

Phase II started in March 1995 and logically commands all available resources to complete as-soon-as-possible.

Phase III will begin this year.

While the challenges of SLD icing appear to be overwhelming, there are procedures to help identify severe icing conditions and exit potentially hazardous icing conditions.

For the longer term, there are promising technologies nearing maturation in both detection and protection equipment, as well as a commitment to a thorough reexamination of the entire icing certification process.

Some Ice Is Insidious

While ice can accrete on many airplane surfaces, the discussion in this article will focus on **wing airfoil icing**. There are an infinite variety of shapes, thicknesses, and textures of ice that can accrete at various locations on the airfoil. Each ice shape essentially produces a new airfoil with unique lift, drag, stall angle, and pitching moment characteristics that are different from the host airfoil and from other ice shapes.

There is a range of effects from these shapes. Some effects are relatively benign and are almost indistinguishable from the host airfoil. Others may alter the aerodynamic characteristics so drastically that all or part of the airfoil stalls suddenly and without warning. Sometimes the difference in ice accretion between a benign shape and a more hazardous shape appears relatively insignificant.

Severe icing (referring to its effects) is often exclusively associated with just ice thickness. For example, it is reasonable, in a given set of conditions, to understand that a certain 3 inch shape would be more adverse than a similar 1½ inch shape in the same place. Contrary to that one criterion, however, there is a case where a 5-inch ice shape on one specific airfoil is not as adverse as a 1-inch ridge located farther aft on the chord. In another example, a layer of ice having substantial chordwise extent is more adverse than a 3-inch ice accretion shaped with an upper and lower horn shaped ridge (double horn)!

"*Severe*" ice, as used in this article, includes ice that forms beyond the limits of ice protection systems. There are means to detect this kind of hazardous ice.

Learning what means are available to assist pilots in recognizing severe ice is important. These means can be visual or tactile cues.

Normal Icing Cues

Visual or tactile icing cues signal the potential for ice to form, the presence of ice accretion, or icing severity. Cues may vary somewhat among airplane types, but typically include:

- **temperature below freezing combined with visible moisture;**
- **ice on the windshield wiper arm or other projections such as engine drain tubes;**
- **ice on engine inlet lips propeller spinners;**
- **decreasing airspeed at constant power and altitude; or**
- **ice detector annunciation.**

Tactile cues such as vibration, buffet, or changes in handling characteristics normally trigger a mental warning that ice has already accreted to a perceptible, and perhaps, detrimental level.

Typically, as ice increases in thickness, cues become more prominent.

Using meaningful cues, AFM instructions provide guidance to pilots when to take adequate steps to or activate the various elements of the ice protection system and, as necessary, to exit the condition.

Abnormal Icing Cues

However, there are event reports involving different airplane types that suggests a disturbing pattern associated with some severe icing. Severe icing may be insidious because it may not present the usual cues to the pilot before hazardous and sometimes irreversible degradation or loss of performance, power, control, or handling characteristics occurs.

Abnormal cues of severe icing will be addressed in following sections describing some conditions that merit action by the pilot. Before addressing that subject, it may be helpful to understand what icing certification implies and other information.

Icing Certification

An airplane may be certificated for flight in icing conditions either as part of the original type certification

(TC) process or a supplement to the type certificate (STC). Icing certification is optional for any aircraft. The icing conditions established as the basis of the approval are defined in Appendix C of Title 14, Part 25 of the Code of Federal Regulations (14 CFR 25).

Appendix C describes the variables of liquid water content (LWC) and mean effective droplet diameter (MED). MED is a measure of droplet size and distribution and is generally assumed to be equivalent to median volumetric diameter (MVD), a more common and convenient measure of the size of the droplets in an icing cloud.

Appendix C also defines temperature and horizontal extent of the icing clouds for maximum continuous and maximum intermittent conditions. These conditions are usually associated with stratiform and cumuliform clouds respectively. The vast majority of aircraft icing encounters are within the icing environment defined by Appendix C.

Icing Envelope

Appendix C is a sound statistical representation of the natural icing environment, but it does not include SLD. Even though the data for the current Appendix C envelope was collected in the mid 1940's, analysis of recent data hasn't invalidated the envelope. Particularly at temperatures near freezing, the MVD and LWC appears to be representative of 99+% of the conditions normally encountered in flight.

Icing Exposure Increases

In the past, there have been infrequent event reports of freezing rain or freezing drizzle encounters. These reports appear to have increased in frequency, especially among the turboprop airplanes used in regional airline (sometimes referred to as "commuter") operation. One possible reason for this increase is that there has been a dramatic increase in exposure to icing conditions in general.

For example, in 1975, the number of annual departures for all U.S. trunk carriers (major airlines) was 4.74 million. In 1994, almost two decades later, just the regional airline (commuter) segment alone has grown to 4.60 million annual departures.

Annual regional airline exposure to icing may be double that of jet aircraft, which service the longer routes and tend to operate at higher altitudes above most icing conditions for a greater percentage of their flight time.

Greater utilization implies greater exposure to all icing conditions. It follows then that there would be a commensurate increase in the number of flights involving SLD. For whatever reasons, exposure to these hazardous conditions appears to be more frequent than previously thought.

Droplet Size Determines Boot Limit

As prescribed by FAA policy, droplet diameter normally used to determine the aft limit of ice protection system coverage is 40 microns (one micron is one millionth of a meter). Drizzle size drops may be ten times that diameter (400 microns). That means they have 1,000 times the inertia, and approximately 100 times the drag, of the smaller droplets.

Because of the these factors, drizzle drops not only impinge on the protected area, but may impinge aft of the ice protection system and accumulate as ice where it cannot be shed.

Freezing raindrops may be as large as 4,000 microns. Freezing rain, however, tends to form in a layer—sometimes coating the entire airplane.

Freezing drizzle tends to form with less extensive coverage than freezing rain, but with higher ridges. It also forms ice fingers or feathers perpendicular to the surface of the airfoil. For some airfoils, freezing drizzle appears to be far more adverse to stall angle, maximum lift, and drag than freezing rain. This is not to suggest that freezing rain be considered harmless.

What About Aircraft Certification Regulations?

No aircraft is certificated for flight in SLD! Although there is ongoing atmospheric research, the SLD environment hasn't been extensively measured or statistically characterized. There are no regulatory standards for SLD, and only limited means to analyze, test, or otherwise confidently assess the effects of portions of the SLD environment.

Ice shape prediction computer codes currently do not reliably predict ice shapes for temperatures near freezing because of daunting thermodynamics.

As it happens, near freezing seems to be where SLD conditions are most often—but not exclusively—reported. Further research using instrumented airplanes is necessary to accurately characterize the SLD environment.

In addition to energy balance problems, there are other challenges not yet addressed by computer codes, such as: the shape—hence, drag —of large droplets as they are influenced by the local flow field; fragmentation of drops; and the effect of drops splashing as they collide with the airfoil. Ice shedding and residual ice are not currently accounted for either.

NASA and others are aggressively working on these challenging computational tasks and simultaneously pursuing validation of icing tunnels to simulate SLD. Those efforts will require comparison against measured natural conditions. Additionally, there is no single universally accepted standard on how to process or accurately characterize data collected in the natural icing environment. Clearly, until these tasks are complete, certification issues can not be resolved. They will be thoroughly addressed in Phase III.

For the sake of argument, assuming that a natural SLD icing environment data base is developed, the icing envelope amended in some way, and test means modified and validated to adequately evaluate aircraft in all, or part, of the SLD environment: What then?

State-of-the-Art Ice Protection Technology

Experience suggests that it has been impractical to protect airplanes for prolonged exposure to SLD icing because—at its extreme—it tends to cover large areas of the airplane. A conventional pneumatic ice protection system able to deal with this extensive ice accretion may affect airfoil performance as much as the ice. It would be expensive and heavy. Conventional electrothermal systems would require extraordinary amounts of power.

Two areas of new technology offer promise for SLD: *detection* and *protection systems*.

Ice Detection and Aero-Dynamic Performance Measurement

Improvements in detection system designs ability to recognize ice are maturing. Even more sophisticated designs appear able to measure the effect of ice on aerodynamic parameters.

Surface ice detectors sense the presence of contamination on the detector surface. Some distinguish between ice, slush, water, freezing point depressants, and snow. There are now strip and area detectors in test capable of detecting the thickness of ice on a deicing boot.

A recent design innovation measures the stall angle and other aerodynamic parameters of a contaminated airfoil. This could be a valuable tool to aid pilots because ice thickness is not the only factor in determining effect. Location, roughness, and shape are important, too. For example, on one airfoil, a ½-inch step on the upper surface of the airfoil at 4% chord reduces maximum lift by over 50%. Yet the same shape at 20% chord decreases maximum lift by only 15%. On another airfoil, distributed sandpaper-like roughness elements on the upper wing may decrease lift by 35%.

These new aerodynamic performance monitors also claim a somewhat predictive function, not just warning of airflow separation as it occurs, but before it occurs.

For detectors to be a viable means of reducing the hazard of SLD, sufficient detection and warning time for the crew to safely exit the condition must be shown. The FAA has generally preferred, where possible, that known hazards be minimized by preventing or removing the formation of ice on a critical surface as opposed to advising of its presence.

Ice Protection

There have been recent advancements in ice protection systems. Innovations include a high pressure pulsed pneumatic system with a conformal metallic or composite leading edge that could replace the familiar black rubber boot. The system uses a 600 psi pulse of air to reliably clear ice in the range of 1/50 of an inch thick. Current pneumatic systems generally are operated when ice is allowed to build to ¼- to ½-inch thick.

Electrothermal systems consisting of metal coated fibers imbedded within the paint system are being tested. One device boasts a low power consumption between ½ watt to upwards of 6 watts per square inch, depending on the ambient temperature. Conventional systems consume 10 to 15 watts per square inch. Hybrid systems that combine conventional pneumatic boots and advanced electrothermal ice protection are also being explored.

Other low-energy innovations are electro-impulsive/expulsive deicing systems (EIDI/EEDS) that rapidly discharge electrical energy stored in a capacitor through a coil or conductive ribbons. Eddy currents or magnetic repulsion forces, respectively, cause the iced surface to move at extremely high acceleration, but small distance, to shed ice in the 1/50-inch thickness range or larger.

Another proposed feature of emerging systems is a closed-loop mode of operation where a detector signals that ice has accreted and actuates the system—then waits for another build up. This feature would allow surfaces to be individually operated at optimum ice thickness.

When Will New Systems Be Operational?

These systems are in various stages of maturity and test. But, as with any system, testing must be successfully completed before there can be assurance that the system will perform its intended function reliably in the entire icing envelope—whatever that may ultimately be.

Historical Perspective

Traditionally, the industry has relied upon the infrequency of occurrence, limited extent of coverage, forecasting, and reporting to avoid freezing rain and freezing drizzle, and recognition to exit the condition. Another factor in some earlier airfoil designs is that they tended to be somewhat less sensitive to lift loss with contamination than some of the newer, more efficient, airfoils.

Forecasting

SCDD is a new challenge. Like freezing rain and freezing drizzle, SCDD conditions generally tend to be limited in horizontal and/or vertical extent. Because of the limited extent of these conditions they are not included in SIGMETS under current definitions since they involve less than 3,000 square miles. There is substantial effort being placed into improving forecasts for all SLD. Starting in the Fall of 1995, there have been preliminary changes to mathematical models used to forecast these conditions. The models will be reviewed and updated periodically based on correlation with observations and PIREP's.

Pilot Reports (PIREP)

Pilots are best situated to submit a real time report of actual icing conditions. Yet, the most obvious factor about the efficacy of a PIREP is that there is no assurance another airplane will transit that small volume of the sky containing SLD. If it does, there must be some way for the pilot to identify that the icing is due to SLD and then submit the PIREP. All pilots may not be sensitive to what SLD icing looks like on their airplane, and PIREP's are not the highest priority at periods of high cockpit workload.

Even if the same volume of the sky happens to be sampled by another airplane, there are many variables involved in the reported encounter that may not reflect the potential hazard of the cloud for other airplanes.

The obvious differences are the size and type of the other airplane's airfoil, configuration, speed, angle-of-attack (AOA), etc. If the other airplane happens to be larger, the effect of icing may have been unnoticed and unreported, but could be a problem for a smaller airplane.

PIREP's from an identical model airplane are most likely to be representative, but even the same airplane climbing through an icing layer would likely result in a different ice accretion than one descending.

As a forecast projects what may be, a PIREP chronicles what was. PIREP's are very useful in establishing a heightened sense of awareness to a possible icing condition and are very valuable to aid forecasters in correlating forecast meteorological data with actual ice.

The most important issue is: "What is the icing condition right now?"

What Is . . .?

For the present time, the pilot is the best means of determining "what is...," if he/she has usable guidelines.

One airline in an island environment with unique atmospheric conditions reports that they periodically encounter and safely exit SLD conditions because of knowledgeable and vigilant crews.

Experienced crews rely on visual cues to determine the presence of SLD. Once the pilots detect the cues, they exit the condition. Since SLD conditions tend to be localized, the procedure has proved to be practical and safe. It does require alertness to existing conditions and a working knowledge about the airplane and the weather. Working knowledge of the weather implies that pilots know what the temperatures and conditions are likely to be to the left, right, ahead, behind, above, and below the route of flight, and what severe icing looks like.

Why Is Some Ice Severe or "Bad"?

Ice accreted beyond ice protection system coverage will not be shed and will continue to accrete until the airplane exits the icing conditions. Remaining in such icing conditions can not improve the situation.

Rime/Clear/Mixed

Extent of ice accretion, shape, roughness, and height are the most important factors in the effect an airfoil. Unfortunately, operational descriptors of rime, clear, or mixed are not adequate to accurately convey nuances of the icing environment and the hazards of SLD. Ice forming aft of the boots may be white, milky, or clear. Non-hazardous ice may also be described using the same terms. In the same cloud, one airplane may accrete rime while another—at a higher speed—accretes mixed ice. With the potential for ambiguity, meaningful terminology is an issue that must be addressed.

Trace, Light, Moderate, or Severe

Severity indices of trace, light, moderate, and severe vary among airplanes for the same cloud and tend to be subjective. Not too far from the Roselawn accident site at about the same time as the accident of October 1994, a jet airplane experienced a rapid ice accretion. The Captain said that he never experienced ice buildup that fast before. One inch of milky ice accumulated on a thin rod shaped projection from the center windshield post in one to two minutes. It was reported as light rime. In these extraordinary conditions, does "*light*" icing convey a message to others suggesting vigilance or complacency?

How Can Ice Affect Roll Attitude?

Ice can contribute to partial or total wing stall followed by roll, aileron snatch, or reduced aileron effectiveness.

Wing stall is not an uncommon consequence of ice accretion. Ice from freezing drizzle can form sharp edged roughness elements approximately 5 to 10 mm high over a large chordwise expanse of the wings lower surface (perhaps covering 30 to 50%), and fuselage increasing drag dramatically thereby reducing speed. Correcting for this demands increased power, increased AOA, or both to maintain altitude. Ultimately such unmitigated adjustments lead to exceedance of the stall angle and a conventional stall, likely followed by a roll.

Aileron "snatch" is a descriptive term that results from an imbalance in the sum of the product of aerodynamic forces at an AOA that may be less than wing stall, that tends to deflect the aileron away from the neutral position. On unpowered controls, it is felt as a change in control wheel force. Instead of requiring force to deflect the aileron, it requires force to return the aileron to the neutral position. All else equal, smaller ailerons would have smaller snatch forces. Aileron instability sensed as an oscillation, vibration or buffet in the control wheel is another tactile cue that the flow field over the ailerons is disturbed.

While flight testing using simulated ice shapes on the ATR (intending to simulate the conditions at Roselawn) demonstrated that these forces were less than the 60 pound certification limit for temporary application in the roll axis, the sudden onset and potential to cause a rapid and steep roll attitude excursion was unacceptable. FAA investigation has revealed similar roll attitude excursions affecting other aircraft types that are equally unacceptable.

Ailerons that exhibit the "snatch" phenomenon have control wheel forces that deviate from their normal relationship with aileron position. However, the ailerons may be substantially effective when they are deflected.

Loss of roll control effectiveness is a different situation, and perhaps the more dangerous. Because of flow disruption over the wing ahead of the ailerons, the controls do not produce the rolling moments associated with a given deflection and airspeed. This can affect airplanes of any size.

When reduction or loss of aileron control due to ice is experienced, it may or may not be accompanied by abnormally light control forces. If the airplane is displaced in roll attitude, for instance, caused by partial stall due to ice, the pilot's efforts to correct the attitude by aileron deflection are defeated by the lack of their effectiveness.

Roll upset due to any cause is totally unacceptable. How can it occur?

Wing Tip Stall!

Ice tends to accrete on airfoils in different ways, depending on the airfoil, the AOA, and other aircraft variables, and of course, the atmospheric variables controlling the size, density, temperature, etc. of the water droplets. Similarly, the ice has differing effects on the airfoils.

The implications of all this can be illustrated with a wing. Consider the airfoil at the tip as a different airfoil than at the root—in all probability it is different. It is probably thinner, may have a different camber, be of shorter chord, and, more than likely, there are two or three degrees of twist or washout relative to the root section.

Because the tip section may have a sharper nose radius and most likely has a shorter chord, it is a more efficient ice collector. As a result of the above differences, ice accretion at the wing tip may be thicker, extend further aft, and have a greater adverse effect than ice at the root.

Twist or washout helps to ensure that, at least, the symmetric stall starts inboard, and spreads in a progressive fashion, so that roll control is not lost. Greater ice accretion has probably occurred at the tip, leaving it more impaired aerodynamically than the inboard wing sections. Stall, instead of starting inboard, may start at the tip.

Even if the ice does build up at the root to nearly the same thickness as that at the tip, it still tends to affect the smaller chord section, such as the wing tip, more adversely.

Power effects can aggravate tip-stall. The effect of the propeller is to reduce the AOA of the section of the wing behind it. At high power settings, stall on the inner wing tends to be delayed by propwash. But the outer wing doesn't see the same flow field, so it tends to stall sooner.

Safety margins for the above factors in normal icing conditions are eroded when ice forms aft of the ice protection systems!

Finally, because of its greater distance from the flight deck to the outer wing, the crew may have difficulty in assessing ice there.

The result of all this means that at some AOA, the outer wings may have at least a partially separated flow, while normal flow conditions still prevail over the inner parts of the wing. If a stall occurs, there may be no pronounced "g" break and the pilot may not sense the stall—hence it is insidious. This partial flow separation also accounts for a degree of loss of aileron effectiveness.

Where Does Ice Accrete?

Where ice builds up on a given airfoil depends on the AOA, airspeed, and icing variables. For example, during the icing tanker testing of the ATR-72 at Edwards AFB flying in drizzle size drops at the test airspeed, ice would predominantly build on the upper surface of the wing with the flaps extended to fifteen degrees (ergo, smaller AOA) and predominantly on the lower surface of the wing with the flaps retracted (larger AOA). This testing was part of the Roselawn investigation.

In the upper surface case, there was little drag increase until separation. On the lower surface, the expanse of rough ice was accompanied by a substantial drag increase.

Ice tends to accrete more on the upper surface at low angle-of-attack associated with higher speeds or flap extension. Ice tends to accrete more on the lower surface at higher angle-of-attack (slower airspeed).

In an icing environment, the propeller wash also tends to influence icing impingement on the airfoil. Unless the propellers are counter-rotating the flow field is asymmetric over the wings and ice impingement tends to be slightly asymmetric as well.

Recovery

Once airflow separation occurs, reattaching flow generally requires a marked reduction of AOA and then refraining from increasing the AOA to the stall angle for that part of the wing. This characteristic is configuration dependent, and is not limited to just one airplane type.

As an example, in the case of two different airplane types studied in detail, the stall angle for the outer wings is about 5° with ice accretion forward of the ailerons on the upper wing surface aft of the deicing boots. The normal stall angle is near 20° with no ice accretion. In both cases, reattachment of flow occurs when the AOA is reduced to substantially less than the stall angle. Applying power and maintaining attitude may not be most effective in recovering from an outer wing stall since the reduction in AOA does not occur as rapidly.

Ice can form aft of ice protection system in SLD conditions where the droplets strike and freeze aft of the boots. Ice formation may be rapid in large droplet and near freezing conditions where ice accretes aft of the boots because of the direct impingement of the large droplets and because temperatures do not allow rapid heat transfer from the droplets that strike the leading edge. They don't freeze immediately, but flow aft to the chordwise ice formation and then freeze.

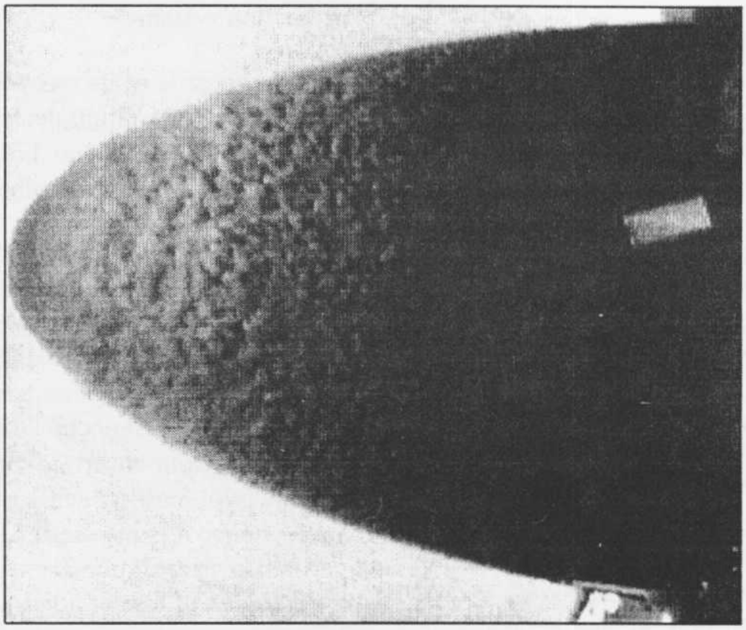
Detecting SLD

Cues

The most effective means to identify severe icing are cues that can be seen, felt, or heard. General information discussed below is intended to assist pilots in identifying and exiting inadvertent encounters with SLD conditions. ***The suggestions below are not intended to be used to prolong exposure to icing conditions, but are a warning to exit the condition immediately.***

Importantly, because of the broad range of environmental conditions, limited data available, and various airplane configurations, ***the manufacturer's AFM/POH should be consulted for guidance on a specific type:***

- **Ice visible on the upper or lower surface of the wing aft of the active part of the deicing boots. It may be helpful to look for irregular or jagged lines or pieces of ice self shedding. For contrast, a portion of the wing may be painted a dark matte color—different than the color of the boots. The matte finish can help in identifying initial formation of SLD ice which may be shiny. All areas to be observed need adequate illumination for night operation.**
- **Observe the aft limit of ice accretion on the propeller spinner. Non-heated propeller spinners are useful devices for sorting droplets by size. Similar to a white wing, a polished spinner may not provide adequate visual contrast to detect SLD ice! If necessary, a dark matte circumferential band may be painted around the spinner as a guide.**
- **Drizzle size drops accrete farther aft on the spinner. Ice is also visible on the wing. In this case—at a somewhat lower airspeed (higher AOA) and colder temperature— it does not appear to extend beyond the active boot area.**
- **Granular dispersed ice crystals, or total translucent or opaque coverage of the unheated portions of the front or side windows. This may be accompanied by other ice patterns on the windows such as ridges. These patterns may occur within a few seconds to half a minute after exposure to SLD conditions.**
- **Unusually extensive coverage of ice, visible ice fingers or ice feathers on parts of the airframe not normally covered by ice.**



Ice accumulation on the propellor spinner of a Model ATR-72 series airplane.

