Federal Aviation Administration

R&D Review

News Source for the FAA Air Traffic Organization's Operations Planning Research & Development Office

2007 Issue 1

The Year in Review

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The Year in Review

A Message from the Acting R&D Director

This issue of *R&D Review* highlights some of our Fiscal Year (FY) 2006 major accomplishments and activities.

Because space prevents me from providing details of all of our accomplishments, I do want to highlight a few things not covered in detail in this issue. For example, our efforts to create a fire proof aircraft cabin remain on track. This past year, our scientists perfected a procedure that will greatly accelerate discovery of ultra fire resistant plastics. The thermal analytical method known as pyrolysis-combustion flow calorimetry allows the FAA to measure quickly the flammability of hundreds of tiny milligram-sized samples of new plastics and compositions. Researchers also synthesized and evaluated nearly three dozen different polycarbonates to find one better suited to build the plastic portion of aircraft cabins. Researchers also supported development of FAA Advisory Circular 25.856-2, which addresses the testing and installation of thermal acoustic insulation. These voluntary guidelines will help airframe manufacturers, customizers, foreign regulatory authorities, and FAA type certification engineers keep aircraft safe.

FAA researchers investigated the ignition hazard of electronic equipment near aircraft fuel tanks. They re-created real-life conditions to determine the lowest electric current needed to short circuit and spark a fire in types of steel wool. Following several cargo fires involving lithium-ion batteries, other scientists discovered a relatively small source could ignite the power supplies for laptop computers. In another surprising study, researchers also found that the hydrogen gas released by the flameless heaters built into some prepackaged meals poses a threat aboard airliners.

Specialists continued their exploration of widespread fatigue damage to aging aircraft by calculating how effectively 20 nondestructive inspection (NDI) techniques can detect small hidden cracks without disassembling aircraft. They created a database to share that information with engineering organizations so the aviation community could calibrate and validate methodologies for finding structural fatigue.

FAA-sponsored engineers developed a risk analysis tool that checks a plane's electrical wire interconnect system. The new software package makes it easier to detect structural hazards and potential fire sources, and helps certification officials analyze wiring designs. Meanwhile, specialists at the FAA Arc Fault Evaluation Laboratory discovered a new method of quantifying damage from electrical hazards. They also determined minimum safe distances between certain wire bundles. These developments will help engineers generate new power system protection technologies and safety guidelines.

FAA and FAA-funded researchers studied possible improvements in the air traffic management system. One team is analyzing current air traffic control workstation procedures and evaluating proposed changes to both personal interfaces and automated functions to reduce controller workloads. Combining electronic flight data with the airport surface detection equipment, another research team designed two touch-sensitive electronic flight data interfaces for use by local and ground controllers in airport traffic control towers. Other researchers are also investigating the roles, responsibilities, resources, and tasks of those who supervise controllers to identify the ►

"best practices" to prevent operational errors. After examining exemplary performance at six Air Route Traffic Control Centers, they developed and distributed an operations supervisor reference guide to the participating centers for their review and comment.

Researchers funded by the FAA are studying processes and procedures to help enhance safety. To date, they have conducted several thousand observations, called Line Operations Safety Audits, involving 25 carriers. Human factors researchers are also looking into how to integrate electronic flight bags onto the flight deck, or the transition from paper to computers for flight operations documents. They published a report this past year detailing methods to help users inexpensively incorporate electronic flight bag technology. In addition, researchers are developing a training program to teach flight crews about new procedures that will enhance their performance.

Researchers at the FAA Civil Aerospace Medical Institute (CAMI) are studying records of more than 20,000 pilots. Doctors hope the investigation leads to ways of reducing risk in determining medical certification requirements. In trying to determine how molecular changes caused by fatigue affect a pilot's performance or perception, scientists have pinpointed 158 operative genes. They hope the sleeplessness study will help the FAA create regulations, and possibly lead to development of intervention therapies for workers with extended-duty shifts. In another study, doctors are testing whether to change regulations stipulating at what altitudes general aviation pilots require supplemental oxygen. Other research this past year supported aircraft seat certification and found computer models tended not to accurately match what really happened to the head of a crash test dummy on the CAMI sled track.

FY 2006 ended with many improvements in the airport technology research and development program. Engineers determined the most conspicuous configuration and combination of color and materials for a screen designed to prevent the pilots of planes moving on end-around taxiways from being distracted by the sight of other planes taking off from runways. With nearly twenty Engineered Material Arresting Systems now installed to decelerate safely aircraft overrunning runways, researchers have constructed a test bed to assess their long-term environmental durability.

Researchers are extending the lifetime of airport pavements. Their testing of rubblization, in which a machine breaks apart existing concrete before workers overlay a new asphalt surface, will help the FAA modernize its design guidance. Engineers also conducted traffic testing on rigid (concrete) overlay pavements, in view of current construction practices and aircraft loads, and will use the results to update data from 35 years ago. They input the latest information into a new computer program, FAA Rigid and Flexible Iterative Elastic Layer Design (FAArfield 1.0), and will use advanced structural analysis to compute pavement design criteria capable of supporting tomorrow's large aircraft. The software will form the groundwork for next year's major revision to the Advisory Circular covering airport pavement design (AC 150/5320-6).

The world's airlines, airports, and aviation authorities depend on the leadership of the United States to make the national aerospace system safer, more efficient, and environmentally friendly. In turn, the U.S. aviation community counts on the FAA to provide vitally needed innovations and improvements through its research and development programs.

Barry Scott, Acting Director
Operations Planning Research and Development R&D Review

For additional information on the FAA R&D program, please visit http://research.faa.gov.

A Distinguished Career

Joan Bauerlein Retires after 30 Years of Federal Service

Joan Bauerlein, the Director of Aviation Research and Development retired January 3, 2007, after a long, distinguished career serving the nation for over 30 years in a variety of positions in the transportation sector. Beginning her career at the Department of Transportation in 1975, Bauerlein created the Department's new car assessment program, and later helped establish the Office of Commercial Space Transportation.

Selected as a Congressional Fellow, Bauerlein worked for Congressman Norman Mineta in the early 1980s. In 1984, the FAA selected Ms. Bauerlein to participate in its SES candidate development program. After completing the program, she became the FAA's Deputy Budget Director. In that role, she successfully provided leadership and stability in the office during an extraordinarily difficult transition period and the effects of the first Graham-Rudman-Hollings reduction. Bauerlein subsequently served as the FAA's first Assistant Administrator for Government and Industry Affairs and later served as the Director of International Aviation. During her ten-year tenure as Director, she established and expanded good working relationships with her international counterparts, working toward the goal of standardizing aviation worldwide.

Because of her extensive international experience, the FAA loaned Bauerlein to the InterAmerican Development Bank, to help that organization with aviation issues. During her short tenure there, she obtained funding for a regional safety initiative in Central America, to date, the only one in the world, and a $15 million program to strengthen aviation security in Latin America and the Caribbean.

Until her retirement, Bauerlein served as the FAA's Director of Research and Development, overseeing critical safety and capacity research programs that are ensuring the FAA and DOT meet their strategic goals and mission. Her vision created one of the government's most productive, proactive research programs. Using its Program Assessment Rating Tool to judge the effectiveness of federal programs, OMB gave the R&D program the highest score ever received by a Department of Transportation organization. OMB stated that the FAA's R,E&D program is well managed and results-oriented, with a strategic plan that sets forth clear long-term goals that are tied to program performance measures.

Believing that everyone, especially public servants, should give back to the community, she led a group of employees to work at a local soup kitchen and worked with her staff to send care packages to U.S. soldiers in Iraq. She set the example for her employees to volunteer within their own communities. She also volunteered her services to the local community, teaching English as a second language to recent immigrants, and she recently went back to college to earn a certificate in teaching English as a second language.

Last year the National Academy of Public Administration and the American Society for Public Administration presented Bauerlein with the 2006 National Public Service Award. The award recognizes creative and highly skilled managers who have exhibited the highest standards of excellence, dedication and accomplishments in their careers. In announcing the award, FAA Administrator Marion Blakey summed up Bauerlein's career, saying "Joan Bauerlein exemplifies what civil service is all about. She is a veteran executive, having served in a variety of senior positions over the years. She makes a difference in how our skies operate."