At temperatures near freezing, other details take on new significance:

- **Visible rain (which consists of very large water droplets). In reduced visibility conditions occasionally select taxi/ landing lights ON. Rain may also be detected by the sound of impact.**

- **Droplets splashing or splattering on impact with the windshield. Droplets covered by the icing certification envelopes are so small they are usually below the threshold of detectability. The largest size of the drizzle drops is about the diameter of a 0.5 mm pencil lead.**
- **Water droplets or rivulets streaming on the heated or unheated windows may be an indication of high LWC of any size droplet.**
- **Weather radar returns showing precipitation suggest increased vigilance is warranted for all of the cues. Evaluation of the radar display may provide alternative routing possibilities.**

Preventative and Remedial Measures

Before Takeoff

Know the PIREP's and the forecast: where potential icing conditions are located in relation to the planned route; and which altitudes and directions are likely to be warmer/ colder. About 25% of the cases of SLD are found in stratiform clouds colder than 0° C at all levels, with a layer of horizontal wind shear at the cloud top. There need not be a warm melting layer above.

In Flight

Maintain awareness of outside temperature. Know the freezing level (0° C SAT). Be especially alert for severe ice formation at a TAT near 0° C or warmer (when the SAT is 0° or colder). Many icing events have been reported at these temperatures.

Avoid exposure to SLD icing conditions (usually warmer than -10° C SAT, but possible to -18° C SAT). Normally temperature decreases with each 1,000 foot increase in altitude between approximately 1½° C (2½° F) for saturated air, to 2¾° C (5° F) for dry air. In an inversion, temperature may increase with altitude.

When Exposed to Severe Icing Conditions

Disengage the autopilot—hand fly the airplane. The autopilot may mask important handling cues, or may self-disconnect and present unusual attitudes or control conditions.

Advise ATC and promptly exit the condition using control inputs as smooth and as small as possible.

Change heading, altitude, or both to find an area warmer than freezing, or substantially colder than the current ambient temperature, or clear of clouds. In colder temperatures, ice adhering to the airfoil may not be completely shed. It may be hazardous to make a rapid descent close to the ground to avoid severe icing conditions.

When severe icing conditions exist, reporting may assist other crews in maintaining vigilance. Submit a PIREP of the observed icing conditions. It is important not to understate the conditions or effects.

If Roll Control Anomaly Occurs

Reduce angle-of-attack (AOA) by increasing airspeed or extending wing flaps to the first setting if at-or-below the flaps extend speed (V_{FE}). If in a turn, roll wings level.

Set appropriate power and monitor airspeed/AOA. A controlled descent is a vastly better alternative than an uncontrolled descent.

If flaps are extended, do not retract them unless it can be determined that the upper surface of the airfoil is clear of ice since retracting the flaps will increase the AOA at a given airspeed.

Verify that wing ice protection is functioning normally and symmetrically by visual observation of the left and right wing. If not, follow manufacturer's instructions.

Summary

Roll upset may occur as a consequence of a wing stall or prior to wing stall due to anomalous control wheel forces that cause the ailerons to deflect, or because the ailerons have lost effectiveness. The latter two may be caused by ice accreting in a sensitive area of the wing aft of the deicing boots under unusual conditions associated with SLD and rarely—normal cloud droplets—in a very narrow temperature range near freezing.

Pilots can minimize the chance of a roll upset by being sensitive to cues that identify severe icing conditions then promptly exiting the icing conditions before control or handling characteristics of the airplane are degraded to a hazardous level.

In the longer term, ice protection equipment may be certificated for all—or part—of the SLD spectrum,

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One Level of Safety

Making the most compre hensive changes ever in aviation rulemaking, U.S. Department of Transportation Secretary **Federico Peña** and FAA Administrator **David Hinson** recently announced the *Commuter Safety Initiative*. The Initiative is a new set of rules that will result in the safe high standard of safety for passengers on scheduled airlines, whether they board a "jumbo jet" or a "10-seater."

Part of the Initiative is "the commuter rule," which requires commuter airlines to meet the same operational, equipment, and performance safety standards as major carriers. It requires all commuters that operate aircraft with 10 to 30 seats to meet the same or equivalent safety standards as the major air carriers. Prior to this rule, there was one set of rules for airplanes with 31 or more passengers, and another set for airplanes with 10 to 30 seats.

President Clinton praised the new standards saying, "A universal high level of safety for all commercial airplanes is a bold step forward in the interest of passengers, and demonstrates how commonsense government can make a real difference in the lives of Americans."

In addition to the commuter rule, the Commuter Safety Initiative includes a final rule requiring more comprehensive training standards for air carrier pilots. These requirements include new Crew Resource Management standards that move forward the FAA's efforts to address "human factor" problems regarding flight crew and dispatches. The FAA also issued a Notice of Proposed Rulemaking that would require airlines to comply with proposed new flight/duty/rest standards for pilots.

"These new rules fundamentally enhance the way a vital segment of the air travel industry operates and meets a personal commitment I made to Americans a year ago, " said Secretary Peña. "These new standards provide the nation with the tools we need to meet the vast growth in commuter aviation. We have made an impressive move forward in government, labor, and industry towards our mutual goal of *'zero accidents.'*"

"These new standards provide the nation with the tools we need to meet the vast growth in commuter aviation."

A major focus of the commuter rule is a new requirement for all commercial operators to:

- appoint a safety officer,
- improve their ground deicing programs,
- upgrade operations and air-crew manuals,
- implement a carry-on baggage program,
- and introduce a proper dispatch system.

It also requires duty limits for aircraft maintenance workers and additional passenger safety equipment, such as medical kits and fire protection devices.

"The Commuter Safety Initiative will be recognized as a bold move in commercial aviation safety, " said FAA Administrator Hinson. "Safety is the fundamental thread running through everything the FAA does, and this new comprehensive package of rules underscores that commitment. I am particularly proud of those in the agency who contributed to this monumental effort . . . [and] who have worked so hard over the past year to make this possible."

Material for this ariticle was previously published in DOT Today, January-February 1996.

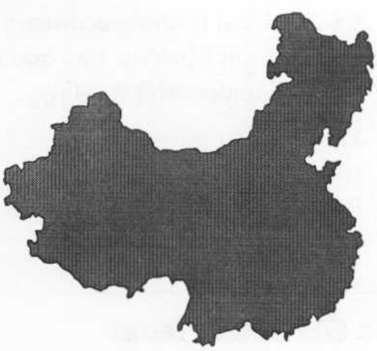
International Airworthiness Programs Activity Update

The FAA Aircraft Certification Service's International Program Staff (AIR 4) is currently involved in various activities concerning the development and implementation of Bilateral Airworthiness Agreements (BAA) and Bilateral Aviation Safety Agreements (BASA) with several countries:

This article provides an update of these on-going activities.

Current Activities

China



In March 1995, implementation procedures of theBAA between the U.S. and the People's Republic of China (PRC) were expanded. The new implementation procedures provide for U.S. acceptance of Part 23 aircraft (up to 19-passenger commuter, 12,500 lbs. or less) of Chinese type design and certain components manufactured to an FAA Technical Standard Order (TSO).

FAA completed its evaluation of the Y-12 (Model IV) aircraft and issued its first type certificate for a Chinese aeronautical product in March 1995. The Y-12 (IV) is a 19-passenger high-wing aircraft with Hartzel propellers and Collins avionics.

FAA also recognized two tires manufactured by Lanyu Aircraft Tire Development Company for the Boeing 737 and the Boeing 757, and issued letters of TSO design approval for the U.S. acceptance of these tires.

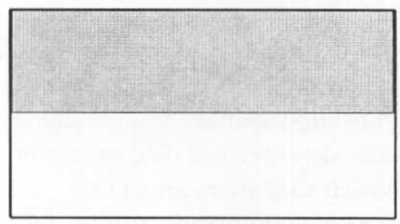
In October 1995, FAA will launch a new assessment to work towards recognition of the Chinese certification system for transport category (FAR Part 25) aircraft using the Y-7-200X. This program is expected to be a 4-year project, culminating in the expansion of the U.S./PRC BAA to accept transport category aircraft with Western engines and avionics.

Indonesia

The United States has had a limited BAA with Indonesia since 1987. This BAA is limited to U.S. recognition of the Direction Générale de l'Aviation Civile's (DGAC) production oversight and airworthiness certification of products produced under license to a U.S. type certificate holder. Indonesia wishes to expand this BAA to permit the export of Indonesian type designs to the United States.

The FAA's BAA assessment was initiated May 1993. Limited progress has been made to date. The FAA's first interim assessment report was presented to DGAC in March 1995.

This shadow certification has been particularly challenging because of the state-of-the art aircraft design



and the relative inexperience of the Indonesian airworthiness authority, the DGAC Airworthiness Certification Directorate, particularly in the engineering disciplines.

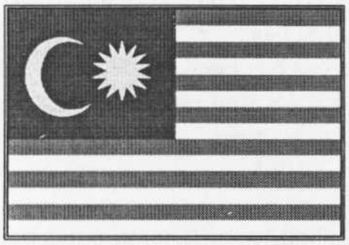
The aircraft being evaluated is the N-250-100: a 64-passenger, fly-by-wire, high-wing aircraft with Allison engines and many U.S. components. First flight of an early version was conducted on August 10, 1995.

The outcome of FAA's assessment could be the expansion of the current limited U.S./Indonesia BAA to cover Part 25 turboprop-powered aircraft of Indonesian type design.

Other activities under the current limited BAA with Indonesia that took place during 1995 included:

- conclusion of a Memorandum of Understanding for DGAC support of FAA oversight of a General Electric Production Certificate Extension for the GE-7-9C engine.

Malaysia



FAA's technical assessment was initiated in September 1994. Malaysia seeks a BAA with the U.S. that will recognize tires manufactured in Malaysia, as well as small airplanes (5 seats or less). Two technical visits have been made to Malaysia as well as discussions in FAA Headquarters about the Malaysian regulatory system.

Malaysia has adopted a unique approach to aircraft design and manufacture by purchasing the design rights to already approved aeronautical products. Malaysia does not envision becoming a state of "original" design and manufacture. Malaysian companies own the type designs to the MD3-160, Dornier Seastar, and are considering other small airplane designs. This approach has policy implications for FAA consideration, as well as challenges for the assessment team since the airworthiness authority will not conduct the original type certification of the product.

FAA anticipates in the near future closing out the remaining action items towards conclusion of a BAA for the acceptance of tires designed and manufactured in Malaysia. FAA will be recommending that the Department of State move forward with a BAA.

An FAA final technical evaluation of the MD3-160 is scheduled for March 1996. At that time, FAA will determine whether the implementation procedures for the BAA could cover small airplanes as well, based on the demonstrated competency of the pertinent Malaysian airworthiness engineering specialists.

Malaysia has made remarkable progress in a short period in developing the skills of its airworthiness specialists and establishing a regulatory framework that could be found acceptable by the FAA for a BAA.

Russia

FAA's technical assessment was initiated in July 1991. The aircraft being evaluated are the Ilyushin-103 (a five-place multipurpose aircraft with Teledyne-Continental engines and Collins avionics) and the Ilyushin-96T (a cargo transport with Pratt & Whitney engines and Collins avionics).

The initial outcome of these efforts is anticipated to be a limited BAA for Part 23 aircraft (with less than 9 seats) that have U.S. engines and U.S. avionics. This initial BAA could then be expanded to allow the U.S. acceptance of Russian cargo transport aircraft with U.S. engines and U.S. avionics.

Progress has been slow towards a BAA, in part because of financial problems of the Russian applicant (Ilyushin Design Bureau). Obstacles to a BAA include the lack of an Air Code in Russia; limited procedural guidance on the new Russian production approval system; dissimilar methods of interior materials testing; and the need for FAA to see in operation a system for continued operational safety.

FAA slowed its technical exchanges with Russia during 1995 because of other financial constraints.

Achievements include:

- conclusion of a Memorandum of Understanding signed by Vice President Gore and Vice Premier Chernomydrin committing both governments to continued cooperation toward a BAA.
- six technical training seminars presented in Moscow and one in the U.S. under AID funding,
- The Russian government's commitment to complete Russian certification of the IL-103 and the IL-96T aircraft.

The FAA BASA Team

The FAA's Aircraft Certification Service chartered a "*BASA Team*" in 1995 to work on all activities related to the transformation of the BAA's to the new "*BASA Implementation Procedures (BASA IP)*". The Team operates on behalf of the Director of the Aircraft Certification Service, and consists of representatives from all the FAA Directorates, the Brussels Aircraft Certification Office, and FAA Headquarters personnel.

The BASA Team has developed a basic process for the BAA-to-BASA IP transformation, which guides the Team and promotes consistency and standardization in its activities. An important part of this process is the conduct of "*re-acquaintance visits*" with our BAA partners. These are visits that will be made by the Team to another non-U.S. Civil Aviation Authority (CAA) for the purpose of re-establishing our relationship under the BAA, and exchanging information on both the FAA's and CAA's regulatory and aircraft certification system in order to ensure that the two systems are sufficiently similar in structure and meaning to produce the same levels of certitude and safety. This exchange of information is vital to the co-development of the BASA airwothiness IP with the CAA.

The BASA Team is currently developing the BASA airworthiness IP covering the topics of:

- design approval,
- airworthiness certification,
- continued airworthiness, and
- mutual cooperation and technical assistance.

This "*generic*" IP will be used as a baseline to further co-develop "*country-specific*" IPs with other CAA's during the transformation of any BAA to a BASA IP.

In November 1995, AIR began the development of a general airworthiness IP with the Joint Aviation Authorities of Europe (JAA). BAA-to-BASA IP transformation activities were scheduled with individual JAA member countries who have BAA's with the U.S., but these countries requested that the FAA postpone these activities for the present time. The JAA Certification Committee has proposed to work with FAA to develop a general or standardized airworthiness IP, which could then be used as a baseline to co-develop "*country-specific*" IP's with individual JAA member countries. After development of the initial IP, the FAA will schedule re-acquaintance visits to individual JAA member countries in order to get re-familiarized with the aircraft certification system of that country, as well as to develop the country-specific IP.

In addition to transforming BAA's to BASA IP's, the BASA Team has been tasked to develop the revisions necessary to expand the existing Schedule of Implementation Procedures (SIP) under any BAA until the BAA for that country is transformed to a BASA IP. This past year, the BASA Team completed an expanded SIP with the People's Republic of China.

Another important task of the BASA Team is to work with CAA's who will not have a BASA in the near future, but who would benefit from the co-development of Operating Procedures under the existing BAA. (Operating Procedures have a format that is almost identical to the Implementation Procedures developed under the new BASA. Existing BAA's have provisions for the development of Procedures -- so the Team has chosen the term *Operating Procedures* for BAA's.) The BASA Team already has conducted two re-acquaintance visits to the Civil Aviation Inspectorate of the Czech Republic to re-establish the relationship under the BAA, to learn more about their

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The U.S. Has Concluded Bilateral Airworthiness Agreements With:		Requests for New Or Expanded BAA
		In the Current Work Program:
Argentina	Italy	Austria
Australia	Japan	China
Austria	The Netherlands	Indonesia
Belgium	New Zealand	Malaysia
Brazil	Norway	Poland
Canada	Poland	Russian Federation
China	Romania	
Czech Republic	Singapore	***Requests on Hold:***
Denmark	South Africa	Chile
Finland	Spain	India
France	Sweden	Ireland
Germany	Switzerland	Mexico
Indonesia	United Kingdom	Romania
Israel		Taiwan
		Ukraine

General News

Landmark Agreement

The reinvention of government continues throughout the U.S. Department of Transportation (DOT) as the Federal Aviation Administration announced that it and 11 U.S. airlines will establish a landmark government-industry consortium to develop the framework for a worldwide Aeronautical Telecommunication Network (ATN). The state-of-the-art ATN system will enable airlines and other airspace system users to communicate rapidly and reliably worldwide well into the 21st century.

The agreement, which completes an action set forth in the administration's National Performance Review, establishes a working model for government and industry cooperation in the development of a worldwide standard for aviation communication.

"This is an example of government/industry cooperation at its best because it is designed to speed delivery of a system to improve safety and service, and at the same time reduce the costs of the system's development to the users and taxpayers," said FAA Administrator David R. Hinson. "By demonstrating a clear need for the network and a commitment to work together, FAA and the aviation industry hope to reduce the risk for equipment manufacturers and create and early market for ATN products."

Under the consortium agreement, the airlines have formed a corporation, ATN Systems, Inc., that will work with FAA to develop the systems to meet the requirements of the various airspace users. The FAA and the airlines will work together to foster commercial development of the equipment and systems required for the network rather than taking a traditional approach of having the aviation industry and government conduct separate lengthy and costly development programs.

"This type of working relationship was a recommendation of the President's 1993 National Commission to Ensure a Strong competitive Airline Industry. it enables us to same time in the development of standards for systems such as the ATN, " said Hinson. "The result of this particular effort will be faster, more efficient, and more reliable communication of data for the improved safety and benefit of all users of the airspace system, which includes airlines, military, business, private pilots, and the flying public."

Continued on page 66

General News

FAA and NASA Form Partnership to Improve Air Transportation Efficiency

FAA Administrator David Hinson and National Aeronautics and Space Administration (NASA) Administrator Daniel Goldin recently signed a memorandum of understanding to initiate joint research and development activities that will improve the efficiency of the nation's airspace system. Using the latest aerospace technology, FAA/NASA initiatives will ultimately improve service to the flying public by decreasing delays through increased flexibility of airspace users.

The initiative will be managed by a FAA/NASA Integrated Product Team. The team will focus on improvements that can be implemented within the next 10 years. "I'm confident that this partnership will help bring aviation into the 21st century," Hinson said.

The combination of NASA's aeronautics expertise and FAA's air traffic management expertise will build upon the recent successes of the National Route Program, which is already providing airspace users with the flexibility to choose the most efficient routes, saving time and fuel.

The FAA's long-term goal of "*Free Flight*" will eventually allow pilots, whenever practical, to choose their own route and file a flight plan that follows the most efficient and economical trajectories.

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New Line of Business

The Office of Commercial Space Transportation (OCST) recently moved from the Department of Transportation's (DOT) Office of the Secretary to the FAA, making it the agency's seventh "line of business." The OCST, under the direction of Frank Weaver, officially became part of the FAA on October 1, 1995.

The OCST was established in DOT in 1984 to license and regulate all U.S. commercial launch activities to ensure that they are conducted safety and responsibly, and to promote, encourage, and facilitate commercial space transportation.

"The safety licensing activities of OCST for launches of launch vehicles and operation of spaceports share a common safety objective with FAA's aircraft, airspace, and airport safety regulatory activities," said DOT Secretary Federico Peña. "This move is consistent with the Clinton Administration's goals for the enhancement of the nation's high technology industries, including an internationally competitive U.S. commercial space transportation industry."

The U.S. commercial space transportation industry is comprised of aerospace companies and entrepreneurial businesses that provide launch service to foreign and domestic customers and the U.S. government. Since 1989, the year of the first licensed commercial space launch, the industry has steadily expanded and OCST has issued licenses for more than 50 U.S. commercial launches, both orbital and suborbital.

According to FAA Administrator David Hinson, "The FAA is well-positioned to advance OCST's goals of ensuring safety, promoting the development of new markets and customers for U.S. products, and maintaining U.S. technological leadership."

This year's agenda of 15 licensed U.S. commercial launches could, for the first time, exceed the number of government launches in a single year. "To meet the regulatory demands of new launch systems and a growing industry, combining the resources and skills of OCST with the FAA allows us to address those challenges," said OCST director Frank Weaver. "I . . . look forward to advancing the goals of the commercial space launch industry to position it competitively for the next century."

General News

Wake Vortex Testing

The FAA and the National Transportation Safety Board (NTSB), in partnership with Boeing and USAir, recently completed wake vortex testing at the FAA Technical Center located in Atlantic City, New Jersey. The tests were conducted using FAA's own Boeing Model 727 and a Boeing Model 737 on loan from USAir. Support test aircraft included a National Aeronautics and Space Administration (NASA) airplane (which provided atmospheric sampling), and a Boeing chase airplane (which filmed the tests).

The NTSB initiated the wake vortex testing in connection with its investigation of the tragic USAir flight 427 accident. Flight 427, a Boeing Model 737, crashed just outside of Pittsburgh, Pennsylvania, on September 8, 1994, killing all 132 people on board. The USAir flight was following a Delta Boeing 727 while descending for approach at Pittsburgh International Airport when it mysteriously lost control and crashed into the ground. The NTSB sought to determine if wake vortices could have played a role in this accident.

A wake vortex is a phenomena caused when an aircraft creates lift. Wake vortices are essentially invisible horizontal tornadoes trailing form the wing tips of aircraft. These vortices gradually sink and dissipate within a few minutes. Large aircraft, such as airliners or military transports, normally generate stronger vortices and can create potential turbulence hazards, especially to light aircraft.

Before conducting the tests, both aircraft required temporary modifications. Because wake vortices are invisible, the FAA Model 727 had to be outfitted with smoke generators under the wing tips to make the wake visible. Additionally, the Model 737 was outfitted with special instruments to collect data for the NTSB's investigation.

The actual flight tests were conducted during the last week of September 1995 at the FAA Technical Center. The Model 727, piloted by FAA test pilot Keith Biehl, was flown approximately 4.1 miles ahead of the Model 727 in conditions similar to the night of the accident. The Model 737 was then able to enter the wake of the Model 727 under various conditions, such a having the autopilot engaged and disengaged. Approximately 20 hours of testing was conducted, which enabled the Model 737 to fly at least 120 encounters with the wake.

The preliminary test results indicate that the vortices produced by the Model 727 are stronger than had been simulated in computer models. Airplane simulators used for airline pilot training will be updated with the new wake turbulence data obtained from these flight tests to provide pilots with enhanced training in this area. Although this test may not ultimately solve the mystery of flight 427, the information gathered during the tests will have a tremendous benefit for the aviation community.

The FAA plans to develop safety information for pilots, including using videos from the tests to demonstrate to pilots what wake turbulence looks like and how it behaves.

The FAA, in conjunction with aviation representatives from around the world, recently developed a "Wake Turbulence Training Aid" (Report No. DOT/FAA/RD-95/6). This document and accompanying video provide a single source compilation of material related to the wake vortex characteristics that all pilots and air traffic controllers should be familiar with. The "Wake Turbulence Training Aid" may be obtained from: National Technical Information Service, Springfield, Virginia 22161.

The FAA also hopes to use the Model 727 at various airshows around the country to demonstrate wake turbulence to pilots.

Portions of this article were published previously in DOT Today, December 1995.