Barry Scott is currently serving as the acting Director of Aviation Research and Development until a permanent replacement is selected. R&D Review

Tools for the Future

PARTNERing for Success

"We face substantial challenges in harmonizing aviation with the environment," states Dr. Lourdes Maurice, FAA Scientific and Technical Advisor for Environment. "Concern over noise and emissions may limit airport expansion and the growth of in-flight operations. Understanding the impacts of aviation on the atmosphere requires new scientific research and the development of new tools, models, and methods – all with important policy implications."

In their 2004 report to Congress, the authors of "Aviation and the Environment: A National Vision Statement, Framework for Goals and Recommended Actions" declared: "Immediate action is required to address the interdependent challenges of aviation noise, local air quality and climate impacts. Environmental impacts may be the fundamental constraint on air transportation growth in the 21st century." The writers, academicians affiliated with the FAA, advised the nation to "develop more effective metrics and tools to assess and communicate aviation's environmental effects."

In response to this recommendation, FAA researchers began developing a comprehensive suite of software tools that will thoroughly assess the environmental effects of aviation. One important benefit of these computer programs will be the ability to evaluate interdependencies between aviation-related noise, emissions, and cost values. An ongoing and intensive development effort involves participation by the U.S. Government (FAA and NASA), industry, academia, and Transport Canada and requires coordination with foreign counterparts through the International Civil Aviation Organization (ICAO) Committee on Aviation Environment Protection (CAEP).

"The focus of this development effort," explains Dr. Maurice, "is to incorporate the best scientific knowledge to advance legacy tool capabilities so we may better understand the relationship between noise and emissions and different types of emissions. We will be able to tap the resulting suite of tools at local, regional, national, and international levels — enabling experimentation and feedback at all stages. An example includes assessing the environmental benefits of alternatives when modernizing the air traffic management system."

PARTNERing for Success

The Partnership for AiR Transportation Noise and Emissions Reduction, a Center of Excellence cosponsored by the FAA, NASA, and Transport Canada, together with the Department of Transportation's Volpe National Transportation Systems Center is taking the lead in developing these software tools. "PARTNER fosters breakthrough technological, operational, policy, and workforce advances for the betterment of mobility, economy, national security, and the environment," explains Dr. Maurice. The Center's operational headquarters is located at the Massachusetts Institute of Technology. Its director, Professor Ian Waitz of the MIT Aeronautics and Astronautics Department, is the primary author of the congressionally mandated National Vision Statement.

Ten universities comprise PARTNER, and projects are funded at three additional colleges. The Center's advisory board comes from all corners of the aviation community. "One of PARTNER's strengths is the advisory board's diversity and inclusiveness," says Dr. Maurice. "Its members include aerospace manufacturers, airlines, airports, national, state and local government, professional and trade associations, and nongovernmental organizations and community groups. All are united in their desire to foster collaboration and consensus among some of the best minds in aviation – so, together, they can advance environmental performance, efficiency, safety, and security."

Now in its fourth year of operation, PARTNER has launched 18 research projects. One of its ongoing major projects is the development of a new suite of analytical tools that will combine the utility of the Environmental Design Space (EDS), the Aviation Environmental Design Tool (AEDT), and the Aviation environmental Portfolio Management Tool (APMT). Each of these tools, as described below, will contribute a key component of an integrated decision-making capability. ►

AEDT

The central building block of this new suite of software tools is the Aviation Environmental Design Tool. AEDT will integrate the FAA's existing noise and emissions models, including the Integrated Noise Model (INM), the Model for Assessing Global Exposure to the Noise of Transport Aircraft (MAGENTA), the Emissions and Dispersion Modeling System (EDMS), and the System for Assessing Aviation Global Emissions (SAGE). The consolidated result will allow experts to assess the interdependencies between aviation-related noise and emissions impacts. AEDT will use detailed schedule and fleet information as input and provide noise and emissions inventories, both locally and globally. The tool will compute and identify mutual relationships among noise, fuel burn, and various emissions at the local, regional, and global levels, both for base years and for future scenarios.