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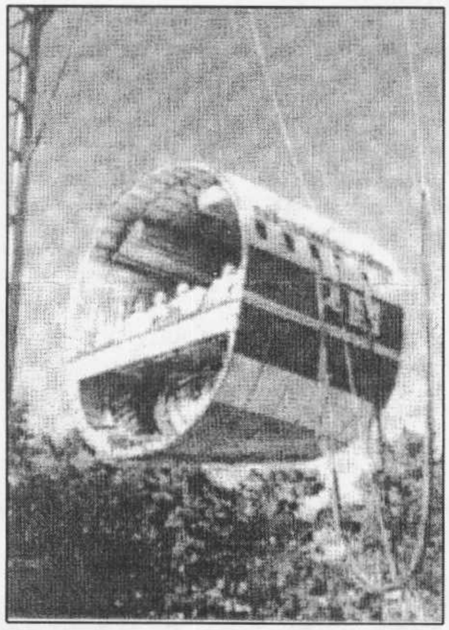
General News

Drop Test of Narrow-Body Fuselage



FAA Technical Report *"Vertical Drop Test of Narrow-Body Fuselage Section with Overhead Stowage Bins and Auxiliary Fuel Tank on Board,"* DOT/FAA/CT-94/116, April 1995, describes a vertical drop test of a narrow-body fuselage section that was conducted at the FAA's Technical Center's drop tower test facility. The test was structured to determine the impact characteristics of some typical items of mass installed aboard transport airplanes to assess the adequacy of the design standards and regulatory requirements for those components.

A primary objective of the test was to determine the dynamic response characteristics of the onboard stowage bins and auxiliary fuel tank systems, as well as the fuselage section itself, when subjected to a potentially survivable impact. The dynamic impact environment and the resultant response of the onboard overhead stowage bins and auxiliary fuel tank system were characterized. The structural support reactions for those onboard items of mass were measured and compared to predicted values that were based on static analyses and tests.

The test was intentionally structured to impose a dynamic load condition in excess of the current design and certification requirements for the onboard items of mass, so that the dynamic fracture loads and modes of fracture for those components could also be determined and evaluated. Bins from two manufacturers and a double-wall, cylindrical auxiliary fuel tank configuration were tested.

The vertical impact velocity for the drop test was 30 feet per second, which resulted in a test section average deceleration of 36 G_{max}. This is considered to be a severe, but survivable, impact. This caused from 4 to 20 inches of crush to the lower tapered fuselage section. There was no loss of habitable space in the cabin area.

Both overhead stowage bins experienced various degrees of attachment fractures. One bin type maintained its structural integrity and remained attached to the structure. The other bin experienced separations between the lower surface and vertical bulkheads. Both bins suffered fractures of their hinges and door locking mechanisms, which resulted in spilled contents.

The auxiliary fuel tank system remained firmly attached to its mounting system during and after the test. There was minimal distress to the cabin floor to which it was attached. The simulated fuel leaked slowly out of the tank after the test. The discharge line attached to the bottom of the tank was forced upward, rupturing the welds around the discharge line in both the inner and outer tank walls.

Compared to similar tests that had been conducted previously, the measured accelerations on the aircraft structure and bins were higher than expected. This was due to the auxiliary fuel tank installation, which prevented additional fuselage crushing, and thus, not allowing the fuselage to absorb additional impact energy. The same aircraft under the same conditions without the auxiliary tank would have experienced less impact force.

FAA Technical Report *"Vertical Drop Test of Narrow-Body Fuselage Section with Overhead Stowage Bins and Auxiliary Fuel Tank on Board,"* DOT/FAA/CT-94/116, is available at no cost. To obtain a copy, please contact:

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General News

Large Panel Tests Completed

The FAA recently completed a testing of a series of large scale aluminum panels containing multi-site damage. This test program was initiated at the National Institute of Standards and Technology (NIST) in Gaithersburg, MD, to test 90-inch wide panels. These panels are the largest structural panels that have ever been tested in tension.

The 90-inch panel gave a wide range of crack lengths (10.65 to 30 inches) in which failure was controlled by fracture mechanics parameters rather than plastic collapse.

Aircraft fuselages are designed to be crack-arrest structures. A fatigue crack may lead to a fracture but, up to the limit load, such a fracture will be arrested at the nearest tear strap or frame, or will turn in the circumferential direction. This results in flapping and a non-catastrophic decompression.

If, however, multiple site damage (MSD) develops in the fuselage, the crack arrest capability may be impaired. A fracture that normally would be arrested may continue past the arrester due to the presence of MSD. The wide-panel configuration was designed so that failure would be controlled by fracture mechanics parameters, not plastic collapse.

A total of ten panels were tested. The first three tests consisted of center-cracked panels with crack lengths of 14, 8, and 20 inches. The other seven tests consisted of panels with a center crack and various MSD configurations, as listed in **Table 1** on the following page.

The first three single crack tests were used to determine the basic material properties, that is, the tentative values of the collapse strength and the effective fracture toughness for the residual strength diagram, and an analytic expression for the R-curve. These results were then used in the analysis of the subsequent tests with MSD. Link-up of the MSD cracks was predicted using the plastic zone criteria based on the Irwin plastic zone size. There was fairly good agreement between the measured values and the results obtained from the models.

Further analysis will be conducted on the results form the test without buckling guides to assess the effects of the anti-buckling guides.

The final report on the testing will be available in the near future.

Test No.	Main crack	MSD cracks				
	2a (mm)	a (mm)	d_{MSD} (mm)	s_{MSD} (mm)	$2a_{MSD}$ (mm)	no. per side
1	355.6	177.8				
2	203.2	101.6				
3	508.0	254.0				
4	355.6	177.8	190.5	25.4	10.16	3
5	142.24	71.12	88.9	38.1	15.24	3
6	508.0	254.0	no anti-buckling guides			
7	508.0	254.0	266.7	28.1	12.7	5
8	482.6	241.3	266.7	38.1	12.7	10
9	254.0	127.0	165.1	25.4	10.16	10
10	508.0	254.0	266.7	38.1	12.7	5

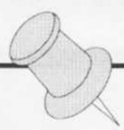
Table 1. Panel test configuration and results

Material for this article was published previously in NAARP News, published by FAA's Airworthiness Assurance R&D Branch, AAR-430, FAA Technical Center. ✠

General News

Advanced Materials Program

Two grants have been awarded recently for research identified by the FAA's R&D coordinating process as having high priority and being consistent with the *Aircraft Advanced Materials Program Plan*, DOT/FAA/CT-94/106, November 1994. The two grants are:



Grants Awarded!!

1. Probabilistic Program

Associated institution:
University of Texas at Arlington

Principal investigator:
Herbert William Corley, Jr.

Length: One year effort

- The grant objectives are focused on developing information on probabilistic design methodology that will ultimately lead to the formulation of acceptance criteria for this technique. Specific tasks consist of review and documentation of probabilistic design methodology, and development of a PC version of the Vought Probabilistic Analysis Program. The documented information will be widely disseminated and will facilitate broader understanding of probabilistic design within the aviation community as well as within the FAA.

2. Manufacturing and Inspection of Composite Structures

Associated institution:
Cerritos College

Principal Investigator: R. Price

Length: One year effort

- An extensive literature review will be conducted to compile methods and approaches for the manufacture and inspection of composite structures. The material will be used to update the FAA's *Handbook on Manufacturing and Repair of Fiber-Reinforced Composites.*

Material for this article was published previously in NAARP News, by FAA's Airworthiness Assurance R&D Branch, AAR-430, FAA Technical Center.

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Full-Scale Pressurization of B-737

A series of ground pressurization tests were conducted recently to measure the strain fields in a Boeing Model 737 airplane. The tests were conducted at the Aging Aircraft Nondestructive Inspection Validation Center (AANC), Albuquerque, NM, on their testbed Boeing 737-200 airplane. This B-737 was in service from August 1968 to February 1992, and had accumulated 46,358 cycles in 38,342 flight hours.

The most important structural feature pertinent to the pressurization test was that the lap splice joints were not altered with the *terminating action*. The *terminating action* is a remedial repair that entails the replacement of the shear head countersunk rivets with universal head rivets that have a larger shank diameter.

The cabin of the AANC airplane was pressurized to a maximum pressure differential of 6.5 psi to simulate the in-flight loads experienced by the fuselage skin and its supporting structure. Ninety-eight strain gages were mounted in five different lap splice bays on the fuselage of the airplane. Sections of the airplane above and below the windows, and forward and aft of the wing, were instrumented to study structural uniformity, effects of fuselage bending, and effects of different frame configurations. Strain gage measurements were recorded from 0 to 6.5 psi in 0.50 psi increments.

The strains in both the skin and the substructure were measured and compared to analytic predictions made using a finite element analysis. The strain gage data from the AANC B-737 test were also compared to other test data from full-scale panel tests conducted by Foster-Miller and B-737 pressurization tests conducted by NASA.

The strains measured in the curved, water-pressurized tests conducted by Foster-Miller were in reasonable agreement with the strains measured in the ground pressurization tests on the B-737. The strains from both the NASA and AANC pressurization tests were also in reasonable agreement.

Reasonable agreement also was obtained between the strain gage measurements and the analysis predictions. The AANC B-737 data agreed better with results from the riveted lap splice model than with those from the adhesive lap splice model. This suggested that the adhesive bond in the lap splice joint was no longer effective.

The nondestructive inspections (NDI) of the lap joints of the AANC B-737 were conducted as part of the benchmarking of the specimen. The detection of corrosion and disbonds confirmed the degradation of the adhesive bond in the lap splice joint. The structural effects of windows, floor beams, and fuselage bending on the strain fields were examined by comparing data among various lap splice test sections. The correlations revealed that the structural influence of windows and floor beams can increase strains from 4% to 46%. Furthermore, the fuselage body bending can increase strains by approximately 30%. Since the tests were conducted while the airplane was one the ground, the bending at the tail was probably more severe than if the airplane had been in flight.

The full report of this testing is contained in the FAA Technical Report, *"Strain Fields in Boeing 737 Fuselage Lap Splices: Field and Laboratory Measurements with Analytical Correlations,"* DOT/FAA/CT-95/25, June 1995.

This publication is available at no cost. To obtain a copy, please contact:

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New Engine Inspection Technology

A critical aspect of modern air transport is the jet engine, a complex engineered system that enables the rapid air travel to which we are accustomed. Aircraft engines are complicated engineered systems designed to operate at high stresses and temperatures. These stresses and temperatures can lead to in-service durability conditions that require management.

Nondestructive inspection, or NDI, which includes various techniques used to assess the health or integrity of a structure, component, or material is used to improve safety. However, the current state-of-the-art has limitations, as evidenced by the 1989 Sioux City crash, an event which was attributed to undetected hard alpha inclusions (material flaws).

Billet Defect Detection

The Engine Titanium Consortium (ETC) was established in 1993 to develop inspection tools for detection of material defects in jet engine titanium. ETC brings together the major U.S. engine manufacturers in a program to address safety-related issues, and to develop implementable tools for use by the billet producers, forgers, engine manufacturers, and airlines. Innovative approaches to billet inspection and in-service tools currently are under development by ETC participants, Iowa State University, and Pratt & Whitney.

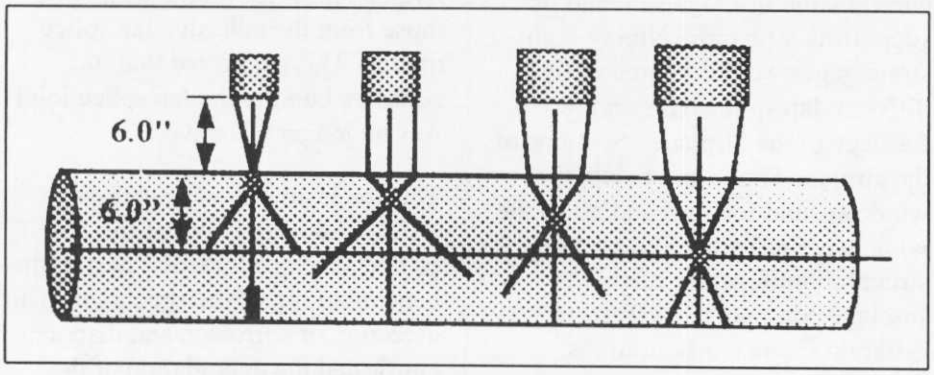
ETC is developing improved inspection techniques for application throughout the life cycle of engine rotating components that are fabricated from titanium. The first opportunity for inspection occurs at the billet phase. Titanium billets are typically 10 to 20 feet in length and 6 to 14 inches in diameter. ETC is developing "zoned approaches" to ultrasonic inspection that examine specific zones of a component. Two approaches are under evaluation are:

a. multiple discretely focused transducers (shown schematically in the drawing below) and
b. electronically-controlled, phased array transducers.

Both approaches divide the billet into multiple zones, providing a more sensitive inspection that is uniform throughout the billet diameter.

The multizone system has been implemented in the field and has demonstrated performance in billet production facilities. The phased array system may provide a more economical approach, since it uses a single transducer and thereby reduces hardware costs.

In a recent demonstration to the billet producers, ETC showed that the multizone system provides a four-fold improvement in sensitivity when compared to the traditional billet inspection methods. Additionally, the multizone inspection system recently detected a 1/4-inch hard alpha defect that was not detected by a conventional inspection method. Without the multizone inspection, that defective material would have moved forward in the production process and, if not



Multizone

detected by subsequent inspection processes, could have remained in the final engine component. This FAA-funded technology has demonstrated very effective performance in detection of hard alpha.

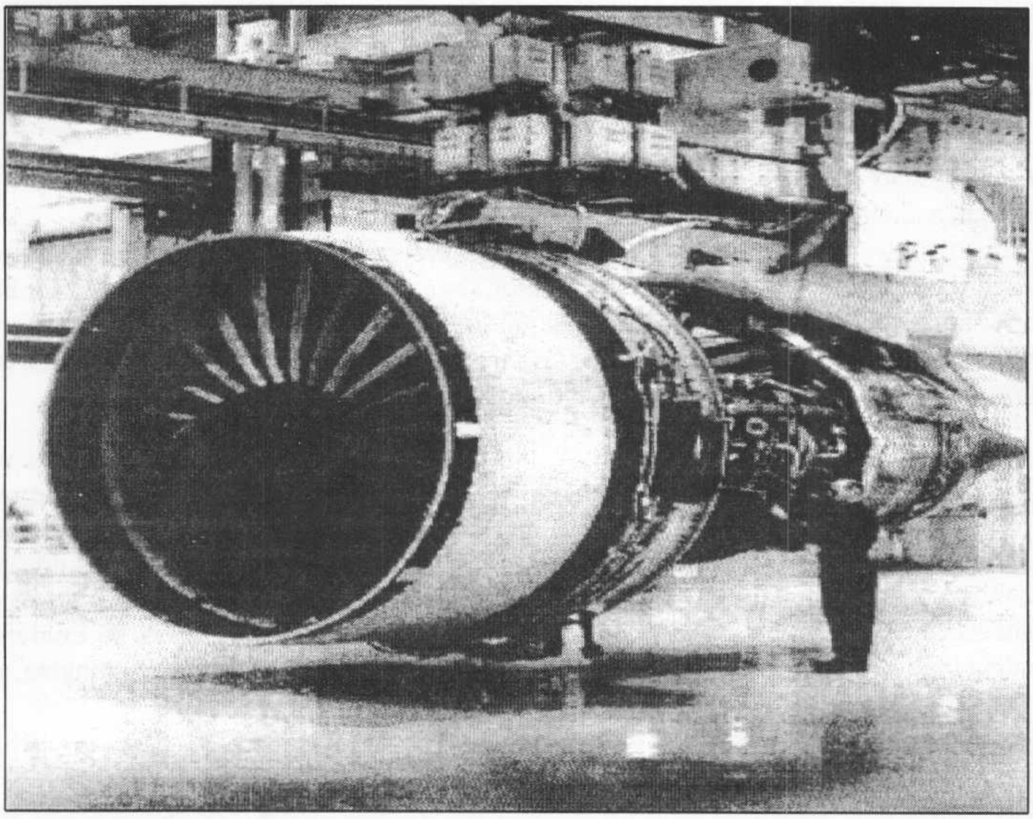
Eddy Current Tools

Eddy current is a standard technology that is used for detecting cracks in in-service components of aircraft engines. It uses electromagnetic waves to examine regions of interest. Cracks in the component change the electromagnetic field generated by the eddy current probe, much like metal objects signal an alarm in airport security systems.

Existing eddy current technology, used by the air carrier industry, involves the use of hand-held probes that are designed for particular applications. ETC has developed innovative, generic tools to improve the sensitivity of eddy current inspection. These tools are applicable across engine makes and models, providing the air carriers with more cost-effective tools for performing these types of inspections.

Eddy current technology innovations like computer data acquisition, signal processing, and controlled scanning have been implemented in manufacturing and defense overhaul centers. However, in the past, the cost of such innovations has prohibited their widespread implementation in field environments. ETC is focusing its efforts on developing cost-effective, implementable tools for the airline industry.

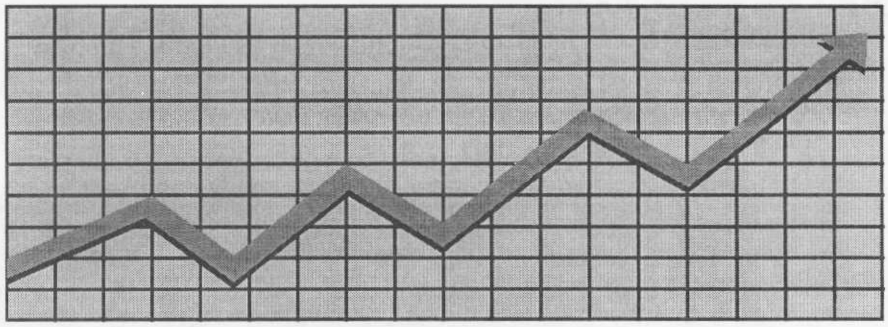
In September 1995, ETC demonstrated a portable scanner at the Air Transport Association Nondestructive Testing Forum. (Forum attendees included representatives from major U.S. carriers, the commuter industry, and third-party maintenance community.) The portable scanner was used to inspect the bore, or inner diameter, of a General Electric CFM-56 titanium disk. This inspection area was selected because it is a highly stressed region, and represents a likely area for use of the portable scanner.



Industry representatives were pleased with the efforts, and several airlines, including Northwest and United, will serve as beta test sites over the next several months. The portable scanner not only will be less expensive to use, but it also is expected to show a 70% improvement in detecting flaws when comparing its inspection results to hand-held scanners typically used in existing approaches.

Landing Loads Survey

In an effort to develop and implement corrective measures to make aircraft landings safer, the U.S. Navy has developed a system for tracking and analyzing aircraft approach and landing data.



Using a technology transfer partnership with the Navy, the FAA Technical Center has developed a four-camera multiplexed system that can view approximately 2,000 feet of runway, spanning the expected touchdown location for most commercial transports. This new video survey technology does not require the installation of any instrumentation on the aircraft, nor does it affect normal aircraft or airport operating procedures.

As part of the FAA's National Aging Aircraft Research Program, a joint FAA-Navy team is conducting a series of video landing load parameter surveys to collect data to characterize commercial transport landings. The initial survey was performed at JFK International Airport (New York) from June 20-30, 1994. This survey collected data on 1,030 landings, with approximately one-third wide-body jets, one third narrow-body jets, and one-third commuter aircraft.

A second survey was conducted at Washington National Airport (Washington, DC) from June 19-30, 1995, and recorded 1,060 landings, primarily of narrow-body jets.

The next survey will focus on collecting heavy wide-body jet aircraft landings.

These surveys will provide typical usage information describing commercial aircraft landing impact kinematics, including sinking speed, touchdown velocity, and pitch, roll, and yaw attitudes.

With over two-thirds of the data from the 1,030 landings at JFK processed, some trends have been observed: (This is only an initial data sample and the trends may not be typical of operations at other airports, or even other runways at JFK.)

The landing data collected at JFK show a strong correlation between aircraft sinking speed and the aircraft's touchdown location on the runway. The highest sink speed landings occurred within the first 1,200 feet from the runway threshold and could be related to the particular approach pattern for that runway of JFK. Further data, particularly on a runway with a different approach pattern, are needed to confirm this. There appears to be a trend towards higher sink rates at higher gross weights.

The observations made to date clearly warrant further investigation. Future video landing surveys will aid in addressing these and other issues.

A paper describing the video landing loads survey system and some preliminary results from the survey at JFK was presented at the International Society of Air Safety Investigators '95 Conference, held in Seattle, Washington, September 25-28, 1995.

The paper, entitled *"Landing Survey Discussions of Landing Parameter Data for Typical Transport Operations,"* was prepared by Terrence J. Barnes, Thomas DeFiore, and Richard Micklos.

Material for this article was published previously in NAARP News, published by FAA's Airworthiness Assurance R&D Branch, AAR-430, FAA Technical Center.

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FAA Policy Concerning Use of Dynamically Tested Seats in New or Modified Transport Category Airplanes

This policy replaces other policy previously issued on this subject.

Part 25 of the Federal Aviation Regulations (FAR) was amended by Amendment 25-64 to include a new section 25.562, entitled "*Emergency Landing Dynamic Conditions*." This section requires the passenger and crew seats in transport category airplanes to be designed and shown, by test, to protect each occupant during an emergency landing. In addition to showing the structural integrity of the seats and seat attachment structures, the tests must also show that occupants would not be subjected to more than specified upper torso, pelvis and lumbar loads and head injuries. Seats that comply with these criteria are frequently referred to as "*16g seats.*"

Airplanes for which the regulations incorporated by reference (frequently referred to as the "*original type certification basis*") include section 25.562, and derivatives of those airplanes, must comply with that section in any event. This article provides guidance concerning the inclusion of section 25.562 in the certification basis for changes to other airplanes.

The Aircraft Certification Service's position is that 16g seats save lives and that section 25.562 is one of those rules that manufacturers should be encouraged to incorporate in significant upgrades to their airplanes. Recognizing that airplanes intended for scheduled commercial service under FAR part 121 or part 135, and those not intended for scheduled commercial service, such as business airplanes, are subject to different economic constraints and passenger exposures, the FAA is recommending a higher level of compliance for the airplanes intended for scheduled commercial service.

With this in mind, each FAA Aircraft Certification Office (ACO) presented with an application for a change to an airplane intended for scheduled commercial service have been advised to evaluate the project in accordance with this memo. If appropriate, the ACO will propose to the applicant the addition of section 25.562 to the certification basis of the airplane. This will include both seat strength and passenger injury criteria.

In the case of airplanes not intended for scheduled commercial service, e.g., business airplanes, the ACO will evaluate the project in accordance with this policy. If appropriate, the ACO should propose that the airplane meet the strength requirements defined in sections 25.562(a), (b), (c)(7), and (c)(8).

Occupant injury criteria should also be applied; except that the head injury criteria need not be applied, provided that the applicant incorporates shoulder harnesses for all seats where head injury due to bulkheads or other structures are a concern. (Note that protection of occupants from injury is required by section 25.785(b), regardless of whether compliance with the occupant injury criteria of section 25.562 is required.)

FAA Order 8110.4A, Section 14(c), gives examples of a number of changes to airplanes which should be evaluated in determining the certification basis. Additional guidance is provided in draft Advisory Circular (AC) 20-ICPTF, Appendix A. This material identifies the magnitude of a particular change which would be considered substantial, significant, or non-significant. Those projects that include changes which are substantial require new Type Certificates. Several of the changes identified as significant directly involve the cabin, specifically those involving fuselage length, diameter changes, and increase in passenger cabin capacity. These changes should result in a seat upgrade, although full compliance with section 25.562 might be waived as discussed below. Other significant changes in isolation should not result in a requirement for 16g seats.

However, if a project involves a number of significant changes, these changes should be evaluated in combination. It may well be that the changes, in total, result in sufficient change to the aircraft that production life is significantly extended and it is appropriate to include 16g seats in the requirements. Multiple significant changes should be discussed with the Transport Airplane Directorate's Transport Standards Staff, which is charged with maintaining standardization on this issue.

Amended Type Certificate changes listed as non-significant and supplemental type certificate changes need not have the seat upgrade.

While AC 20-ICPTF is still in draft form, it is a product of the Aviation Rulemaking Advisory Committee (ARAC) and was therefore developed in a public process. It will be used as guidance material while formal rulemaking proceeds. After a final rule and AC are issued, this policy will be reviewed.

Applicants for changes not requiring a seat upgrade to airplanes intended for revenue service, or applicants for whose projects the cost of full compliance with section 25.562 cannot be justified, should be made aware of the modular nature of the 16g seat rule: Where imposition of the entire regulation may be prohibitively expensive, careful application of ***particular*** requirements can still yield sizable benefit.

At the same time, applicants should be advised that the FAA is proceeding with an amendment to FAR part 121 that would require retroactive installation of 16g seats in existing transport category airplanes used in air carrier service. If this amendment is promulgated, their customers will realize some benefits from the previous installation of seats meeting the strength requirements of section 25.562. It might therefore be in their best interest to install seats that meet at least the strength portion of section 25.562. In that regard, the applicants should be encouraged to watch for publication of the new amendment in the ***Federal Register***.

If the guidance discussed above suggests that 16g seats should be required on a specific project, the ACO should make a strong case to the applicant for the inclusion of the later requirements. The Transport Airplane Directorate will work with the ACO in development of logical arguments, consulting with other interested parties in the FAA, as necessary. The intent of this exercise is to make the applicant consider the pros and cons of compliance, and to make an informed decision as to whether or not to volunteer compliance. The FAA believes that manufacturers will opt for the later requirements, in most cases, when they address the long-term benefits of compliance.✠

Policy and Guidance

In-Flight Beta Lockout Systems

The FAA has been undertaking a review of a number of incidents and accidents, involving turbopropeller-powered airplanes, in which there has been evidence of intentional or inadvertent operation of the propellers in the beta range during flight.

"*Beta*" is the range of propeller pitch settings intended for use during taxi, ground idle, or reverse operations, as controlled by the power lever settings aft of the flight idle stop.

Sections 23.1155 and 25.1155 ("*Reverse thrust and propeller pitch settings below the flight regime*") of the Federal Aviation Regulations (FAR) state:

> *"...each control for ... propeller pitch settings below the flight regime must have a means to prevent its inadvertent operation. The means must have a positive lock or stop at the flight idle position and must require a separate and distinct operation by the crew to displace the control from the flight regime..."*

Generally, compliance with this requirement has been accomplished by the installation of a stop or detent that requires a separate and distinct action by the pilot (such as lifting the power levers up and beyond the stop) to displace the power levers from the flight regime.

Despite the requirements of FAR 23.1155 and 25.1155, the FAA has received at least fifteen reports over the last seven years of incidents or accidents, all involving airplanes equipped with turboprop engines, in which the propeller control was intentionally or inadvertently displaced from the flight regime into the beta range during flight.

Of those fifteen in-flight "beta events," five have been classified as accidents. The (in-flight) beta operation that preceded these accidents has resulted in two distinct types of unsafe conditions:

1. Permanent engine damage and total loss of thrust on all engines when the propellers that were operating in the beta range drove the engines to overspeed; and
2. Loss of airplane control because at least one propeller operated in the beta range during flight, inducing high rolling and yawning moments.

In the most recent accident, both engines of a Saab Model SAAB 340B series airplane permanently lost power after eight seconds of operation with the propellers in beta range. The propellers subsequently drove the engines into overspeed. This engine overspeed condition caused extensive internal engine damage, which prevented both engines from being restarted.

In this example, the airplane was substantially damaged during an emergency landing (without engine power).

One of the means used currently on certain airplanes to prevent the pilots from obtaining beta during flight is a "*beta lockout system*".

This is an electro-mechanical system that typically uses air-ground (squat) sensor logic, wheel spin-up, radar altimeter, gear-up switch activation, or combinations of these to activate (or deactivate) a solenoid that physically blocks the power levers from being retracted beyond the flight idle stop and prevents the selection of beta in flight.

The FAA currently is considering issuing airworthiness directives that would require the design and installation of in-flight beta lockout systems on all turbopropeller equipped airplanes certified in the transport category under FAR part 25; as well as on all turbopropeller equipped airplanes certified in the commuter category under FAR part 23, Special Federal Aviation Regulation (SFAR) 23, and SFAR 41.

In order to make a determination if this proposed action is appropriate to prevent future occurrences of in-flight beta operation on airplanes powered by turboprop engines, the FAA is planning to hold a public meeting later in the summer of 1996 to solicit comments from the public about the proposed means of action and the supporting beta lockout system certification criteria.

(The exact time and location of the meeting has not yet been determined.)

The FAA will evaluate all comments and ideas submitted from the public, and will determine whether any type of rulemaking is actually warranted, and if the certification criteria that is proposed is adequate or if it should be modified.

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Engine Oil System Independence

The purpose of this article is to explain FAA policy relative to the determination of compliance with the provisions of FAR section 25.1011, "Oil System". The Transport Airplane Directorate was requested to provide an interpretation of this regulation with regard to what was intended by the requirement for independent oil systems, and whether it was acceptable for accessories to share oil with the engine system.

Section 25.1011 requires:

"*Each engine must have an independent oil system that can supply it with an appropriate quantity of oil at a temperature not above that safe for continuous operation.*"

The regulatory history shows that the requirement was stated within Civil Air Regulation (CAR) Part 4a, dated November 1, 1947, as follows:

"Each engine shall have an independent oil supply. The oil capacity of the system shall be at least 1 gallon for every 25 gallons of fuel but shall not be less than 1 gallon for each 75 maximum (except takeoff) rated horsepower of the engine or engines. A special ruling concerning the capacity will be made by the Administrator when oil may be transferred between engines in flight or when a suitable reserve is provided. The suitability of the lubrication system shall be demonstrated in flight tests in which engine temperature measurements are obtained. The system shall provide the engine with an ample quantity of oil at a temperature suitable for satisfactory engine operation."

The Transport Airplane Directorate considers that the intent of the requirement for independent oil systems was relative to engine independence and that the FAA would consider the acceptability of transferring oil between engines. The rule was not intended to preclude using engine oil for other engine accessories, but merely to require separate, independent oil systems for each engine.

This interpretation is consistent with the wording of section 25.1027, "Propeller Feathering System," which states:

"*If the propeller feathering system depends upon engine oil, there must be a means to trap an amount of oil in the tank if the supply becomes depleted due to failure of any part of the lubricating system other that the tank itself.*"

This wording indicates that it is acceptable to use engine oil for the propeller system. Based on current application of the rule, the engine oil can be shared with engine accessory systems, provided sharing of engine oil with accessories does not result in an unsafe feature.

The requirement for a separate propeller feathering sump provides a good example of a case where sharing of the oil could result in an unsafe design feature. An oil leak in an engine/propeller shared system could result in the need to shutdown the engine, and also could cause loss of propeller feathering capability.

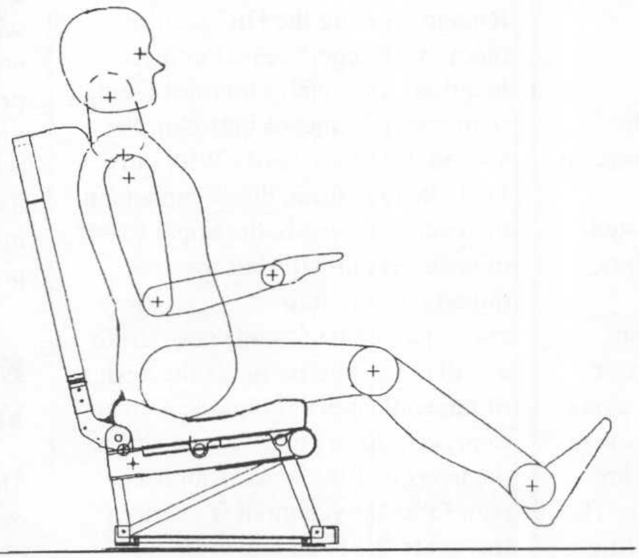
The interrelationships between the functions of shared oil system components should be reviewed to validate that no unsafe feature is created by sharing of the oil.

Although the regulatory basis of section 25.1011 does not preclude sharing of engine oil with accessories, sharing of engine oil may affect compliance with other regulations. For example, the reliability of the auxiliary power unit (APU) or engine may be affected if failure of the accessory caused engine shutdown. Any reliability data, particularly for use in Extended Range Twin-Engine Operations (ETOPS) approvals, should include the effects of accessories on engine shutdown rates. The Part 33 engine block runs should include actual operation of all accessories that could impact durability or operability. In addition, care should be taken to assess the impact of accessory operation on the required oil cooling/heating capabilities.

If you have any questions on this subject or need more information, please contact ***Michael Dostert*** *of the FAA's Transport Standards Staff, Airframe and Propulsion Branch, at (206) 227-2132, or fax (206) 227-1100.*

Policy and Guidance

Developments in Head Injury Protection For Airline Passengers



By VAN GOWDY
Biodynamics Research Section, CAMI

Crash injury protection is an important topic of public interest. Automobile advertisements market safety features as a motivation to buy a particular model. Auto manufacturers spend millions of dollars on television advertisements that show crash tests and point out how well the dummies riding in the car were protected. Consumer publications and the news media closely monitor the crash testing of new car models and report which cars provide the best protection from injury in an accident.

Less publicized but equally significant are improvements for crash injury protection that have been developed for airplanes. Federal Aviation Regulations (FAR) now require seats in new aircraft to be tested under simulated impact conditions. In addition to the structural integrity of the seat, the results of the tests must satisfy requirements to provide protection from serious injuries to the occupants head, spine, chest, and legs. These regulations are in effect for small aircraft, large transports, and rotorcraft.

The requirement for head injury protection is often the most difficult of the criteria to meet. In an aircraft accident, head injury can occur due to impact of an occupant's head with interior surfaces such as the instrument panel, forward row seat backs, and wall structures in the cabin. Seats located behind walls require special consideration for the head protection problem. This article addresses research that has occurred at FAA's Civil Aeromedical Institute (CAMI) in Oklahoma City, Oklahoma, on a variety of methods that provide head protection for passengers seated behind walls in transport aircraft.

Background of Dynamic Impact Tests

The airworthiness regulations for large transport aircraft are contained in FAR Part 25.562. Among other things, Part 25 requires seats on new aircraft to withstand a 16 G horizontal impact test to demonstrate crashworthiness performance. In layman's terms, the sled test for a

Part 25 seat is similar to a vehicle traveling 44 feet per second (30 mph), being subjected to a frontal crash event, coming to a complete stop in 0.2 seconds, and stopping within a distance of about 45 inches. During the crash, the deceleration forces on the seat peak above 16 Gs. This means each occupant and the seat experience forward horizontal forces equal to 16 times their respective weight.

In contrast to automobile crash tests, aviation regulations adopted in 1988 do not require the entire airframe of an aircraft to be tested. Only the seat, occupant restraints, and some of the surrounding structures are subjected to a controlled impact test. The results of these impact tests must demonstrate that the seat can withstand the crash loads when occupied by an anthropomorphic test dummy (ATD). The ATD used for airplane seat testing is the size of an average adult male weighing 170 pounds. They are similar to the ones used in automobile tests. Crash data recorded from sensors within the ATD must be within specified human injury tolerance values. Thus, the design and installation of seats and restraint systems must combine the disciplines of structural design and biomechanics.

Head Protection

The method measuring potential head injury in an impact test is known as the Head Injury Criteria (HIC). This is the same method used by the automobile industry. Accelerometers mounted within an ATD record the severity of impacts to the head as it hits any of the surrounding airplane furnishings on the test sled. A computer program then processes the head acceleration data to produce an HIC value. That value must be less than 1,000 for the seat to be certified. A HIC value above 1,000 indicates that serious head injury is likely.

Passenger seats located behind a cabin wall, such as those near a class divider, lavatory, or galley, present difficult installation problems in meeting the HIC requirement. Passengers seated in these locations are usually forward facing with about 35 inches between the seat back and the wall. With only lap belts to restrain the occupants in the event of a crash, the upper torso of each person will flail forward quickly during impact. In a severe crash, passengers' heads may strike a wall at high velocity. If the design of the wall does not include a means to prevent head contact or to absorb the energy of the impact, an occupant faces the potential for serious trauma to the skull and brain.

Moving the seats far enough away from the wall would alleviate the problem of head impact, but this would cause the loss of a row of seats, which is economically unacceptable to the airlines. Providing shoulder straps on these seats is another option. This would require a significant change in the design of a passenger seat. Placing seats behind walls in the rear facing position would prevent the high velocity torso motion into the wall, but would require the development of crashworthiness aft facing seats. Aft facing seats at various locations in the cabin would also require a change in the conventional interior arrangement for passenger seating.

Realistic Means of Protection

Transport aircraft operators prefer solutions to the HIC requirement that do not change traditional cabin layout practices or the seat-occupant interface. In other words, passengers and crew members would not notice any significant change in the cabin. CAMI has studied concepts that have the possibility of being deemed "acceptable." Through cooperative research arrangements with the Boeing Company and an engineering subcommittee comprised of Air Transport Association members, the Biodynamics Research Section of CAMI conducted impact sled tests to evaluate various means of providing head impact protection.

Energy Absorbing Wall Pad

The first method investigated is perhaps the simplest and most obvious: adding energy absorbing material to the walls in areas of potential head strikes. This would reduce the force of impacts to the head. However, due to the high velocity of head impact developed during a 16 G sled test, the shock absorbing properties of the material "pad" on the wall must be carefully selected. Biomechanical considerations require the material to crush or deform in a predictable manner, with no elastic or spring-like properties. The pad must be thick enough to allow the head to penetrate into the material until the energy of the impact is dissipated. From a practical standpoint, the material should be lightweight and durable. The FAA regulations also will require the material to meet fire and evacuation requirements. These are demanding criteria.

A variety of material pads have been evaluated in this project. Pad materials developed for the automobile interior did not produce acceptable results in airplane seat tests. The most successful results thus far come from a common material found in airplane structures: aluminum honeycomb. The pad is constructed of a light-weight honeycomb panel with hexagonal cells made from aluminum foil. A variety of different crush strengths and panel sizes are available from the manufacturer, Hexcel.

Sled tests with simulated seat-behind-wall installations were conducted with honeycomb panels on the wall to absorb the head impact energy. HIC values of less than 700 have been achieved using this concept. However, the depth of the pad must be at least 4 inches. The inconvenience of such a pad protruding from the wall, plus aesthetic problems, are two of the drawbacks with this method. Durability and maintenance are two unknowns that must be addressed for practical considerations.

Articulating Seat Pans

A second method of head impact protection being developed can be characterized as a "crash controlled seat pan." Basically, when impact forces occur, the seat pan (i.e., the metal frame beneath the cushion) rotates and pitches forward. Highly complex computer modeling techniques have been applied to determine how much the seat pan will move and the resulting effect on the occupant's head motion. This concept has undergone extensive development by the aviation seat industry during the past three years. CAMI has conducted tests with seats designed to demonstrate this concept. The results were promising. In fact, United Airlines selected articulating seats for specific cabin rows in the initial deliveries of the new Boeing 777.

Air Bags

Air bags are standard equipment in many new models of automobiles. The auto industry has refined air bag technology over many years of biomechanics research. The expertise and manufacturing capabilities are readily available, but air bag applications for airplanes have yet to be developed.

The minimal effect on the traditional cabin layout makes air bags has desirable features for airplane installations. Changing the existing seat or restraint systems may not be necessary. The air bag equipment could be mounted flush with the wall without aesthetic tradeoffs or intrusion into the cabin.

Other properties of air bags are more complicated. Location of the crash sensor on the airframe is critical for sensing a crash and deploying the air bag. Analysis and verification of the crash sensor location may be very complex, especially on large aircraft. Air bag systems require electrical power and structural support at a precise mounting location on the wall. Air bag deployment is often an explosive event, igniting powerful pyrotechnics and gas generation to fill the bag. Precise deployment must be achieved to insure the airbag functions as an injury protection system and not a cause of injury. Maintenance procedures, system reliability checks, and evacuation problems must be addressed. Development of air bag equipment must address these issues.

CAMI conducted a series of sled tests with wall-mounted air bags as part of a research program on head impact protection. Unlike automobile air bags, some of the air bags tested by CAMI were large air bag systems--big enough to protect a double- or triple-wide seat installation. Some of the prototype air bags performed well: They successfully deployed during impact; the bags pressurized before the ATDs moved forward; and, the ATDs' heads were restrained from striking the wall. Various size of test dummies, including small females as well as large male size dummies, were used in the airbag tests to evalutate the effectiveness of airbags.

Airbags for small airplanes and rotorcraft are also under development. The systems designed for the confined enviroment of a small airplane will probably be similar to automobile airbags.

Research and Development Proceeds

Each of the three methods described above has its own advantages and disadvantages. Test results so far indicate that satisfactory performance is achievable with each method. Incorporating laboratory concepts into real world applications, however, has just begun, and economic and operational factors have not been fully evaluated.

Different methods to reduce the likelihood of serious head injuries will likely be included in airplanes of the future. Of course, the ultimate assessments of the performance of these methods can only be made by careful analysis of data

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Simplified Procedure for Addressing the Head Injury Criteria of FAR 25.562

With the adoption of Amendment 25-64 to add section 25.562 ("*Emergency Landing Dynamic Conditions*") of the Federal Aviation Regulations (FAR), quantified human tolerance parameters were introduced into the regulations for the first time. One of these human tolerance parameters is the ***head injury criterion (HIC)***. The HIC has proven to be one of, if not the most, onerous aspect of the regulation.

The regulations require that the potential for head injury be assessed, if the head can contact airplane interior structure when exposed to the test conditions specified in section 25.562. If head contact occurs, the HIC must be calculated, and must be less than 1000 units. In the case of repetitive rows of seats, determining the critical area for head injury potential on a seat back can be difficult, and can often result in several tests, just to determine a critical case. This procedure is very expensive, and in most cases unnecessary. However, many applicants lack the data to make an analytical assessment to define a minimum set of tests, and are therefore forced to conduct many tests. The procedure defined in this article will help serve to minimize testing.

One of the aspects of compliance that has been somewhat contentious is the consideration of a "*range*" of occupant heights for HIC. The dynamic test requirements specify the type of test dummy to be used. This dummy represents the approximate stature of a 50th percentile male. This does not mean that only the 50th percentile male is of concern from a head injury standpoint. In fact, section 25.785(b) ("*Seats, berths, safety belts, and harnesses*") requires that a "*person*" be protected from serious injury under the condition specified in section 25.562. The dynamic test provides the means for making the assessment, but does not change the fundamental requirement to protect each occupant. Historically, we have used a range of occupant heights from the 5th percentile female to the 95th percentile male as a reasonable envelope for consideration. Advisory Circular 25.562 - 1 alludes to the need to consider other occupants, but does not specify or suggest a means for doing so. This lack of methodology has resulted in poor standardization in application of the requirement.

In an effort to reduce the regulatory burden, and simplify/clarify the procedure for demonstrating compliance, the FAA has developed the procedure described in the following portion of this article. This procedure should allow demonstration of compliance for HIC with two tests in the majority of cases. The procedure takes into account seat pitch, the relative position of the seat and the row behind it as well as range of occupant sizes.

The intent of this procedure is to provide default conditions that can be used in lieu of conducting several tests, or performing lengthy analytical studies. It is recognized that this procedure will not account for every eventuality. The purpose, however, is to provide for reasonable test conditions that meet the intent of the requirements, without causing excessive testing to be performed.

This procedure previously was distributed at the Public Meeting on Dynamic Testing of Seats, that was held in Seattle in October 1995. Comments received from participants at that meeting have been considered in the final issuance.

Seat-to-Seat Installation Tests for Compliance with the HIC in Transport Airplanes

The following is a set of criteria for use in evaluating HIC with "default" parameters. These criteria can be used to standardize the approach to seat-to-seat HIC, and should enable seat-to-seat HIC for the majority of seats to be addressed in only two tests. The general guidelines are based on a typical passenger seat, although the philosophy could be applied to any seat for which it was valid to do so.

Head Strike Envelope:

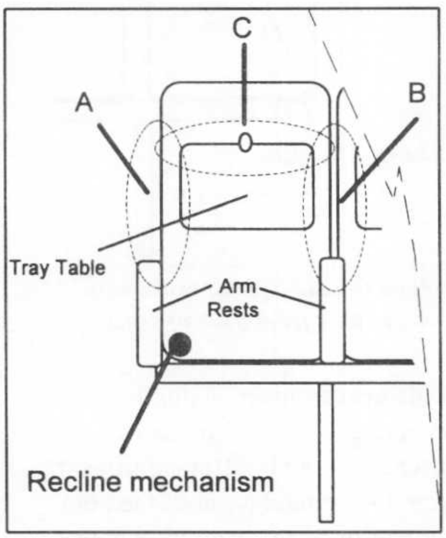
All dynamic tests and HIC evaluations are to be conducted with a 50th percentile male anthropomorphic test dummy as defined in 25.562. The head strike envelope includes the three dimensional space through which the ATD's head may traverse when tested in accordance with the dynamic conditions defined in 25.562. This three dimensional space includes the ATD's head path which occurs during the vertical test as well as the horizontal-yaw test conditions defined in 25.562 (although the horizontal condition typically produces the critical head path). Since the head of the ATD is a three dimensional object, the head strike envelope encompasses the path of all points defined by the surface of the ATD's head. This includes the back of the head. The head strike envelope for the horizontal-yaw test condition (Test 2) includes the path through which the ATD's head may traverse when tested with a yaw angle of Ø, -10 < Ø < +10 degrees.

Structures Within The Head Strike Envelope:

If the head strike envelope results in head contact with a structure located on or in the vicinity of the seat installation in an aircraft, the HIC requirement in 25.562 must be demonstrated by test(s). There are some seat-to-seat installation practices which are common to contemporary aircraft, and general guidelines on certification test procedures can be defined. The following examples describe how the various factors affecting the seat-to-seat HIC result can be addressed in the test(s) protocol.

Seat-to-seat HIC, Double Row Horizontal-Yaw Tests:

Head Strike Zones. Due to the dynamic deflection of the forward row seat back during the impact test, it is usually difficult to accurately predict exactly where the aft row seated ATD's head will strike the seat back. The typical seat back



Head strike zones (view from back of seat)

has three areas that are considered head strike zones within the +/- 10 degree yaw range of impact orientation. These are illustrated in Figure 1, below. Note the recline mechanism is on the left side of the seat back in this illustration. The recline mechanism can affect the stiffness of the seat back on the side it is located (Zone A.) Thus, head impact must be evaluated on both the left and right (Zone B) sides of the seat back. The third area of potential head impact is the center of the seat back (Zone C), which may include areas on the seat back containing a tray table, telephone handsets, or video displays.