In 2006, a research team led by the Department of Transportation's Volpe National Transportation Systems Center completed AEDT Version 1.0. This version includes most of the system's computational and database components. PARTNER tested the prototype in a nitrogen oxide (NOx) demonstration study for the FAA. "Nitrogen oxide is the generic term for a group of highly reactive gases, all of which contain nitrogen and oxygen in varying amounts," explains Dr. Maurice. "NOx forms when fuel is burned at high temperatures, as in the combustion process. People commonly refer to NOx as smog."

In the NOx study, FAA-funded researchers achieved a landmark measurement of noise and emissions produced both locally and globally. They entered detailed schedule and fleet information to produce both local and global noise and emissions inventories. The team used AEDT to integrate common databases, calculation methodologies, and the performance-based modules that specialists currently use in aircraft noise calculations, to support the simultaneous calculation of aircraft emissions.

The FAA benchmarked this new capability against a 2004 ICAO CAEP study that examined global emissions below 3,000 feet. The demonstration included a queuing model to capture the effects of the flight schedule in airports at which noise restrictions hinder capacity. Using the AEDT prototype, researchers incorporated radar data to assess emissions – from scheduled as well as unscheduled aircraft and from certified and noncertified engines – to extend the global coverage of aircraft activity.

The NOx demonstration quantified emissions at and below 3,000 feet, below 10,000 feet, and throughout entire flights. The research team also adjusted emissions values, based on required aircraft thrust and meteorological conditions, to further refine the analysis process. FAA's NOx demonstration reproduced CAEP's global assessment of NOx stringency options in a fraction of the time ICAO's committee took to complete its original analysis. ►

EDS

The Environmental Design Space tool is a mathematical model that estimates source noise, exhaust emissions, performance, and economic parameters for future aircraft designs that incorporate varying levels of technology. EDS is designed to explore trade-offs within current technology; and the impacts of potential future technical resources. Once EDS is connected to AEDT and APMT, the FAA expects the combined tool suite will assess operational, policy, and market scenarios.

In 2006, a research team led by the Georgia Institute of Technology and the Massachusetts Institute of Technology, completed EDS Version 1.0 for the FAA. This edition incorporates improved emissions calculations and flight performance modeling. The development team, in collaboration with industry, is now conducting a thorough assessment of the EDS tool. This will enable better understanding of the tool's accuracy, and will highlight any components that need improvement.

The first phase of the assessment, conducted with General Electric Aircraft Engines and Pratt & Whitney, focuses on an engine-level trade-off for systems offered on Boeing B777-200 and -300 aircraft. In addition to this development work, participants completed one sample problem in 2006, and several other capability demonstration assessments are ongoing to demonstrate the tool suite's capability to the international community.

APMT

The Aviation Environmental Portfolio Management Tool provides the economic analysis component of the comprehensive suite of software tools needed to assess the environmental effects of aviation. The main goal of the APMT effort is to develop a new source of comprehensive cost and benefit estimates of environmental impacts of aviation-related noise and emissions compatible with a range of assumptions and stakeholder viewpoints. The APMT tool suite will help users address complex aviation environmental issues more comprehensively, more consistently, and more efficiently.

In the past year, design requirement research saw completion of the APMT requirements and architecture studies as well as development of APMT prototype Version 0.0. The prototyping effort focused on the construction of an APMT functional module, that would possess more limited capabilities than the final versions. This achievement enabled the initial testing of APMT's abilities to address policy questions, assess uncertainties, and determine priority areas for future development and refinement. The 2006 assessment of the APMT prototype provided a roadmap for future development and a preliminary evaluation of fidelity requirements for subsequent versions. It also established a procedure for future assessment.