Since it is common for the recline adjuster mechanism to be positioned on the left side of some seat backs and the right side of others of the same assembly, the seat-to-seat HIC test for Zones A and B can usually be accomplished in one double row test using two instrumented ATD's in the aft row, with the yaw angle set to effect a head strike in Zone A by one ATD and Zone B by the other. Alternatively, it may be possible to relocate one adjuster mechanism **for test purposes**. In addition, properly documented developmental test data, that indicate that one condition or the other is more critical, could be used to justify head impact on only one side of the seat.

Seat Pitch. The range of intended seat pitch for a particular model of seat should be defined in the certification test plan. The HIC assessment test(s) should include, as a minimum, head impact responses for the three head strike zones described above. As a general rule, head impact in Zones A and B is likely to be more severe as the seat pitch increases. This is because the head will strike the seat back at a lower point and will be more likely to contact the arm rest structure. Thus, the maximum intended seat pitch should be evaluated in the critical yaw orientation (within the +/- 10 degree envelope) with head impacts directed at Zones A and B.

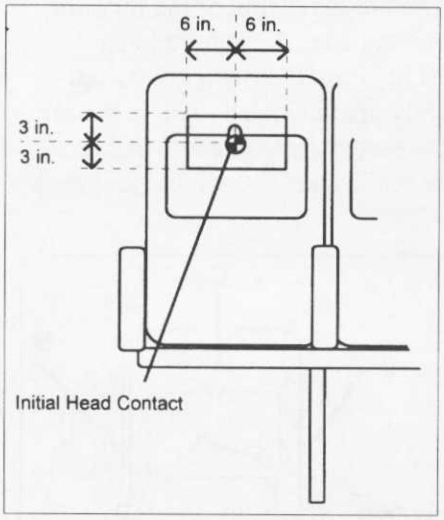
Another general rule can be applied to head strike Zone C. The severity of head impact in the middle of the seat back can be affected by the tray table and its latch mechanism.

Also, convenience items such as telephone handsets or video displays in the vicinity of the tray table may be contacted by the ATD's head. To assess the severity of head impact in Zone C, an impact test should be conducted at the minimum intended seat pitch in a 0° yaw (no yaw) impact orientation.

Thus, the seat pitch range for a particular model of passenger seat can be certified in a minimum of two tests. The maximum pitch is tested in the yaw orientation with head impacts directed at Zones A and B. The minimum pitch is tested in 0° yaw with head impact in Zone C. Note that this is based on a typical passenger seat, that has an essentially homogeneous contact area across the seat back, in Zone C. Designs that differ from this might require an additional test(s), if the contact surfaces are not consistent.

Occupant Height. Although the seat-to-seat HIC tests do not require evaluating head impact with a range of different size ATD's, the strike zone near the center of the seat back (Zone C) may contain significantly different structures within the close proximity of the head contact area for a 50th percentile ATD. For example, at the minimum seat pitch, a 50th percentile ATD may barely miss a telephone handset installed above the tray table. Under the same impact condition, a taller occupant's head may contact the handset. Likewise, a 50th percentile ATD's head may strike the seat back above the tray table, whereas a shorter occupant's head may strike the top edge of the tray, which may be worse.

In order to provide a consistent level of head impact protection in Zone C for a range of occupant height, it is necessary to examine an area on the seat back near the initial contact point of the 50th percentile ATD's head on the seat back. As a minimum, a rectangular area on the seat back centered at the 50th ATD's initial head contact point must be evaluated. As shown in Figure 2, below, the area to be evaluated is a 6 x 12-inch rectangle centered on the initial head contact point of the 50th percentile ATD.



Zone C head contact evaluation area (view from back of seat).

If the head contact evaluation rectangle in Zone C includes structures which differ significantly from the contact point of the 50th percentile ATD, an additional test may be necessary. Conversely, if there are data available to predict the contact point of the 50th percentile ATD, these may be used to select the critical test condition, as the initial test in lieu of the zero degree test discussed above. The relative position of the seats in a double row setup must be adjusted to produce head contact with a 50th percentile ATD on the area of concern. Vertical adjustment of the seats' relative position will ensure that a comparable head impact velocity as that measured from the normal position Zone C test is achieved, although other methods that achieve the same objective are acceptable. As a general rule, additional tests are only required if the head contact evaluation rectangle contains rigid items (such as telephone handsets, video screens, and oxygen mask container units.) Areas which are less rigid than the initial contact point within the evaluation rectangle do not require additional tests.

Airplane Taper Section. HIC evaluations in the taper sections of the airplane may be conducted with the seat(s) in the normal position without simulating the floor track yaw angle due to taper. The lateral offset between rows of seats in a taper section may be neglected (e.g. the double row HIC tests may be conducted with no lateral offset) if the lateral offset of the cabin installation is less than 6.0 inches. Note, structural tests of seats installed in the taper section must be conducted *with* the additional yaw angle due to taper.

Staggered Seating. Seats that are staggered (resulting in more than 6-inch offset) due to a change in the number seat-places for example, should be addressed considering the actual installation. This may prove to be the critical evaluation for the airplane installation, if contact with armrests or other hard structure occurs. Such an installation may supersede the "Zone A & B" evaluations discussed earlier. Consideration of such installations should still be possible within the framework of a two-test program, provided that the basic designs are the same.

Forward Row Seat Setup. It is acceptable to conduct the double row seat-to-seat HIC test(s) with

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Aircraft Self-Induced Electromagnetic Interference

By JOHN PIERRE DIMTROFF
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Jefferson Approach: *"Calypso Air Flight, descend and maintain 2,000, turn left heading 210."*

Calypso Air Flight 266: *"Roger, Jefferson Approach, out of 5,000 for 2, left heading 210."*

Jefferson Approach: *"Calypso Air 266, turn left heading 270, maintain 2,000 until estabilished on the Sawmill localizer. Contact Sawmill tower on 120.0 MHz when ILS capture. Do you have current ATIS Bravo?"*

Calypso Air Flight 266: *"Left to 270, maintain 2,000 until ILS capture, Sawmill tower 120.0 MHz when estabilished on ILS. Have ATIS Bravo? Calypso 266. G'day."*

Jefferson Approach: *"G'day Calyspo 266."*

[Calypso 266 First Officer tunes #2 VHF radio to 120.0 MHz and switches it from standby to active status. At the point of frequency changeover, both pilots hear loud tones and squeals in headsets.]

Captain of Calypso 266: *"What's going on? I can't hear anything but load screeching in my headset!"*

First Officer: *"Same with mine. Does someone out there have their mike keyed, or is that coming from us?"*

Captain: *"Don't know. Try calling Sawmill ATC."*

First Officer: *"Sawmill Tower, Calypso Air 266, how do you read?"*

[No response from Sawmill Tower. Loud squeal still in headsets.]

Captain: *"Switch back to Jefferson Approach and inform them of the problem."*

First Officer: *"Jefferson Approach, Calypso Air 266 back with you. Unable to contact Sawmill Tower on 120.0, receiving loud tones, sounds like stuck mike or something."*

Jefferson Approach: *"Roger Calypso 266, you're the fourth one today with the problem. Contact Sawmill on ground control frequency 121.8."*

First Officer: *"Going to Sawmill Ground 121.8. Calypso 266."*

First Officer: *"Sawmill Ground, Calypso Air 266, inside outer marker at 1,200 ft., unable to use tower frequency 120.0. Have visual contact runway 27."*

Sawmill Ground Control: *"Roger, Calypso 226. In sight, cleared to land. Reain this frequency. Taxi to terminal."*

First Officer: *"Roger, Sawmill Ground. Going to terminal. Calypso Air 266, g'day"*

Unlikely scenario? Not really! The scenario described above is one that is showing up with greater frequency due, in part, to the proliferation of modern

It is this concern -- the electromagnetic compatibility between installed avionics/electronic systems -- that we write this article. Self-induced "jamming" of communications and navigation equipment resulting from on-board electromagnetic emissions may not even be known until a specific frequency or frequencies are tuned in. In the case of Calypso Air 266, the source of interference was the result of harmonics in the air data computer (ADC) radiating "on channel" (120.0 MHz). The problem wasn't known until the pilot tuned its VHF receivers to 120.0 MHz, at which time the jamming was detected. In this particular case, an 8 MHz clock frequency, used for the microprocessor timing, was the source of the EMI. As it turns out, the 15th harmonic of 8 MHz, or 120.0 MHz, is the exact frequency of Sawmill Tower's local control. *(See Figure 1.)*

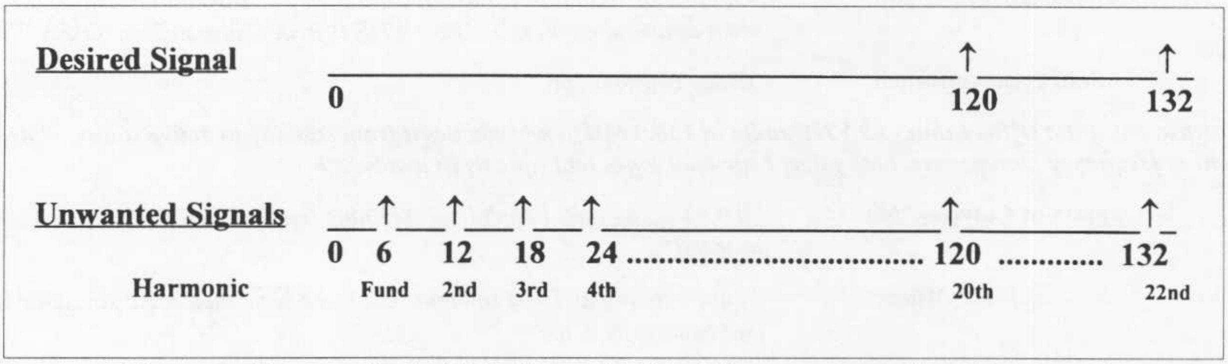

Figure 1. Frequencies in MHz (Note: 6 MHz=Microprocessor Clock Frequency)

Although the digital system (in this case, the air data computer) was not designed to produce emissions at the 15th harmonic, it nonetheless did. And even though the emissions were at a very low level in the installed configuration, they were significant enough to sneak into the RF world of the VHF receiver and show up as unexpected, and unwanted, EMI.

Federal Aviation Regulations sections 25.1301, 25.1309, and 25.1431 require that any installed electrical equipment meets its intended function, and that one avionics system does not interfere with another. As depicted in the above scenario, several aircraft types of recent digital design have experienced sufficient levels of internally-generated EMI to render some communications and navigation systems unusable on certain frequencies. This is inspite of the rigorous equipment tests required by many system Technical Standard Orders (TSO). A TSO is an FAA minimum performance standard for specified articles used on civil aircraft. Of the many TSO's applicable to avionics equipment, several call out the use of RTCA Document No. RTCA/DO-160 (latest version), "*Environmental Conditions and Test Procedures for Airborne Equipment*." Most avionics systems, though not all, are required to meet some level of the "*Emissions*" portion of DO-160, Section 21. This is a good first step in minimizing any unwanted RFI/EMI, but meeting the DO-160 performance specifications may not, in itself, provide adequate protection from unwanted RF.

One problem arises when testing system line replaceable units (LRU) to specific limits. Depending on the criticality of the LRU, DO-160 may allow the LRU to radiate signals at levels, which, in an isolated environment, may not be problematic. However, when the unit is in its installed configuration, it may subject nearby system components to undesirable levels of RF. The RF may show up as a radiated field, or conduction in cables or grounds. The point here is that intersystem electromagnetic compatibility (EMC) requires thoughtful design and testing techniques to ensure the equipment enjoys interference-free performance.

Careful consideration must also be given to the installation itself. Improper installation practices can become root causes of EMI/RFI problems, causing costly modifications or changes to equipment long after delivery of the aircraft. Modern noise suppression techniques, such as RF filters, double or triple shielded cables, RF protected connectors, and special airframe grounding/bonding techniques can help assure that the installation is "quiet". The routing of a VHF antenna feed line in the vicinity of an LRU radiating the 15th harmonic of the 8 MHz clock frequency may prove to be too easy a path for the 120.00 MHz resultant signal.

Chapter 3.2.2, "*Interference Effects,*" of RTCA Document DO-186a "*Minimum Operational Performance Standards for Airborne Radio Communications Equipment Operating Within the Radio Frequency Range 177.975 - 137.000 MHz*" states that:

"The equipment shall not be the source of harmful conducted or radiated interference and shall not be adversely affected by conducted or radiated interference from other equipment or systems installed in the aircraft."

DO-186a goes on to state:

"Electromagnetic compatibility problems noted after installation of this equipment may result from such factors as design characteristics of previously installed systems or equipment, and the physical installation itself. It is not intended that the equipment manufacturer design for all installation environments. The installing facility will be responsible for resolving any incompatibility between this equipment and previously installed equipment in the aircraft."

Intersystem EMC has, and will continue to be, a concern to today's commercial aircraft fleet. Given the rich RF environment the aircraft operate in, it behooves system designers, integrators, and installers to be aware of RF compatibility issues. Ensuring that each system/subsystem is as "quiet" as possible early on in the design phase will help to prevent costly changes or modifications once they are installed and operating.

Finally, more comprehensive test procedures are needed to verify that, prior to aircraft delivery, all VHF navigation and communication channels are functional and available to the pilot! The process begins with the avionics manufacturers, and carries through to the airframe manufacturers, and lastly to the customers/operators. Each has a role to play in assuring the aircraft systems are functional, reliable, and capatible.

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Policy and Guidance

FAA's Unapproved Parts Policy Statement

Suspected unapproved aircraft parts, commonly referred to as *"SUPs,"* have been a concern of the FAA, the aviation industry, and the flying public for some time. Determined to eliminate the potential risk these parts pose to aviation safety, the FAA convened a Task Force comprised of experts to conduct a thorough review of the SUPs issue, taking into account concerns that had been expressed both within Congress and the Department of Transportation's Office of the Inspector General regarding SUPs.

Working from a vision *"to promote the highest level of aviation safety by eliminating the potential risk posed by the entry of 'unapproved parts' in the U.S. aviation community,"* the Task Force proposed a series of recommendations. Two of these recommendations that fell into the category of *immediate action* were: (1) establish an FAA National SUPs Program Office, and (2) clarify the FAA's policy on SUPs.

On November 13, 1995, the FAA's National SUPs Program Office was officially opened. In December 1995, FAA Administrator David Hinson issued the following policy statement:

Unapproved Parts Policy Statement

It is the policy of the Federal Aviation Administration to eliminate the potential safety risk posed by unapproved parts in the U.S. aviation system by:

- Conducting aggressive and consistent surveillance for suspected unapproved parts.
- Investigating thoroughly and expeditiously when suspected unapproved parts are detected or reported.
- Responding with rapid and uniform enforcement when unapproved parts are found.
- Providing a sound regulatory basis and associated guidance for FAA personnel and the public.
- Coordinating FAA efforts with law enforcement agencies engaged in the prosecution of criminal activity.

Policy and Guidance

Unauthorized Markings on the Face of Supplemental Type Certificates

Transport Canada (which is the airworthiness authority of Canada) has advised the FAA that some Supplemental Type Certificate (STC) holders in the United States are marking or stamping the face of their STC with a "proprietary right" statement. This action by STC holders apparently is intended to control aircraft serial numbers for which their proprietary data can be used for modification installations. The "proprietary right" statements caution against unauthorized duplication of the modification.

Neither the FAA nor Transport Canada support this practice.

Such marking and alteration to the face of the STC is misleading, since it gives the impression that the approved STC also contains the statement and, thus, is sanctioned by the FAA. If the original STC document is altered, it would be a violation of law, as stated on the STC Form 8119-2.

In view of this, STC's should *NOT* be marked, stamped, or altered after being issued by the FAA. Any proprietary notices or instructions, furnished with STC kits or data, should be attached as a separate document. It should be made clear that the document has been added by the STC holder or representative and is not part of the STC approval.

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Rulemaking

Recently Issued FAA Rulemaking

Advisory Circular (AC) 25.562-1A, "Dynamic Evaluation of Seat Restraint Systems and Occupant Protection on Transport Airplanes"

- Issued January 19, 1996.

This AC, developed by the Seat Test Harmonization Working Group of the ARAC, provides information and guidance regarding acceptable means of compliance with part 25 of the FAR applicable to dynamic testing of seats intended for use in transport category airplanes. The AC provides background and discussion of the reasoning behind the test procedures. It also describes the test facilities and equipment necessary to conduct the tests.

Amendment 25-86, "Revised Discrete Gust Load Design Requirements"

- Issued February 2, 1996.
- Published February 9, 1996

This amendment to part 25 of the Federal Aviation Regulations (FAR) revises the gust load design requirements for transport category airplanes. This amendment replaces the current discrete gust requirement with a new requirement for a discrete tuned gust; modifies the method of establishing the design airspeed for maximum gust intensity; and provides for an operational rough air speed. These changes are made in order to provide a more rational basis of accounting for the aerodynamic and structural design characteristics of the airplanes. These changes also provide for harmonization of the discrete gust requirements with the Joint Aviation Requirements (JAR) of Europe as recently amended.

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Aviation Rulemaking Advisory Committees (ARAC): Update of Activities

The Aviation Rulemaking Advisory Committees (ARAC) are formal standing committees, comprised of representatives form aviation associations and industry. Established by the FAA Administrator in 1991, ARAC provides industry input in the form of information, advice, and recommendations to be considered in the full range of FAA rulemaking activities. (This is a regular feature of the ***Update***.)

Flight Test Working Group

Working Group Chair:
Jerry Zanatta, Boeing

Task 1 - *AIA/AECMA Petition for Rulemaking:* Make a recommendation to the ARAC Transport Airplane and Engine Interest Group concerning the disposition of the joint Aerospace Industries Association of America, Inc. (AIA), and Association Europenne des Constructeurs de Material Aerospatial (AECMA) petition for rulemaking dated May 22, 1990. More specifically, these issues relate to harmonization of the strength of pilots table of maximum control forces and associated advisory material; harmonization of FAR/Joint Airworthiness Regulations (JAR) maneuverability requirements and associated material; and harmonization of the minimum control speed requirements of the FAR/JAR. [FAR sections 25.143(c), 25.143(f), 25.149, 25.201]

Status: *Amendment 25-84 to FAR part 25 was adopted June 2, 1995, and published in the* ***Federal Register*** *on June 9, 1995 (60 FR 30744). This task is considered to be* ***completed.***

Task 2 - *Gate Requirements for High Lift Devices:* Recommend to the ARAC simplified and clarified requirements related to gate positions on the control used by the pilot to select the position of an airplane's high lift devices.

Status: *At the January 28-29, 1996, ARAC meeting on transport airplane and engine issues, a draft notice of proposed rulemaking, as well as changes to Advisory Circular (AC) 25-7, "Flight Test Guide for Certification of Transport Category Airplanes," were approved for transmittal to the FAA.*

Task 3 - *Flight Characteristics in Icing Conditions*: Recommend to the ARAC new or revised requirements and compliance methods related to airplane performance and handling characteristics in icing conditions.

Status: *The fourth meeting on this subject was held in February 1996. The airworthiness authorities proposed rule changes in Subparts B and F of FAR Part 25 to better reflect the operation of modern transport category airplanes. New interpretive material was proposed that will be integrated with advisory material developed thus far; this material is based on the JAA Notice of Proposed Amendment (NPA) 2JF-219, "Flight in Icing Conditions -- Acceptable Handling Characteristics and Performance Effects."*

Loads and Dynamics Harmonization Working Group

Working Group Chair:
Vic Card, Civil Aviation Authority (CAA), United Kingdom

Task 1 - *General Design Loads*: Develop new or revised requirements and associated advisory and guidance material for the general design loads for transport category airplanes (FAR sections 25.331, 25.335, 25.341, 25.345, 25.351, 25.371, 25.427, 25.483, 25.511, 25.561, 25.963, and other conforming changes).

Status: *Amendment 25-86 was issued on February 2, 1996. Awaiting publication in the* ***Federal Register***.

Task 2 - *Engine Torque and Gyroscopic Loads:* Develop new or revised requirements and associated advisory and guidance material for determining the design loads for engine seizure conditions (FAR sections 25.361, 25.371, and other conforming changes).

Status: *The Working Group is in the initial drafting stages of this recommendation.*

Task 3 - *Flutter, Deformation, and Fail-Safe Criteria:* Develop new or revised advisory and guidance material for flutter, deformation, and fail-safe criteria (FAR section 25.629).

Status: *Working Group is in the initial drafting stages of this recommendation. Initial FAA legal and inter-Directorate coordination has taken place.*

Task 4 - *Interaction of Systems/ Structure:* Review existing special conditions for fly-by-wire airplanes and existing requirements for control systems, including automatic and/or power-operated systems, and recommend any new or revised general requirements needed for flight control systems and structures affected by those systems (FAR sections 25.302, 25.671, 25.1329, Part 25 Appendix K).

Status: *Economic evaluation was received December 12, 1995. The summary portion of this evaluation is currently being incorporated into the notice of proposed rulemaking document. Review by the Working Group will be solicited, followed by FAA legal approval.*

Task 5 - *Continuous Turbulence Loads:* Review the requirement for the continuous turbulence standard in light of the ARAC proposal for a tuned discrete gust requirement in order to determine whether the continuous turbulence requirement should be revised or removed from the FAR/JAR for better consistency with the new proposed tuned discrete gust criteria [FAR section 25.305(d)].

Status: *The Working Group is in the initial drafting stages of this recommendation.*

Task 6 - *Strength and Deformation:* Review the recent requirements adopted in the FAR by Amendment 25-77 (for the design of transport airplanes against buffet and forced structural vibrations) and consider appropriate changes for the JAR and FAR to harmonize these rules [FAR sections 25.305(e) and (f)].

Status: *The Working Group is in the initial drafting stages of this recommendation.*

Task 7 - *Design Flap Speeds:* Review the current flap design loads requirements to resolve differences in interpretation between the FAA and the JAA concerning the structural design stall speeds on which the flap design speeds are based. Recent measurements of gust speeds at low altitudes, where flaps are normally extended, indicate a more severe gust environment may be present. Review all aspects of the flap design load requirements, including the design airspeeds, vertical and head-on design gust criteria, and the effects of automatic retraction and load relief systems [FAR section 25.335(e)].

Status: *The Working Group is reviewing issues.*

Task 8 - *Residual Strength Loads for Damage Tolerance:* Review the differences in residual strength design load requirements between the FAR and JAR and resolve differences to harmonize this rule. Prepare a Notice of Proposed Rulemaking (NPRM) or make recommendations to other ARAC efforts concerning FAR section 25.571, so that they can be included in rulemaking that may be forthcoming from those efforts [FAR section 25.571(b)].

Status: *The Working Group is reviewing issues.*

Task 9 - *Shock Absorption Tests:* Review the changes recently introduced into the JAR that have resulted in differences between the FAR and JAR in regard to the requirement for shock absorption tests. Review those changes in view of harmonizing the FAR and JAR {FAR section 25.723(a)].

Status: *The Working Group has developed an initial draft, and the document is currently undergoing FAA inter-Directorate coordination.*

Task 10 - *Rough Air Speed:* The ARAC has proposed a new section 25.1517 concerning rough air speed design standards in its proposal for a tuned discrete gust requirement. This action is harmonized with the current JAR 25.1517; however, further changes in the rough air speed requirement may be needed in both the FAR and JAR. Review

JAR 25.1517 and the new proposed FAR 25.1517 to determine if further changes are needed [FAR section 25.1517)].

Status: *This project is in the early planning stage.*

Task 11 - *Taxi, Takeoff, and Landing Roll:* Prepare an advisory circular that establishes criteria that may be used to calculate rough runway and taxiway loads, as required by FAR sections 25.491, 25.235, and 25.305.

Status: *This project is in the early planning stage.*

Task 12 - *Braked Roll Condition:* Review the provisions of section 25.493 of the FAR and JAR concerning the braked roll condition and finalize a harmonized notice of proposed rulemaking.

Status: *On November 6, 1995, the ARAC forwarded to the FAA a recommendation consisting of a draft NPRM for publication in the **Federal Register**. This document should be published in the **Federal Register** by June 1996.*

General Structures Harmonization Working Group

Working Group Chair:
Herb Lancaster, Boeing

Task 1 - *Bird Strike Damage:* Develop new or revised requirements for the evaluation of transport category airplane structure for inflight collision with a bird, including the size of the bird and the location of the impact on the airplane (FAR sections 25.571, 25.631, and 25.775).

Status: *The Working Group has prepared a draft NPRM. Initial FAA legal and inter-Directorate coordination has taken place. Alternatives are to be discussed at the next meeting of this Group..*

Task 2 - *Safe Life Scatter Factor*: Develop recommendations for new or revised advisory and guidance material concerning the safe life scatter factors (FAR section 25.571).

Status: *The Working Group has developed a change to advisory circular (AC) 25.571-1A, "Damage-Tolerance and Fatigue Evaluation of Structure." This change addresses the evaluation of scatter factors for the determination of life for parts categorized as safe-life. This document is currently in the final stages of coordination within the FAA internal team.*

Task 3 - *Proof of Structure:* Review FAR section 25.307, corresponding paragraph 25.307 of the JAR, and supporting policy and guidance material, and recommend to the FAA appropriate revisions relative to the issue concerning limit load tests, ultimate load tests, and structural testing for harmonization, including advisory material (FAR section 25.307).

Status: *The Working Group is reviewing issues.*

Task 4 - *Material Strength Properties and Design Values*: Review FAR section 25.613, corresponding paragraph 25.613 of the European JAR, and supporting policy and guidance material, and recommend to the FAA appropriate revisions for harmonization, including advisory material (FAR section 25.613).

Status: *The Working Group is reviewing issues.*

Task 5 - *Damage Tolerance and Fatigue*: Review FAR section 25.571, and corresponding paragraph 571 of the JAR and supporting policy and guidance material and recommend to the FAA appropriate revisions for harmonization including advisory material (FAR section 25.571).

Status: *The Working Group is reviewing issues.*

Powerplant Installation Harmonization Working Group

Working Group Chair:
Bruce Housberger, Boeing
Wim Overmars, Fokker

Task 1 - *Installations (Engines):* Develop recommendations concerning new or revised requirements for the installation of engines on transport category airplanes and determine the relationship, if any, of the requirements of FAR section 25.1309 to these engine installations (FAR section 25.901).

Status: *The Working Group is in initial drafting stages of this recommendation.*

Task 2 - *Windmilling Without Oil:* Determine the need for requirements for turbine engine windmilling without oil (FAR section 25.903).

Status: *Awaiting completion of work by Engine Harmonization Working group. It is antici-*

pated that no change will be needed in part 25, and the JAA will delete JAR 25.901(e).

Task 3 - *Non-Contained Failures*: Revise advisory material on non-contained engine failure requirements (FAR section 25.903; related provisions of FAR parts 23, 27, 29, 33, and 35, as appropriate; AC 20-128). The Working Group should draw members for this task from the interests represented by the General Aviation and Business Airplane and Rotorcraft Interest Groups.

Status: *The Working Group has completed review and approved a revised AC. The FAA is scheduled to publish a Notice of Availability (of this AC) during the first quarter of 1996. The Task Group also is studying several complex issues that may result in yet another AC revision.*

Task 4 - *Thrust Reversing Systems:* Develop recommendations concerning new or revised requirements and guidance material for turbojet engine thrust reversing systems (FAR section 25.933).

Status: *The Task Group has developed a preliminary draft NPRM(and NPA, the JAR counterpart) and draft AC (and ACJ, the JAR counterpart), which was presented to the Working Group for review.*

Task 5 - *Auxiliary Power Unit (APU) Task Group:* Develop harmonized installation requirements for APU's (all applicable FAR part 25 requirements).

Status: *The Task Group has developed a preliminary draft NPRM, which is currently in review internally.*

Task 6 - *Engine In-Flight Restart Task Group:* Develop harmonized engine restart compliance methodology to address normal and engine restart (i.e., all-engine power loss).

Status: *This task is in the process of being approved for assignments to the Task Group.*

Seat Testing Harmonization Working Group

Working Group Chair:
Dean Klippert, Douglas Aircraft

Task: Make recommendations to the ARAC Transport Airplane and Engine Interest Group concerning the requirements and guidance material for the certification of flightcrew seats and the associated test conditions (FAR section 25.562; AC 25.562A).

Status: *AC 25.562-1A, was issued by the Transport Airplane Directorate on January 19, 1996. This Working Group action is considered **closed**.*

Cargo Standards Harmonization Working Group

Working Group Chair:
Dean Klippert, Douglas Aircraft

Task: Make recommendations to the ARAC Transport Airplane and Engine Interest Group concerning new or revised requirements for main deck Class B cargo compartments, a subject which has recently been coordinated between the FAA and JAA.

Status: *The Working Group is in the initial drafting stages of this recommendation.*

Direct View Harmonization Working Group

Working Group Chair:
Dean Klippert, Douglas Aircraft

Task: Review the proposed guidance material contained in FAA draft AC 25.785 for finding compliance with the cabin attendant's direct view requirements of FAR section 25.785, and make recommendations to the ARAC Transport Airplane and Engine Interest Group for new or revised guidance (FAR section 25.785; AC 25.785).

Status: *The Working Group's recommendation is being evaluated by ARAC for next action.*

Hydraulic Test Harmonization Working Group

Working Group Chair:
Jim Draxler, Boeing

Task: Make recommendations concerning new or revised requirements for hydraulic systems and the associated test conditions for hydraulic systems installed in transport category airplanes (FAR section 25.1435).

Status: *The FAA accepted the ARAC recommendation (NPRM and AC) and a principals briefing was held on February 16, 1996.*

Systems Design and Analysis Harmonization Working Group

Working Group Chair:
Ed Schroeder/Jean-Claude Boquet

Task: Develop guidance material concerning the evaluation and control of certification maintenance requirements created to satisfy the requirements of FAR section 25.1309 for newly certificated transport category airplanes.

> **Status**: *ARAC recommendation was forwarded to the FAA July 14, 1994; AC 25-19 was issued by the FAA on November 28, 1994. This Working Group action is considered* ***completed.***

Airworthiness Assurance Working Group

Working Group Chair:
Ron Wickens, Federal Express

Task 1 - *Structural Modifications*: Conduct periodic reviews of manufacturer service bulletins to determine whether new or revised structural modifications or inspections should be instituted and made mandatory as the airplane ages beyond its original design life goal. This review should cover the following airplanes: Airbus A-300, British Aerospace BAe 1-11, Boeing B-707, B-727, B-737, B-747, Douglas DC-8, DC-9/MD-80, DC-10, Fokker F-28, and Lockheed L-1011.

> **Status**: *This action is considered* ***completed.***

Task 2 - *Corrosion:* Develop recommendations concerning whether new or revised requirements and compliance methods for corrosion prevention and control programs should be instituted and made mandatory for the Airbus Model A300, British Aerospace BAC 1-11, Boeing Models 707, 727, 737, and 747; McDonnell Douglas Models DC-8, DC-9, DC-9-80 series, and DC-10; Fokker Model F-28; and Lockheed Model L-1011.

> **Status**: *Airworthiness Directive (AD) actions have been completed for all models. Action on this task is now considered* ***completed*** *by the Working Group.*

Task 3 - *Repairs*: Develop recommendations concerning whether new or revised requirements and compliance methods for structural repair assessments of existing repairs should be instituted and made mandatory for the Airbus Model A300, British Aerospace BAC 1-11, Boeing Models 707, 727, 737, and 747; McDonnell Douglas Models DC-8, DC-9, DC-9-80 series, and DC-10; Fokker Model F-28; and Lockheed Model L-1011.

> **Status**: *The Working Group has developed a draft NPRM and associated advisory circular, which are currently under review by the FAA internal team.*

Task 4 - *Structural Fatigue Audit:* Develop recommendations on whether new or revised requirements for structural fatigue evaluation and corrective action should be instituted and made mandatory as the airplane ages past its original design life goal.

> **Status**: *The Working Group's recommendation, in the form of a draft revision to AC 91-56, "Structural Fatigue Evaluation for Aging Airplanes," was forwarded to the FAA on July 14, 1994. This document is currently under review within the FAA.*

Task 5 - *Supplemental Structural Inspection Document*: Conduct a review of existing supplemental structural inspection programs to determine whether any new or revised requirements should be instituted and made mandatory as the airplane ages past its original design life goal. This review should cover the following airplanes: Airbus Model A300, British Aerospace BAC 1-11, Boeing Models 707, 727, 737, and 747; McDonnell Douglas Models DC-8, DC-9, DC-9-80 series, and DC-10; Fokker Model F-28; and Lockheed Model L-1011.

> **Status**: *ARAC review of this issue is considered* ***completed.*** *Manufacturers are completing final documents.*

Braking Systems Harmonization Working Group

Working Group Chair:
Bob Amberg, Boeing

Task: Recommend to the ARAC new or revised requirements for approval of brakes installed on transport category airplanes. The product of this exercise is intended to be a harmonized standard, acceptable to both the FAA and the JAA.

> **Status**: *The working group has completed and is reviewing a*

preliminary draft Technical Standard Order (TSO). Work on draft regulatory language (NPRM and AC) continues.

Performance Standards Working Group

Working Group Chair:
Jay Anema, Boeing

Task 1: - The Performance Standards Working Group is charged with making a recommendation to the ARAC Emergency Evacuation Interest Group concerning whether new or revised standards for emergency evacuation can and should be stated in terms of safety performance rather than as specific design requirements. Specifically, the working group should address the following issues as a minimum:

- Can standards stated in terms of safety performance replace, supplement, or be an alternative to any or all of the current combination of design and performance standards that now address emergency evacuation found in Parts 25 and 121 of the FAR.
- If a performance standard is recommended, how can the FAA evaluate a minor change to an approved configuration, or a new configuration that differs in either a minor or a major way from an approved configuration.

Task 2: The Performance Standards Working Group is charged with making a recommendation to the ARAC Emergency Evacuation Interest Group concerning new or revised emergency evacuation requirements and compliance methods that would eliminate or minimize the potential for injury to full scale demonstration participants.

Status: *The Working Group developed a Recommendation in response to Task 2. An NPRM, Notice No. 95-9, was published in the* ***Federal Register*** *on July 18, 1995. The period for public comment on the notice closed on October 16, 1995. The FAA representative on the Working Group is reviewing public comments that were submitted.*

Additional information concerning ARAC activities can now be obtained through the Internet at (800) 322-2722 or (202) 267-5948. The information available features current ARAC information, including a full listing of all working groups, their leaders, their members, and their tasks. Also included is a calendar of ARAC meetings, and contact points for those who wish to become involved in the process.

More information on the system is available by calling FAA's Washington D.C. headquarters at (202) 267-3345.

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Publications and Media

New Publications Available

The following reports are available from the:

- National Technical Information Service, Springfield, Virginia 2216; and
- FAA Technical Center in Atlantic City, New Jersey, by contacting **C. A. Bigelow**, telephone:
  (609) 485-6662
  FAX:
  (609) 485-4569
  e-mail:
  cathy_bigelow_at_ct27@admin.tc.faa.gov

"An Analysis of Ground-Flight Loads Measure on the Instrumented B-727, N40," Report DOT/FAA/AR-95/82, October 1995, by William Cavage, Tom DeFiore, and Terence Barnes. This report describes an analysis of data collected on a Boeing Model 727 airplane that is owned and operated by the FAA Technical Center.

"Nondestructive Inspection of Piper PS-25 Forward Spar Fuselage Attachment Fitting," Report DOT/FAA/AR-95/51, September 1995, by David G. Moore. This report describes an ultrasonic test procedure that was developed to identify the material thinning in a forward spar fuselage attachment fitting of a Piper Model PA-25 airplane.

"A Methodology for the Economic Assessment of Nondestructive Evaluation Techniques Used in Aircraft Inspection," Report DOT/FAA/AR-95/101, November 1995, by Vanessa Brechling. This report details a methodology for the economic evaluation of emerging nondestructive inspection methods applicable to aircraft inspections.

"Validation of the Magneto-Optic/Eddy-Current Imager," Report DOC/FAA/AR-95/100, November 1995, by Vanessa Brechling and Floyd Spencer. This report describes the validation analysis of the Magneto-Optic/Eddy-Current Imager, including both a reliability analysis of the systems and an economic analysis of the potential benefits and costs related to its use.

"Corrosion of Aluminum Alloys in the Presence of Fire-Retardant Aircraft Interiors Materials," Report DOT/FAA/CT-94/110, October 1995, by Drs. Talia and Chaudhuri. This report consists of an evaluation of the potential for fire-retardant materials commonly used in aircraft interiors to cause corrosion of aluminum structural alloys.

"Corrosion of Fire-Damaged Aircraft," Report DOT/FAA/CT-94/89, April 1995, by William Westfield. This report describes an investigation of the possible connection between a fire, extinguishing the fire, and a subsequent increase in the incidence of corrosion.

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Service Difficulty Report Data Available

A proof of concept investigation has been launched to assess the public demand for Service Difficulty Report (SDR) data in an interactive data base format. In support of this effort, an abridged SDR data base is now available for public access by users of personal computers (with modems).

Selected data fields from each SDR record are included in the data base. Currently, about eight months of SDR data are available (more than 22,000 records). This service is free of charge, but access is limited at this time to one telephone line, so please limit your time on-line.

The following instructions are provided for the accessing the data:

Connecting via modem by telephoning: **(405) 954-2025**

User ID:	**CIVIL**
Password:	**SDR**

After logging on, select **"O"** ODR Data on the main menu. Begin your search by selecting one of the following criteria:

ACMODEL	*aircraft model*
ENGMODEL	*engine model*
PROPMODEL	*propeller model*
ATA	*ATA code*
ORDATE	*difficulty date in YYMMDD format*
PTMFGNO	*manufacturer's part number*
OPERDESIG	*4 character operator designator*
DISTOFF	*4 character identifier for FAA district office*

After selecting the initial search criteria, you will be prompted for a condition. Choices are:

EGL	*equal to*
GTR	*greater than*
GEQ	*greater than or equal to*
LSS	*less than*
LEG	*less than or equal to*

After the condition is selected, you will be prompted for the comparison value. For example, if you are interested in SDR's submitted for Cessna Model 172N airplanes:

- enter *criteria* **ACMODEL**,
- enter *condition* **EQL**, and
- enter *172N* for the comparison value.

Continued on page 67

Certification Implications of the Aeronautical Telecommunications Network: A Safety Case

By TOM KRAFT
FAA, Aircraft Certification Service

Summary

This article comprises a paper that was presented by Mr. Kraft to the 2nd meeting of the International Civil Aviation Organization (ICAO) Aeronautical Telecommunication Network Panel (ATNP) working group in Toulouse, France, on March 20, 1995. It proposes to use safety analyses methods to address the implications of certification during development of Standards and Recommended Practices (SARPs) for the communication, navigation, and surveillance/air traffic management (CNS/ATM) packages. The safety analyses methods would provide substantiation of decisions that directly affect the design of the aeronautical telecommunication network (ATN), the distributed data applications, and the overall system architecture. These decisions would take the form of high-level safety requirements or safety objectives. That part of the safety analyses, which is accomplished during SARPs development, would support the validation of SARPs and the intent is that each state gives credit to safety analyses activities performed at the SARPs level to minimize the safety analyses activities performed for each specific implementation. This paper presents the underlying philosophy for addressing the safety aspects of systems and equipment installed on aircraft and proposes a framework for applying that philosophy to the SARPs activities. These safety aspects apply directly to the airworthiness approval and operational authorizations for aircraft and the commissioning of air traffic services within each state.

The ICAO ATNP working groups accepted the recommendations outlined in this paper.

1.0 Introduction

This paper proposes to use safety analyses methods to address the implications of certification during development of Standards and Recommended Practices (SARPs) for the communication, navigation, and surveillance/air traffic management (CNS/ATM) packages. The safety analyses methods would provide substantiation of decisions that directly affect the design of the aeronautical telecommunication network (ATN), the distributed data applications, and the overall system architecture. These decisions would take the form of high-level safety requirements or safety objectives. That part of the safety analyses, which is accomplished during SARPs development, supports the validation of SARPs and the intent is that each state gives credit to safety analyses activities performed at the SARPs level to minimize the safety analyses activities performed for each specific implementation.

This paper presents the underlying philosophy for addressing the safety aspects of systems and equipment installed on aircraft and proposes a framework for applying that philosophy to the SARPs activities. These safety aspects apply directly to the airworthiness approval and operational authorizations for aircraft and the commissioning of air traffic services within each state.

The methods proposed in this paper substantiate decisions made during SARPs development in the context of assessing hazards associated with the communications infrastructure and the distributed data applications for the ATN. Particular design features, architecture, and development assurance methods can be used to adequately preclude failure modes from contributing to hazards. The safety analysis would provide substantiation, a means to identify specific safety requirements contained in the SARPs, and ensure adequate treatment of those requirements during implementation (i.e., that there is an acceptable level of assurance that implementations satisfy safety requirements).

Additionally, the safety analysis would ensure that the SARPs provide a viable solution to implementing the ATN and application processes from a certification perspective as systems containing parts that are highly integrated, complex, and non-deterministic may be impractical to certify if their characteristics are not addressed in the overall system architecture.

1.1 Scope

This paper discusses the following topics and proposes a means for their consideration during SARPs development:

a. **Definition of functionality**. Methods for determining minimum performance for safety critical systems.

b. **Definition of integrity and availability**. Methods for considering hazards and failure conditions of functions in safety critical systems. Determines minimum integrity and availability.

c. **System architecture, design features, and development assurance**. Methods for treatment of complexity and non-determinism in safety critical systems.

d. **"End-to-end" safety and interoperability assessment**. Methods for treatment of aircraft/ground interaction of safety critical systems.

To clarify the intent of the safety analysis, as applicable to SARPs development, examples are included as they relate to the definition of the CNS/ATM-1 package.

1.2 U.S. Activity

The FAA is developing guidelines for conducting safety analyses on ground/space system implementations for systems it owns and operates or services it acquires.

This activity is based on the methods currently employed within the aircraft certification community to evaluate systems and ensure adequate protection against the effects of failure conditions leading to known hazards to the aircraft.

Although the FAA has certified aircraft with data communication capabilities that are currently being used for certain air traffic services (ATS), the Boeing 747-400 Flight Management Computer System (FMCS) Future Air Navigation System One (FANS-1) package, provided the main thrust behind the FAA's development of Notice 8110.50, "*Guidelines for Airworthiness Approval of Airborne Data Link Systems and Applications*," dated April 20, 1994. The notice provides a means to account for failure conditions, which exist outside the aircraft and which could contribute to the cause of known hazards; however, its scope is limited to the airworthiness approval of the aircraft and only provides a means to support an "end-to-end" safety assessment, not to perform it. **Figure 1-1**, taken from Notice 8110.50, outlines the scope of the airworthiness approval process and its relationship to other

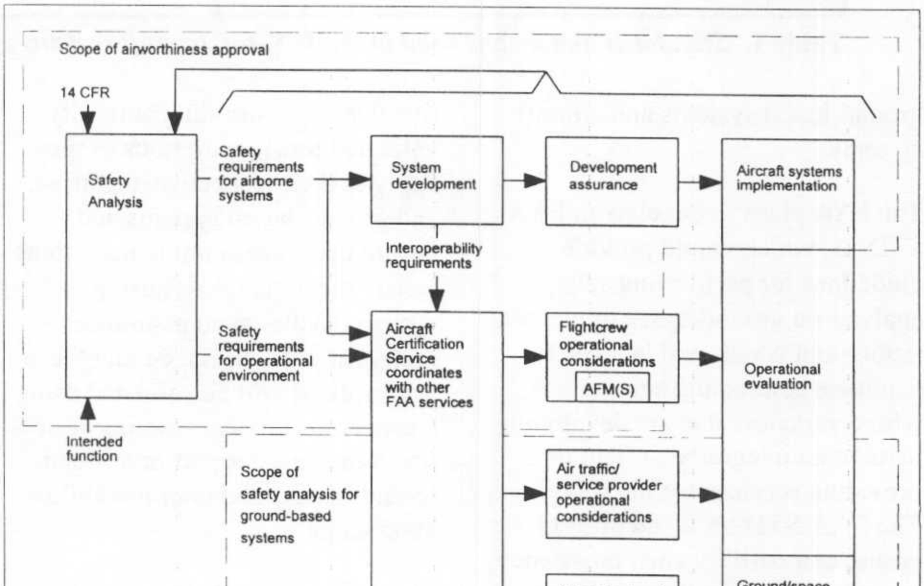

Figure 1-1. Overview of the airworthiness approval process

FAA processes associated with the ground/space implementations that interoperate with the aircraft.

Currently, each controlling authority uses different standards and means to implement different parts of the system. From a total systems perspective, there appears to be a mis-match in the use of these standards. **Table 1** exemplifies the different and incompatible standards that are used within the U.S. for ground-based systems and aircraft systems.

Ground-based System	Aircraft
Federal Aviation Regulations (FAR)	Title 14 Code of Federal Regulations (CFR)
FAA Standards, Directives, etc.	Advisory Circulars (public comment)
FAA makes decisions regarding ground system design for FAA-owned systems. Non-federal systems FAA approved under the provisions of 14 CFR, part 171, are typically done by similarity of FAA owned system.	FAA has statutory authority to regulate aircraft design, but does not make design decisions.
FAR do not regulate design decisions for ground system. Design decisions are not regulated.	14 CFR regulates design decisions.
FAA may use service providers to support ground-system functionality. Service level certification is typically done.	Service providers are not part of aircraft certification.

Table 1. ***Standards and means used in the U.S. for aircraft systems and ground-based systems.***

The FAA plans to develop an FAA-STD-xx, which would provide guidelines for performing safety analysis on ground/space implementations and which will be used to negotiate contractual agreements with contractors that are developing parts of an integrated system or providing services for the FAA. The FAA-STD-xx is intended to ensure compatiility and consistency among each controlling authority.

To support this activity, the FAA is conducting a safety analysis for the advanced oceanic automation system (AOAS). The safety analysis will initially apply to the ground-based oceanic ATS system with AOAS Build 2 capabilities. Conducting this safety analysis early in the development process should allow for the allocation of requirements to the AOAS Build 2.

To provide adequate substantiation of safety, assumptions will be made pertaining to parts of the "end-to-end" system that are not part of the AOAS Build 2 design. It is imperative that the controlling authority validate these assumptions as they apply to their respective air, space, and ground-based systems and ensure that system implementations satisfy the assumptions using system development assurance methods. It is envisaged that these assumptions will be validated using a consensus process among controlling authorities as part of an "end-to-end" safety and interoperability assessment.