To help evaluate policy costs, APMT architecture uses aviation demand and guideline scenarios to simulate producer and consumer behavior. Detailed operational modeling of the air transportation system provides estimates of the emissions and noise outputs. Then, a benefits valuation module puts a price tag on the health and welfare impacts of aviation noise, local air quality, and climate effects. Working together, these modules produce a complete cost-benefit analysis of policy alternatives.

Although the research to develop this analytical tool suite will last a decade, initial capabilities will come online between 2006 and 2009 – in time to influence the seventh and eighth meetings of the ICAO CAEP. When the EDS/AEDT/APMT tool suite is fully operational, the FAA expects it will ease regulatory decision making; and provide significant cost savings along with other user benefits. R&D Review

For additional information on the FAA environment and energy research program, please see http://www.faa.gov/about/office_org/headquarters_offices/aep/models/. For information on PARTNER, see http://mit.edu/aeroastro/partner/.

Avoiding Potential Disaster

Fire Tankers Loads

Since the loss of two firefighting aircraft a few years ago, the FAA has been helping the U.S. Department of Agriculture Forest Service review its entire fleet. The interagency technical support assesses the Forest Service's custom of transforming retired military airplanes to combat wildfires. Crews gut their avionics, remove missile brackets and bomb pylons, and install tanks that hold 3000-plus gallons of water and/or fire retardant. "That shifts some of the planes' weight from the wings to the center of the airplane," says Thomas DeFiore, FAA operational loads program manager.

Most large air tankers are operated in the public use category and, therefore, do not require their operators to comply with Title 14 of the Code of Federal Regulations (14 CFR). Under Part 137, the agricultural airplanes used to fight forest fires are also exempt from federal aviation regulations, and the Forest Service retains the responsibility for their maintenance and safe operation.

Aviation safety experts have determined that the wings of two air tankers separated in 2002 because of undetected fatigue cracks at the wing root along the fuselage. To prevent a recurrence, the Forest Service plans to install equipment to monitor in-service loads usage on its more than 40 firefighting aircraft. To date, teams have equipped six heavy Lockheed aircraft with strain gauges, accelerometers, and other instrumentation.

These converted tankers, five P-2 Neptunes and one P-3 Orion, had served mostly as patrol aircraft and gunships before the U.S. Navy retired them. Although the Forest Service operates a firefighting aircraft at a lower gross weight than during its military service, the relatively different distribution puts greater bending and torsion loads on some parts of the airframe.

Five years ago, while a refitted U.S. Air Force C-130A Hercules was dumping retardant, its wings simply folded up. "The common thinking has been that – because dramatic photographs were taken of the aircraft during the drop – a particularly heavy load was associated with the drop itself," says DeFiore. "Upon further study, that stage of flight does not appear to place the highest wing bending loads. Yes, there are wing bending loads at the time of the drop – and they're meaningful – however, they're less than those the aircraft typically sustains earlier in its mission."

That prompted researchers funded by the Forest Service to begin evaluation of wing torsion loads. They have determined degrees of actual stress by analyzing approximately 800 flights over the past two firefighting seasons. "Pilots are pushing their planes on their way to the scene," explains DeFiore, "They are rushing to help crews on the ground. They're operating at lower altitudes, and consequently experiencing a more severe gust and turbulence environment than planes encounter at higher altitudes."

Engineers at the Wichita State University National Institute for Aviation Research and Avenger Aircraft and Services are developing the usage spectrum for air tankers. DeFiore says these calculations show when the highest loads occur, as well as their magnitudes. "Plots of multiple accelerations, the main parameters in determining bending loads, are fairly high early on," he points out. "There's also a slight decrease of bending load as the aircraft uses fuel, and then there's a modest bending load or two during the drop. After the drop, when the air tanker is much lighter, the 'g forces' may increase somewhat, but the bending loads are considerably lower." ▶

DeFiore identifies bending loads experienced during gusts and turbulence while cruising at altitudes between 500 and 5,000 feet as a major challenge to the safe operation of firefighting aircraft. Researchers study five variables to determine how flying through choppy air results in wing bending on a loaded aircraft. First, they consider the aerodynamics of the wing – and they factor in vertical acceleration, altitude, airspeed, and weight. At altitudes less than 500 feet, where the retardant drops occur, engineers have occasionally observed loads that approach the certification standards for the aircraft.

DeFiore poses three recommendations to the Forest Service, one of which could be implemented immediately. The agency could quickly choose the design values dictated in 14 CFR Part 25 for 1,500 to 4,500 feet as a conservative bending loads usage spectrum. A second possibility, which could take only a couple of months to implement, would be to adapt low-altitude gust velocities calculated for transport aircraft. DeFiore says the third option would require much more time and more work, for it would be based on the extensive measurement of gust velocities from the specially instrumented Forest Service aircraft.

"These are public-use airplanes, and the FAA has no jurisdiction over them," says DeFiore; "however, the FAA is lending the Forest Service our loads technology, and we hope it results in safe operation of the existing firefighting fleet." R&D Review

FAA
Air Traffic Organization

The Federal Aviation Administration Human Factors Research and Engineering Group provides scientific and technical support for the civil aviation human factors research program and for human factors applications in acquisition, certification, regulation, and standards. It develops and assures implementation of human factors policies, regulations, programs, and procedures which promote the safety and productivity of the national airspace system. It also formulates and manages the aviation human factors research program and provides human factors support to acquisition and regulatory activities.

We anticipate at least two openings!

Help the FAA develop the next generation air transportation system (NextGen) by identifying challenges, understanding barriers, and developing solutions across the parameters of capacity, safety, environment, controller efficiency, and pilot workload. Apply with us to manage human factors programs and projects within a portfolio of research and engineering for

Research Program Leader for

air traffic control systems

or

flight deck and aviation maintenance.

You will plan, design, and develop human factors research programs and projects. Work with operational sponsors to develop and manage project requirements. Coordinate with human factors scientists to provide technical products that satisfy the operational requirements. Identify and assess existing or potential issues, risks, and solutions involving human factors in civil aviation operations; plan multidisciplinary research or engineering projects to achieve the programs' strategic objectives. Plan, defend, and manage budgets in support of research and engineering projects.

For more information and application instructions, send an email according to your interest to…