The ATN is intended to provide a seamless worldwide data communication system to implement the FANS CNS concepts. As the ATN evolves to its full capabilities, it is imperative that an acceptable level of safety and interoperability be maintained. Therefore, acceptable levels of safety and interoperability must be defined and a means provided to ensure that those levels are maintained. The specification of such acceptable levels of safety and interoperability in the SARPs provides an elegant solution that ensures consistency in the application of safety analysis throughout the implementation of the ATN.

2.0 Safety and Performance Considerations for the ATN and CNS/ATM Packages

The International Civil Aviation Organization (ICAO) and related ISO standards provide a certain degree of assurance that systems will interoperate with each other. Today, those standards that apply to the future air navigation system (FANS) communication, navigation, and surveillance (CNS) functions, such as the ATN standards, are not mature enough to provide this assurance. However, the aviation community is seeking a means to allow evolutionary development of such standards, and use the capabilities provided by implementations of interim standards. To use these capabilities, it is imperative to assess safety along the migration path, by providing traceability of CNS functionality, which is defined in terms of performance, integrity, and availability, to the intended uses.

The ground-based components and the aircraft components may contain potential error sources that could contribute to a hazard. Safety analyses substantiate that operational procedures and systems adequately mitigate the hazards.

Currently, the scope of safety analyses are limited to the aircraft or ground-based system domain. Assumptions must be made about the unknown part with no effective means to validate those assumptions. Ideally, the goal of the activities performed at the standards level should be to maximize the substantiation of high-level safety requirements that are applicable to each implementation.

The safety analysis needs to be defined formally and executed systematically through the development of standards by ICAO and through the implementation of those standards by each state. Achieving this goal would minimize efforts in performing a safety analysis for each implementation of the standard. This goal can be achieved particularly through the validation of the requirements themselves.

Figure 2-1 portrays the one-to-many relationship between standards development and implementations of those standards and suggests that the safety analysis plays a role in each domain. Recognize that

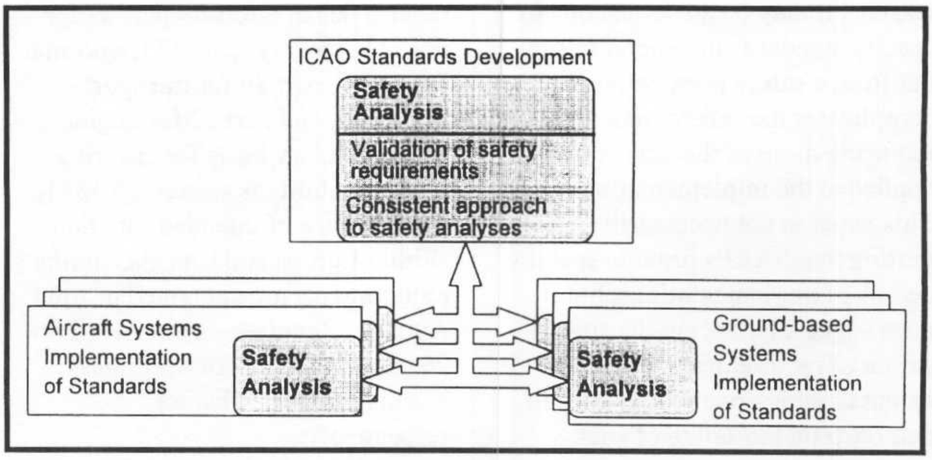

Figure 2-1. ***Relationship of safety analysis, standards development,***

it would not be possible to provide the complete safety analysis within standards development because of implementation specific dependencies. These dependencies are addressed by using safety analyses methods to assess system architecture and design features unique to each implementation and employing development assurance methods throughout system development. Also, it is important to note that within each domain, there is a different controlling authority responsible for performing the safety analysis and specifying safety requirements resulting from the analysis. As a result, it is necessary to develop a minimal set of conventions and terminology for conducting the safety analyses. This aspect of the analysis will be discussed further in *Section 3.4*.

2.1 Validation and verification of requirements

It is important to note the distinction between the *validation* and the *verification* of the requirements. There are similarities in the methods or tools used to *validate* a requirement or *verify* that a system satisfies that requirement, but the objectives are quite different.

Validation ensures a complete and correct set of requirements. Verification ensures that the implementations satisfy those requirements.

Given that ICAO SARPs include safety requirements for the ATN, it would seem appropriate to use safety analysis methods to validate those safety requirements to ensure that they are correct and complete. As each implementation of the requirement will likely be different, the validation of derived requirements specific to each implementation would be necessary, but the validation effort completed for the high level safety requirements defined in the SARPs could be applied to each implementation. Derived requirements are those that do not map directly to a higher level requirement, but may be safety-related (e.g., a partitioning requirement).

Therefore to minimize the level of effort to validate requirements during implementation, it would be necessary to minimize the creation of derived requirements. This could be achieved through increased specificity of the SARPs. For other reasons, it may be advantageous to specify standards in general terms, but from a safety perspective, it complicates the safety analysis by requiring more of the analysis to be applied at the implementation level. This paper is not necessarily suggesting that SARPs provide specific details of implementations, but it does suggest balancing the specification of requirements with the extent to which one would have to demonstrate the safety of each specific implementation.

3.0 Safety Analysis

This section of the paper provides a framework for discussing the safety analysis based on concepts applied within the aircraft certification community. It suggests how these concepts could be applied to other parts of a system, particularly in cases where the system consists of aircraft and ground-based components, and performs complementary functions. Emphasis is placed on the role that the safety analysis plays during SARPs development. The framework could be further developed or modified and applied to the ATN and associated distributed data applications.

For U.S. type certificated transport category aircraft, the regulatory basis for requiring a safety analysis is Title 14 Code of Federal Regulations (CFR) (also known as the Federal Aviation Regulations, or FAR), part 25, section 25.1309. There are specific safety regulations for individual functions that use probabilistic terms. However, within the U.S., section 25.1309 is a generic rule and applies to aircraft functions for which there is no specific requirement (e.g., controller-pilot data communications). Other parts of 14 CFR regulate other types of aircraft: part 23 for normal category; part 27 for normal rotorcraft, part 29 for transport rotorcraft, and part 33 for engines. The regulatory basis for ensuring interoperability is section 25.1301, performance of intended function. Within Europe and Canada, similar requirements are contained in Joint Aviation Requirements (JAR), Part 25, and Canadian Airworthiness Manual (CAM), Chapter 523, respectively.

Today, a safety analysis is required for aircraft systems to examine aircraft level functions, identify potential hazards, and classify related failure conditions according to the severity of its effects on safety considering the operational environment. The operational environment includes the air/ground subnetwork, the ground data communications, the ground portion of the distributed data applications, and operational aspects, such as operational and maintenance procedures.

The safety analysis determines the safety requirements for the aircraft data communication system and the distributed data applications in the context of the safety requirements that define the operational environment. Therefore, the safety analysis needs to make assumptions about the operational environment to substantiate the classification of failure conditions and to substantiate that the failure conditions are adequately precluded.

For the aircraft systems, the safety analysis interacts with the system development processes to validate the safety requirements allocated to aircraft systems and to ensure that the aircraft implementation satisfies its requirements.

It would be advantageous to employ safety analysis methods to assess hazards of the FANS CNS functions, particularly the communications and surveillance functions, because of the nature of distributed data applications, which consist of aircraft, space, and ground-based components, performing complementary functions. In these cases, there exists potential error sources in systems located in all the components, error sources that can contribute to hazards associated with the aircraft. Using safety analysis methods similar to those methods used for aircraft certification would provide a consistent approach to conducting safety analyses and provide a means to assess "end-to-end" safety and interoperability throughout the implementation of the ATN worldwide.

For SARPs development, the safety analysis should substantiate the minimum performance, integrity, and availability required for an operational use. Minimum ***performance*** requirements for a particular function are substantiated by analysis of the operational concept and the role that function plays in the overall concept. Minimum ***integrity*** and minimum ***availability*** requirements are substantiated by analysis of the hazards associated with malfunction (e.g., misleading information) or loss of the function, respectively.

The following summarizes this section of the paper:

Section 3.1. Prepares a means to assess the minimum performance requirements for the automatic dependent surveillance and contoller pilot communications.

Section 3.2. Presents a means to assess the minimum integrity and availability requirements.

Section 3.3. Discusses the use of architecture and design features to address safety aspects.

Section 3.4. Provides a framework for integrating all the pieces of the safety analysis using an "end-to-end" safety and interoperability assessment.

3.1 Definition of Functionality and Minimum Performance Requirements

To support the safety analysis, it is necessary to specify the functionality of the ATN in terms of performance, integrity, and availability requirements, which are based on an operational context. This can be accomplished by providing a mapping of logical functionality of the ATN to operational uses expected from the implementation of that functionality. Operational uses of the ATN, however, are part of a complete suite of functionality provided by the FANS CNS model. Therefore, it is necessary to consider the ATN as part of a FANS CNS model. This will provide viable options for substantiation of the safety of the ATN; however, it will be necessary to validate any assumptions made about functions that are beyond the scope of the ATN (e.g., navigation functions).

Figure 3-1 suggests a top level model depicting the relationship between communication, navigation, and surveillance functions associated with tactical control of aircraft. The model is intended to provide a high level framework to further discuss safety analyses concepts associated with defining the ATN functionality. The safety analysis is integral with the activities associated with defining the function; therefore, it may be necessary to revise the functional definition to accommodate the analysis.

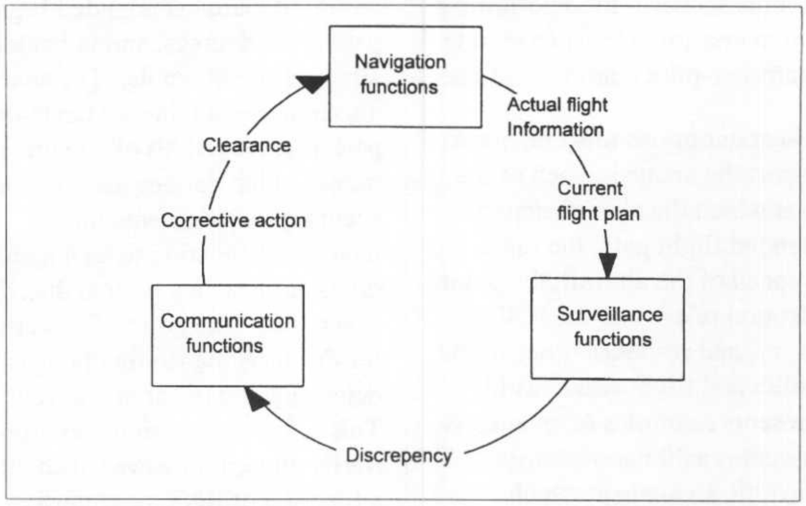

Figure 3-1. ***Relationships of the elements of the FANS CNS Model associated with tactical cnotrol of the aircraft.***

To exemplify the methods of the safety analysis used to substantiate the minimum performance requirements, this paper presents a safety argument for specifying the end-to-end response times for automatic dependent surveillance (ADS) reports and for the corrective action following a discrepancy detected by the surveillance functions. The analysis requires knowledge about the operational uses of the function. The analysis assumes an oceanic environment with separation standards of 30 nautical miles laterally and longitudinally. Note for simplicity of the analysis, vertical separation is not considered.

End-to-end response time of the data communications between the controller and the flight crew can be determined based on the time required for an aircraft to depart the allocated airspace in the event an undetected error occurs in the navigation function. **Figure 3-2** provides an illustration of an

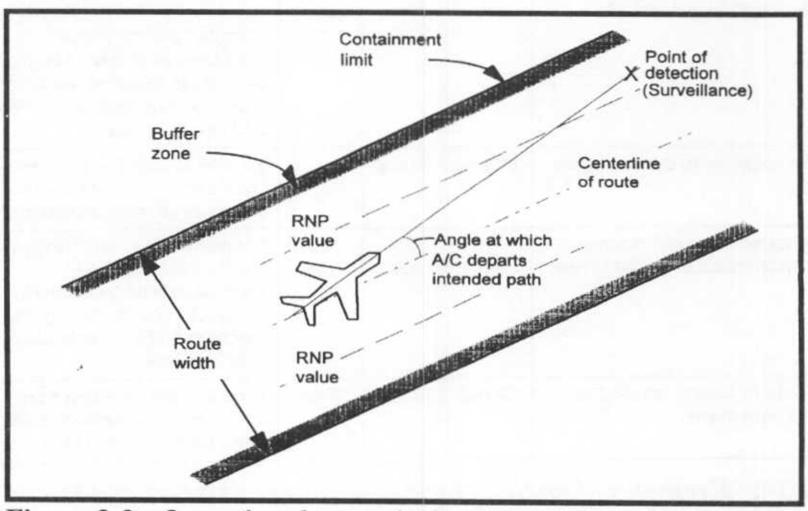

Figure 3-2. ***Operational scenario for determining minimum end-to-end response time for controller-pilot communication***

operational scenario for determining minimum end-to-end response time for controller-pilot communication.

Certain assumptions must be made to support the analysis, such as the angle at which the aircraft departs its intended flight path, the maximum speed of the aircraft, the point of detection relative to the RNP boundary, and response times of the controller and flight crew. **Table 3-2** presents examples of an analyis that assumes a 30 nautical mile route width, an angle at which aircraft departs its intended flight path of 15 degrees, and indicated airspeed of 600 knots. The analysis also assumes a required navigation performance (RNP) of 4 nautical miles, which defines the position accuracy requirements for the navigation function to be 4 nautical miles at 95% on a normal distribution curve. The point of detection for the surveillance functions is determined to occur at 1.2*RNP. This point of detection was arbitrarily chosen; however, it should be a function of RNP, not interfere with aircraft monitors that are capable of detecting exceedance of RNP, and be at a point in the route to allow sufficient time to contain the aircraft within the allocated airspace defined by the containment boundary and buffer zone. Based on the time (190 sec) from the point of detection to the point at which the aircraft enters the buffer zone, minimum performance times can be allocated to various parts of the system, including reaction times for the controller and flight crew.

Assumptions	Value			Notes
Route width	30 nm	30 nm	30 nm	
RNP	1 nm	4 nm	6 nm	Based on a family of RNP values: 20, 12.6, 4, 1, (RGCSP)
Angle at which A/C departs intended flight path	15 deg	15 deg	15 deg	
Indicated airspeed (IAS)	600 kts	600 kts	600 kts	Speed of aircraft
Calculations				
Distance from route centerline to containment boundary	15 nm	15 nm	15 nm	½ route width
Point of detection from route centerline	1.2 nm	4.8 nm	7.2 nm	1.2*RNP to avoid interference with aircraft monitoring of RNP.
Width of buffer zone	.5 nm	2 nm	3 nm	½*RNP
Distance from point of detection to buffer zone	13.3 nm	8.2 nm	4.8 nm	Controller intervention should not be before aircraft monitor indicates exceedance of RNP to flight crew.
Along track distance from point of detection to buffer zone	51 nm	32 nm	18 nm	
Time to exceed buffer zone from point of detection	**308 sec**	**190 sec**	**111 sec**	**This value is allocated to parts of the system**
Time to detect discrepancy and provide indication to controller	124 sec	65 sec	26 sec	Minimum "end-to-end" response time for ADS, Conflict Probe, and any other automation used to detect and intervene. Assumed to be ½ of the total time remaining after allocating times to controller-pilot reaction times.
Time for controller to decide course of action	30 sec	30 sec	30 sec	Time for a controller to determine course of action. Validate using a sample of air traffic controllers.
Time to transmit course of action and provide indication to flight crew	124 sec	65 sec	26 sec	Minimum "end-to-end" response time for controller-pilot communications. Assumed to be ½ of the total time remaining after allocating times to controller-pilot reaction times.
Time for flight crew to respond to controller commands	30 sec	30 sec	30 sec	Time for flight crew to act on controller's command. Validate using sample of flight crews.

Table 3-2. ***Examples of analysis for determining minimum end-to-end response time for controller-pilot communication.***

Note that for higher RNP values, such as those that may be applied to inertial navigation systems, the distribution curve is different. Drift rates over time must be a factor in the analysis. Also, the track deviation angle is purely an assumption and a more systematic approach could be taken to establish its validity, such as conducting an analysis of error sources that could cause the angle at which the aircraft would depart its intended flight path. The buffer zone was introduced to account for uncertainties in the engineering analysis and primarily represents a predetermined safety margin. The minimum response times, shown in **Table 3-2**, for surveillance and controller-pilot communications are each assumed to be one half of the total time remaining after allocating times to controller-pilot reaction times.

Because the point of detection and the width of the buffer zone are a function of RNP, the minimum communication performance requirements are dependent on minimum navigation performance requirements for a given operational context. Given the scenario described in **Figure 3-2**, if, hypothetically, the minimum navigation performance requirement was RNP 6, then 111 seconds would provide the basis for allocating response times. If the minimum navigation performance requirement was RNP 1, then 308 seconds would provide the basis. A proper balance between the minimum communication performance requirement and minimum navigation performance requirement could be determined by balancing the capabilities of the technologies providing the functions, the costs associated with implementing the requirement, and other factors.

The analysis assesses required performance times from a safety perspective. The surveillance and communication functionality are provided to monitor and protect against the aircraft entering the buffer zone. There may be other factors that may take precedence over the results from the safety analysis.

Human factors, such as the cognitive and psychological characteristics of the controller and flight crew, may play a significant role in determining minimum performance response times.

For RNP 4, even though the safety analysis indicates a minimum end-to-end response time of 65 seconds for ADS, etc., this may be unacceptable from a psychological perspective, since current radar updates occur at approximately 4-second intervals.

The safety analysis is not intended to provide a means in itself. Engineering and operational judgment may be necessary to specify more stringent requirements; however, the safety analysis may serve to provide confidence in the validity of these judgments.

3.2 Definition of Minimum Integrity and Availability Requirements

The minimum integrity and availability requirements can be derived from an analysis of hazards associated with malfunction (e.g., misleading information) and loss of function. Failures and design errors in the system contribute to hazards of different severity, for example, a clearance message that the flight crew never received may not be as severe as a corrupted clearance message that misleads the flight crew. The aircraft certification community classifies failure conditions according to the severity of its effects on the aircraft. This section presents this classification scheme and suggests modifications to the definitions, to provide for consideration of failure conditions of air traffic services.

Currently, failure conditions are classified according to the severity of the effect the failure condition has on the aircraft. Title 14 CFR identifies 3 categories; two categories are quoted from 14 CFR, part 25, section 25.1309(b):

"*(b) The airplane systems and associated components, considered separately and in relation to other systems, must be designed so that-*

(1) The occurrence of any failure condition which would prevent the continued safe flight and landing of the airplane is extremely improbable, and

(2) The occurrence of any other failure conditions which would reduce the capability of the airplane or the ability of the crew to cope with adverse operating conditions is improbable."

The third category is implied - the occurrence of any failure condition that has minor effects is probable.

The FAA, Aircraft Certification Service, has published an advisory circular (AC) 25.1309-1A, which provides guidance for how to interpret Title 14 CFR, part 25, section 25.1309. The European Joint Aviation Authorities (JAA) have published advisory material joint (AMJ) 25.1309, which is nearly equivalent and is used throughout Europe.

AC 25.1309-1A maps the three categories described in the rules into 4 categories: catastrophic, severe-major (or the JAA use the term "hazardous"), major, and minor. The four categories evolved because the range of probability of failure conditions classified as "improbable" was too broad (e.g., in numeric terms 10^{-5} > improbable ≥ $10^{-9 \text{ per flight hour}}$). This AC together with the rule itself are currently under review by the Systems Design and Analysis Harmonization Working Group (SDAHWG) chartered under the FAA-JAA Harmonization Work Program and the Aviation Regulatory Advisory Committee (ARAC).

Based on current directions of the SDAHWG and other industry committees, the following categories are suggested:

Catastrophic

Failure conditions which prevent continued safe flight and landing of one or more aircraft.

Hazardous

Failure conditions which would reduce the capability of the aircraft, air traffic services, or the ability of the flight crew or controller to cope with adverse operating conditions to the extent there would be:

- A large reduction in safety margins, functional capabilities, or airspace separation
- Physical distress or higher workload such that the flight crew or controller cannot be relied upon to perform their tasks accurately or completely
- Serious or fatal injury to a relatively small number of aircraft occupants

Major

Failure conditions which would reduce the capability of the aircraft, air traffic services, or the ability of the flight crew or controller to cope with adverse operating conditions to the extent that there would be, for example, a significant reduction in safety margins or functional capabilities, a significant increase in flight crew or controller workload or in conditions impairing flight crew or controller efficiency, or some discomfort to aircraft occupants, possibly including injuries.

Minor

Failure conditions which would not significantly reduce safety, and which involve flight crew or controller actions that are well within their capabilities. Minor failure conditions may include, for example, a slight reduction in flight crew or controller workload, such as routine flight plan changes, or some inconvenience to aircraft occupants.

No effect

Failure conditions which do not affect the operational capability of the aircraft, air traffic services, and do not increase flight crew or controller workload.

Figure 3-3 provides the relationship between the failure condition classification and the minimum requirement for its probability of occurrence and development assurance level for systems that implement the function. The minimum integrity requirement is determined based on the classification of failure conditions that can cause malfunction.

The minimum availability requirement is determined based on the classification of the failure condition, "loss of function."

For ATS that use data communications, the FAA notice classifies this failure condition as "minor," provided "the operational authorizations continue to require alternative communication systems that meet current operating rules." This translates to a minimum availability requirement of 10^{-2} per flight hour probability.

Effect on aircraft or air traffic services	Normal	Nuisance	Operating limitations; emergency procedures	Significant reduction in safety margins; difficult for flight crew or air traffic controller to cope with adverse conditions; passenger injuries	Large reduction in safety margins; flight crew or air traffic controller extended because of workload or environmental conditions; serious or fatal injury to a small number of occupants	Multiple deaths, usually with loss of aircraft
Classification of Failure Conditions	<---No effect--->	<---Minor--->		<--Major-->	<Hazardous>	<Catastrophic>
U.S. probabilistic terms	<---Probable--->			<---Improbable--->		Extremely <---> Improbable
European probabilistic terms	<---Frequent--->		Reasonably <---> Probable	<---Remote--->	Extremely <---> Remote	Extremely <---> Improbable
Integrity requirement	$<10^{0}$	$<10^{-2}$	$<10^{-3}$	$<10^{-5}$	$<10^{-7}$	$<10^{-9}$
Development assurance level	E	D		C	B	A

Note: The value signifies probability of undetected error per flight hour. The minimum integrity requirement is associated with the effect of failure conditions that would cause malfunction. The minimum availability requirement is associated with the effect of loss of function.

Figure 3-3. ***Relationship between failure condition classification and the minimum requirement for its probability of occurrence and the development assurance level for systems that implement the function.***

For data communications, FAA notice 8110.50 has identified the following failure conditions that can cause malfunction: "ATS messages received out of sequence, errors in the ATS message address, and errors in ATS messages." The notice classifies these failure condition effects on the aircraft as "major." This translates to a minimum integrity requirement of 10^{-5} per flight hour probability. The requirement would apply to parts of the system, whose anomalous behavior would contribute to the cause of these failure conditions.

Because of the subjective nature of the definitions, to aid in the classification of particular failure conditions, **Table 3-3** provides a decision matrix based on the attributes of a failure condition. These attributes are:

a. Consequences that the failure condition has on the aircraft or the air traffic service

b. Indication of the failure condition to the flight crew or the air traffic controller
c. Intervention capabilities
d. Reconfiguration capabilities

Based on these attributes, one could provide a more precise definition of the failure condition classification, particularly between the major and hazardous category. The matrix could also be used during system development to reduce the classification of a failure condition by specifying requirements that would change its characteristics.

3.3 System Architecture and Design Features

As mentioned earlier, the safety analysis is integral to system development. Functions are defined and associated hazards and failure conditions are identified and classified. The functions are allocated within a system architecture based on the severity of the hazards associated with the function. The system architecture and certain design features can be used to minimize the complexity of parts of the system performing safety critical functions. The classification scheme provides a means to identify which parts of the system are critical.

Based on the safety analysis, it may be more cost effective to use one system architecture instead of another. Where the system architecture and/or design features do not provide adequate protection against the anomalous behavior of certain parts of the system, then assurance must be derived through rigorous development methods to ensure adequate protection. Also, for those parts of the system that are considered complex and non deterministic, development assurance methods may not be practical, particularly in cases where the anomalous behavior of those parts could contribute to the more severe failure conditions.

An example of the use of system architecture and design features to address safety aspects is the requirement for an integrity algorithm as part of the communication infrastructure for the ATN: the cyclic redundancy check (CRC) implemented at the link layer and the Fletcher's checksum implemented at the transport layer. This feature of the ATN is based on optimizing the performance of the network. From a communication performance perspective, it makes sense to employ an integrity algorithm that is most appropriate for the types of errors one is looking for, and implement the integrity algorithm as close to the error source as possible. From a safety perspective, one is

Attributes of failure condition	Scenarios				
	S1	S2	S3	...	S*n*
Aircraft/Air Traffic Services Consequences					
Safe flight and landing jeopardized	X				
Operationally, significant functional capability lost, or increased risk of major equipment damage					
Operational efficiency reduced or system redundancy compromised		X			
No operational impact, but dispatch requirements impact			X		
Failure Condition Indication					
Masked or misleading condition not readily determinable, or determinable only through subtle indications of performance changes, or evident only to persons having unique knowledge.	X				
Implicit condition clearly determinable from indications used in normal operation or from readily sensible changes in performance					
Explicitly unique indication provided specifically identifying the condition or intervention requirement		X	X		
Pilot/Controller Intervention Alternatives					
None, no intervention alternatives provided or possible	X				
Excessive, continuous and unusual skilled task or decision making without direct procedural or training support					
Demanding, continuous exercise or routine skilled task or extended decision making with procedural and training support					
Routine, brief skilled task or simple decision making with procedural or training support					
Dispensability decision only, no workload impact		X	X		
Reconfiguration Capability					
No reconfiguration possible	X				
Manual reconfiguration possible		X			
Automatic reconfiguration active			X		
Decision alternatives					
Catastrophic	X				
Hazardous					
Major					
Minor		X			
No Effect			X		

Table 3-3. ***Failure condition classification decision matrix.***

trying to minimize the complexity and non-determinism of the safety-critical parts of the system, and the system development assurance methods. Therefore, it makes sense to implement an integrity algorithm as close to the user of the data as possible. Otherwise, the integrity algorithm specified by the ATN standards will not detect anomalous behavior of the distributed data applications and the human computer interface and, therefore, must be addressed by each specific implementation.

Guidelines for software development assurance methods, according to software level, are contained in RTCA DO-178B/EUROCAE ED-12B, "*Software Considerations in Airborne Systems and Equipment.*" Software level is defined based upon the contribution the anomalous behavior the software has to the potential failure condition. As such, the level of effort required to show that software complies with certification requirements varies with the failure condition category.

There is no requirement to reduce the amount of software whose anomalous behavior contributes to a failure condition; however, placing emphasis on the use of system architecture and design features to mitigate the hazard makes sense, particularly when considering distributed data applications. For example, the use of the Fletcher's checksum in the transport layer alleviates the concern for undetected corruption of data messages caused by software used in the ground networks. This eliminates the need for certification requirements on softwre in ground networks, which are considered complex, both from a technical and institutional standpoint.

The system architecture and design features of the ATN may be directly applicable to substantiating the safety aspects of the system. It may also be desirable to identify, in the SARPs for the ATN, system architecture and design features related to safety to minimize certification requirements for development assurance methods.

3.4 End-to-End Safety and Interoperability Assessment

Figure 2-1 suggests that safety analyses methods, currently being applied to systems installed on aircraft at the time of implementation may be applied during ICAO standards development. This part of the safety analysis would validate safety requirements identified in the ICAO SARPs and provide a consistent approach to the safety analyses performed later during implementation of the standards.

In *Section 3.1*, the paper discusses the need to define functions in terms of minimum performance, integrity, and availability required for a specific operational use. Because of the inherent nature of distributed data applications and the ATN and the relationship of communication performance requirements to the navigation performance requirements, the definition of functionality and the safety analysis itself logically (e.g., C,N,S) and physically (e.g., aircraft, space, ground-based) transcend any one piece of the system.

Section 3.0 discusses the safety analysis as integral to the system development process, yet there is a different controlling authority responsible for implementation of each part of the system and for each safety analysis associated with that part of the system.

As a result, there is a need for a consistent approach to the safety analyses. The use of a consistent approach would provide a means for each piece of the safety analysis to support an "end-to-end" safety and interoperability assessment.

Figure 3-4 shows the relationship of the "end-to-end" safety and interoperability assessment to the safety analyses, systems development process, and approval process for each part of the system. The assessment would be commence at the start of a change development activity that would require a revision to assumptions made during the original safety analyses about other parts of the system or the operational context.

A change to operational context would include, for example, a change in separation criteria, but the system would not necessarily change. The "end-to-end" safety and interoperability assessment would provide a means to ensure continued operational safety.

The "end-to-end" safety and interoperability assessment should be performed by the controlling authorities responsible for each part of a specific system. The ICAO SARPs could provide recommended practices for conducting the "end-to-end" safety and interoperability assessment. This "end-to-end" assessment would be considered part of implementation of the standards and would ensure that the operational requirements specified for the system are complete and correct (i.e., validate requirements).

The operational requirements include the safety requirements, which are derived from safety

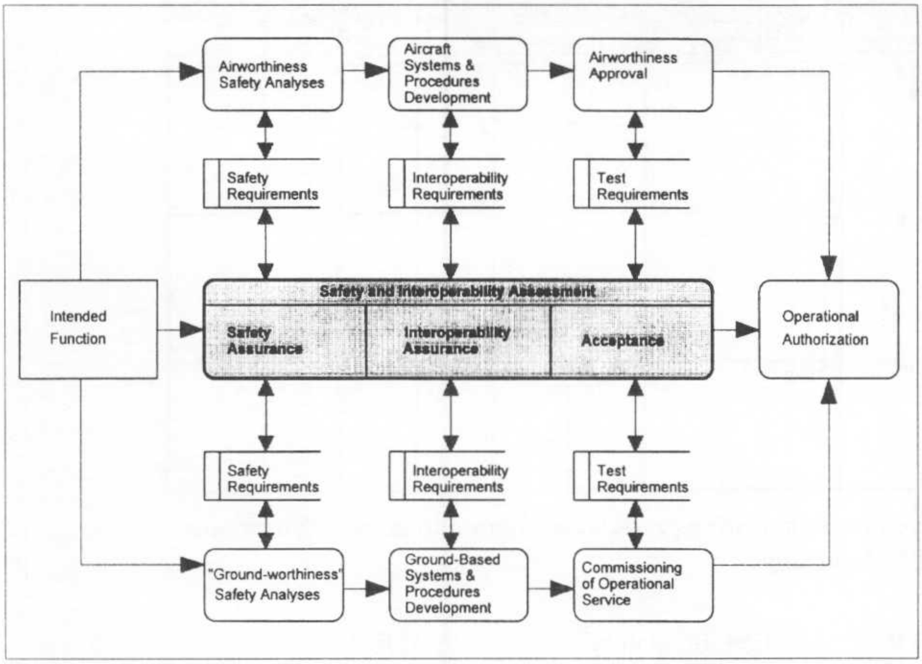

Figure 3-4. ***Relationship of safety and interoperability assessment to safety analyses, systems developments, and approval for each part of the system.***

analyses and interoperability requirements, which are derived from international standards (e.g., ICAO, ISO). More specifically, the "end-to-end" safety and interoperability assessment would:

a. Rely on substantiation provided by each of the controlling authorities for its piece of the system, but ensure that the assumptions in each safety analysis made about other parts of the system were, in fact, valid.

b. Provide a two-way conduit across the domains to resolve inconsistencies.

c. Maintain distinctions between domains to ensure flexibility during the implementation of the standards.

d. Accommodate change activity, inherent in an evolutionary development, rather than prohibit changes. For example, the findings of this assessment may provide substantiation for changes to the subsequent CNS/ATM packages.

4.0 Recommendations

This paper presents the methods of safety analysis currently used within the aircraft certification community and proposes modifications to the definitions to allow the use of these methods to substantiate the minimum performance, integrity, and availability requirements for CNS functions.

The working groups of the ATNP should consider a joint effort with the certification community and implementers to develop these methods further and apply these methods to the development and validation of the ICAO SARPs for the CNS/ATM-1, CNS/ATM-2, and CNS/ATM-3 packages. This effort reduces the certification effort and provides a systematic approach to ensure safety during the evolutionary development of the ATN in operational service. The following summarizes specific recommendations discussed in this paper:

a. Assess the safety of the functionality of the CNS/ATM packages from a total system perspective and develop guidelines and recommended practices for conducting safety analyses to ensure a consistent approach among the different controlling authorities involved in the deployment of a complete system. These guidelines should be described in the ICAO SARPs and include tangible and recognizable products as outputs of the safety analysis.

b. Specify, in the ICAO SARPs for CNS/ATM packages, safety requirements in terms of minimum performance, integrity, and availability requirements for each function of the CNS/ATM-1 package. The minimum requirements should be derived from the results of the safety analysis to validate the CNS/ATM functions in the context of a FANS CNS model. **Table 3-4** proposes a structure for specifying these minimum requirements. The contents of the structure are shown for clarity only and may not necessarily reflect expected operational uses. The structure, however, is intended to show the mapping of operational uses to CNS/ATM functionality and the transition from one CNS/ATM package to another.

c. Continue the U.S. efforts to conduct a safety analysis for the Advanced Oceanic Automation System (AOAS) and encourage other states to engage in similar activities to ensure that operational systems satisfy safety requirements identified by

Operational Use	Separation Standards	Communication Capability (Apps/Equip)	ES-to-ES response time			Availability		Integrity
			Mean	95%	99%	Mean	Max Outage	
Airspace Access Lateral Flex Tracks DARPS Random Route Vertical 2000 ft Climb	15 nm rad/1000 ft reduced vertical	CNS/ATM-2						
Airspace Access Lateral DARPS Random Route Dynamic Route Vertical Cruise Climb	10 nm rad/1000 ft	CNS/ATM-3						
Airspace Access Lateral Random Route Dynamic Route Vertical Cruise Climb	5 nm rad/1000 ft	CNS/ATM-4?						

Figure 3-4. ***Proposed structure for specifying minimum communication performance requirements for CNS/ATM-1 package.***

appropriate safety analyses. Identify the need for an "end-to-end" safety and interoperability assessment performed by controlling authorities responsible for implementing various parts of a system that will satisfy the standards and requirements of the CNS/ATM-1 package. This assessment should validate the assumptions made during the safety analysis, address specific implementation issues that pertain to the end-to-end safety and interoperability, and identify specific issues with the CNS/ATM-1 standards for consideration in future CNS/ATM packages.

Acronyms Used in This Article

AC: Advisory Circular

ADS: Automatic Dependent Surveillance

AMJ: Advisory Material Joint

AOAS: Advanced Oceanic Automation System

ARAC: Aviation Regulatory Advisory Committee

ATN: Aeronautical Telecommunication Network

ATNP: Aeronautical Telecommunication Network Panel

ATS: Air Traffic Service

CAM: Canadian Airwothiness Manual

CFR: Code of Federal Regulations

CNS/ATM: Communication, Navigation, and Surveillance/Air Traffic Management

CRC: Cyclic redundancy check

FAA: Federal Aviation Administration

FANS CNS: Future Air Navigation System-Communication, Navigation, and Surveillance

FANS-1: Future Air Navigation System One

FAR: Federal Aviation Regulation

FMCS: Flight Management Computer System

IAS: indicated speed

ICAO: International Civil Aviation Authorities

JAA: Joint Aviation Authorities

JAR: Joint Aviation Regulations

RNP: required navigation performance

SARPs: Standards and Recommended Practices

SDAHWG: Systems Design and Analysis Harmonization Working Group

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Mystery Photograph

"Knowledge is of two kinds: we know a subject ourselves, or we know where we can find information upon it." -- Jonathan Swift

While foraging through the photograph collection of the FAA Archives, we've come across several unlabeled and undated photos for which we need help in identifying. The photograph on this page is an example.

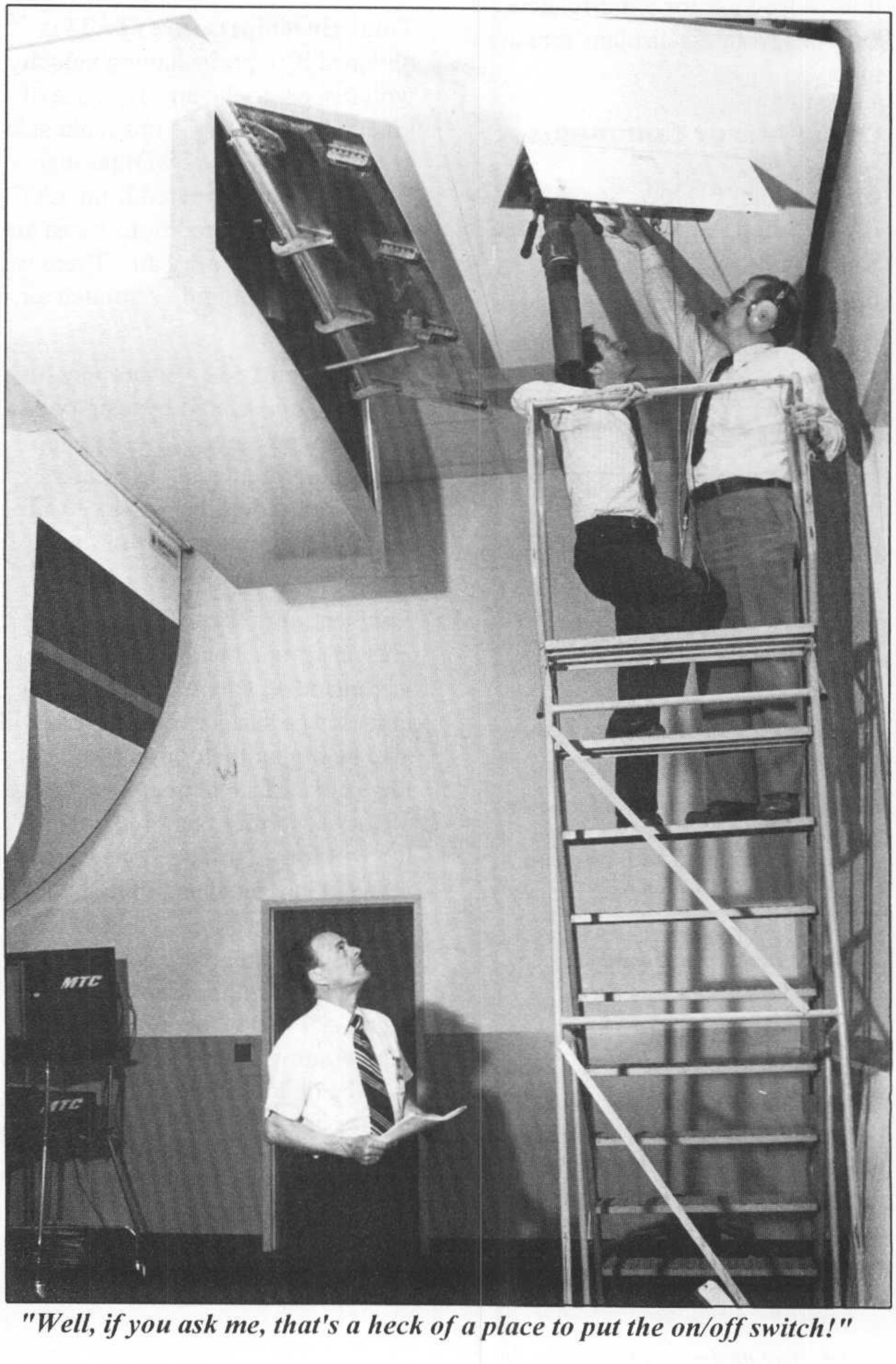
We are soliciting your input in helping us to make a positive identification concerning certain aspects of this photograph. Specifically, can you tell us:

- when and where the scene took place,
- who the individuals are, and
- what it is they are doing.

If you have any such information, we would be grateful if you would forward it to:

R. Jill DeMarco, Editor-in-Chief
Transport Airplane Directorate
1601 Lind Avenue SW., ANM-103
Renton, Washington 98055-4056

If this effort proves fruitful, we will include other "mystery photographs" in upcoming issues of the Update. While we are unable to offer a reward for information, we can certainly assure those who submit key identifying data that their efforts will go a long way towards helping the FAA to make its historical records consummately complete. ✠



"Well, if you ask me, that's a heck of a place to put the on/off switch!"

Roll Upset

Continued from page 17

or systems may be installed to help the crew detect the formation of ice or determine its effects.

It is important to review the AFM for aircraft type specific information. Also look for icing-related bulletins from the airplane manufacturer.

Questions or Comments . . .

Contact John P. Dow, Sr., at the FAA's Small Airplane Directorate in Kansas City, Missouri, at:

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TERMS

Static air temperature (SAT) is what would be measured from a balloon, and is the temperature given in a forecast or report. It is also referred to as **outside air temperature (OAT).**

Total air temperature (TAT) is obtained by a probe having velocity with respect to the air. Because of kinetic heating on the upstream side of the probe, TAT is warmer than SAT. SAT is computed from TAT and other flight conditions by an air data computer for dry air. There is less kinetic heating in saturated air than dry air.

Indicated outside air temperature (IOAT) is measured by a simple sensor in the airstream — essentially a thermometer. Typically, IOAT values will be SAT or OAT plus approximately 80% of the difference from SAT to TAT.

Surface temperature varies with pressure along the airfoil. At the leading edge, where pressure is the highest, the surface temperature will also be higher than further aft. If the local surface temperature on the airfoil is warmer than freezing, no ice will form. Infra-red measurements of a typical airfoil in the icing tunnel at a true air speed of 150 knots show that there can be a decrease in temperature of more than 3.5°F along the airfoil. At temperatures close to freezing, there may be no ice on the leading edge, but ice can form further aft because of the lower temperatures. Because there is liquid runback, any ice formation aft of the leading edge tends to act like a "dam" making ice growth more rapid.

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Int'l Airworthiness

Continued from page 21

aircraft certification system, and to co-develop a set of Operating Procedures. These new Operating Procedures are expected to be finalized and signed by the Civil Aviation Inspectorate and FAA in early 1996.✠

FAA and NASA

Continued from page 22

"ATN data communications are the key to meeting the air traffic management needs of the future," said ATN Systems, Inc., president Bill Cotton, formerly a captain for United Airlines. "The ATN will be an inter-connected, worldwide system that will verify and communicate accurate information about the location of all users, including aircraft in flight, to all users of the network."
"The airline industry is excited with the innovative approach to new technology development, and the Air Transport Association (ATA) is pleased we were able to play a part in the project," said ATA president Carol Hallett. "Technology and new ways of doing business go hand-in-had, and the industry will be looking at the ATN system as a model for future efforts."

Today's aeronautical telecommunication system is a combination of very-high frequency (VHF) and high frequency (HF) voice and data transmission and systems that will not be capable of handling the projected demands of the future. Over the next decade, for example, the FAA expects air travel in the U.S. to increase by 60 percent, from 500 million to 800 million passengers annually, and to double by the year 2015.

The ATN will incorporate the elements of satellite communication with a ground-based distribution system to meet these new needs.

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Head Injury

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collected from accident investigations. To judge the effectiveness of each method, crash severity will have to be determined, injuries documented, and physical evidence from airplane accidents inspected. These devices will not eliminate head injuries, rather, the goal is to reduce the potential for death and serious injury.

A Quiet Revolution Continues

The public may never become as aware of advances in aviation safety as they are of the improvements in the automobile industry. Passengers on commercial air transports expect the highest level of safety, and the excellent safety record over the past decades justifies their expectations. Seat designers, airframe manufacturers, and FAA research and regulatory offices have all contributed to major advances that have reduced injuries and deaths from airplane accidents. Industry and the FAA will continue to develop and apply new technologies that will further enhance aviation safety.

Van Gowdy is the supervisor of the Biodynamics Research Section at CAMI. For the past 12 years he has directed testing and research activities towards improvements in occupant protection from crash injuries.

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Simplified Procedure

Continued from page 40

no ATD's in the forward row seat. Floor deformation should not be induced on either the forward or aft row seats for evaluation of HIC.

Other Factors:

Head Floor Strikes. HIC need not be determined for ATD head strikes with the simulated floor of the aircraft should it occur.

Occupant to Occupant Strikes. Occupant (ATD) to occupant (i.e., opposite facing seats) strikes should be prohibited. The biofidelity of the ATD and appropriate injury criteria related to occupant to occupant strikes is unknown and beyond the scope of the seat dynamic performance standards evaluations.

Sharp Object Strikes. Head strikes with sharp objects are not evaluated with the HIC, but they are prohibited under the requirements of FAR section 25.785. ✠

Service Difficulty

Continued from page 51

A total of three criteria are available but not required. Just answer the questions as they are shown on the screen. All SDR's will be screen-printed one at a time. All criteria are available after the first one is selected.

You may answer "**x**" to any prompt to back out of the search routine.

If you have problems or comments concerning this SDR data base system, please contact the FAA's Safety Data Analysis Section, AFS-643, P.O. Box 25082, Oklahoma City, Oklahoma 73125. The telephone number is (405) 954-4171.

Other SDR information is available on the FEDWorld Bulletin Board (BBS), accessible through the information superhighway. FEDWorld can be reached as follows:

- To connect via modem, telephone (703) 321-3339 or (703) 321-8020. Set communications software to show
  modem parity = none
  databits = 8
  stopbit = 1
  terminal emulation = ANSI
  duplex = full
- To connect through the Internet, telnet to **fedworld.gov** *(192.239.92.201).*
- For file transfer protocol (FTP) services, connect to **ftp.fedworld.gov/pub/faa** *(192.239.92.2050).*
- Using the World Wide Web (WWW), connect to **www.fedworld.gov**

After setting up your software, connect, enter "**new**," and follow the prompts. After you enter your name and a password, select "**U**" for utilities/file/mail; "**F**" for file libraries; and "**S**" for select a library. At the prompt, enter "**FAA**" for the FAA Library (FAA Safety Data). The BBS is menu-driven and user friendly.

For assistance with connection to FEDWorld, contact the help desk at telephone (703) 487-4608.

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