Air Traffic Control Systems

Dino.Piccione@FAA.gov

Flight Deck and Aviation Maintenance

Tom.McCloy@FAA.gov

Job Title

Scientific & Technical Advisor for Human Factors

Status

Full Time

Locations

Washington, DC

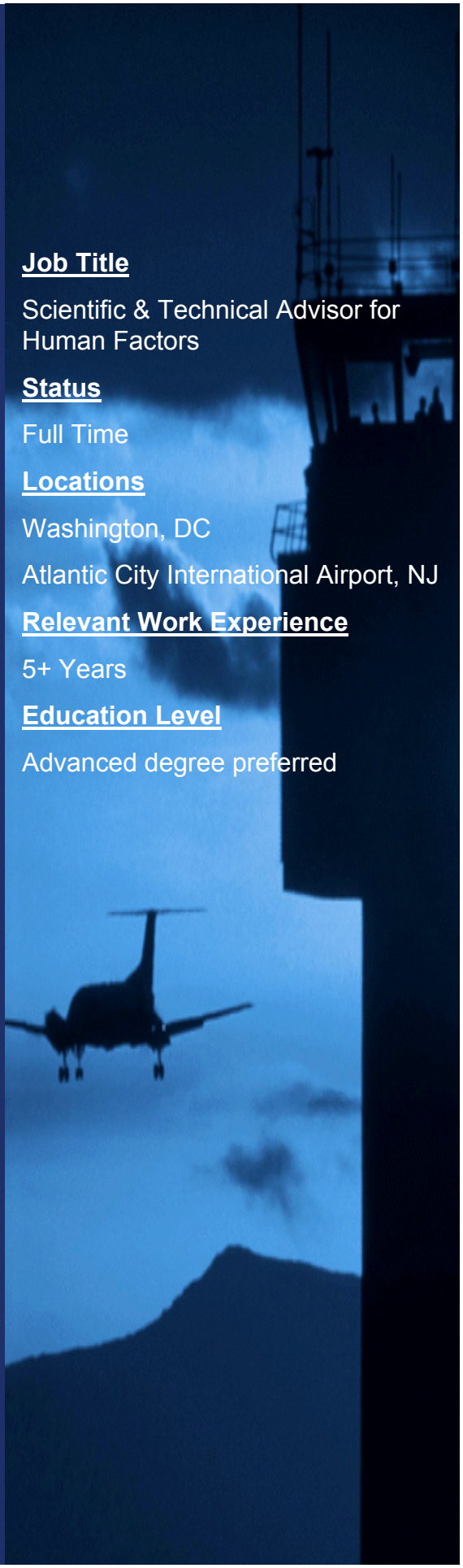
Atlantic City International Airport, NJ

Relevant Work Experience

5+ Years

Education Level

Advanced degree preferred



Fueling What Matters

General Aviation's Plan for Fuel

FAA researchers are trying to do for general aviation what Detroit did for cars – get the lead out of gasoline. Of course, an edict forced the automakers to switch to unleaded gas before 1995. Although not immediately applied to general aviation, the FAA is trying to do what is best for the environment by investigating alternative fuels.

"We're looking for a replacement for 100 low-lead, the main fuel used in general aviation piston engines," says H. Stewart (Skip) Byrnes, manager of the FAA's unleaded aviation fuels program. "Much to the surprise of a lot of people, today's fuel still contains tetraethyl lead. The fact is general aviation piston engines are old-type designs which still need the antiknock quality in their fuel that lead provides."

It took drivers of cars only a few years to change over to unleaded gas, because people normally do not keep their vehicles for decades. However, most owners of the more than 162,000 general aviation aircraft do not have the resources to change models every two or three years. ►

"The planes that need high-octane aviation gas make up only 30 percent of the fleet," Byrnes states. "These big-bore engines – small air taxi services, shuttles, charters – people who fly to make a living – are burning 70 percent of the fuel."

Byrnes explains that finding a technically and economically viable substitute for leaded aviation gasoline has become a much more difficult problem to solve than was the case with automobile gas. "We're trying to find a fuel we could just switch without the pilot realizing it," he says. "We don't want to have to retrain the pilot, and we don't want to have to change the flight manual of the aircraft. We want a seamless and transparent replacement, and nothing fits the bill yet."

Any alternative either falls short of stopping knock in airplane piston engines or has other limitations. "But this is most importantly a safety issue," stresses David Atwood, FAA aerospace engineer. "Having an engine problem with your aircraft is not like when you have an engine problem with your car – you can't just pull over to the side of the road."

Atwood defines detonation as the spontaneous ignition of unburned gas in a cylinder ahead of the flame front. The brief burst of a large amount of energy can damage the engine, and ultimately shut it down. "Ideally," says Atwood, "what you want is a steady pressure increase, almost like using your hand to push open a door steadily – instead of

(continued on page 14) ►

2006 One of the Safest Years in History: Citing the Geneva-based Aircraft Crashes Office as its source, the Associated Press reports, “the number of air crashes around 2006 was the lowest in 53 years; making it one of the safest in aviation history.” According to the independent watchdog agency.

punching it – you can appreciate the difference of what it would do to your hand. Punching is the equivalent of engine detonation, and the lead in the gas actually quenches the thermally-excited free radicals that cause the chain reaction, and keeps the unburned fuel from igniting spontaneously."

In the middle of the 20th century, manufacturers designed most general aviation engines to run on leaded fuels. As Atwood points out, "The older technology, with its large-diameter cylinders, leaves a lot of distance and time for the thermal excitation of the unburned gas ahead of the flame front to occur, which can lead to detonation and subsequent engine problems.

"And, aircraft require a lot of octane," continues Atwood. "The premium pump octane you put in your car at the corner gas station is 87 motor octane. Automobile engines today are so well designed and controlled that you don't have the same problems as with airplane engines' 50-year-old technology. To replace 100 low-lead aviation gas with unleaded, you would need at least 104 motor octane for these large-bore, high-power engines. So it's almost 20 numbers higher than auto gasoline – that's a huge difference."

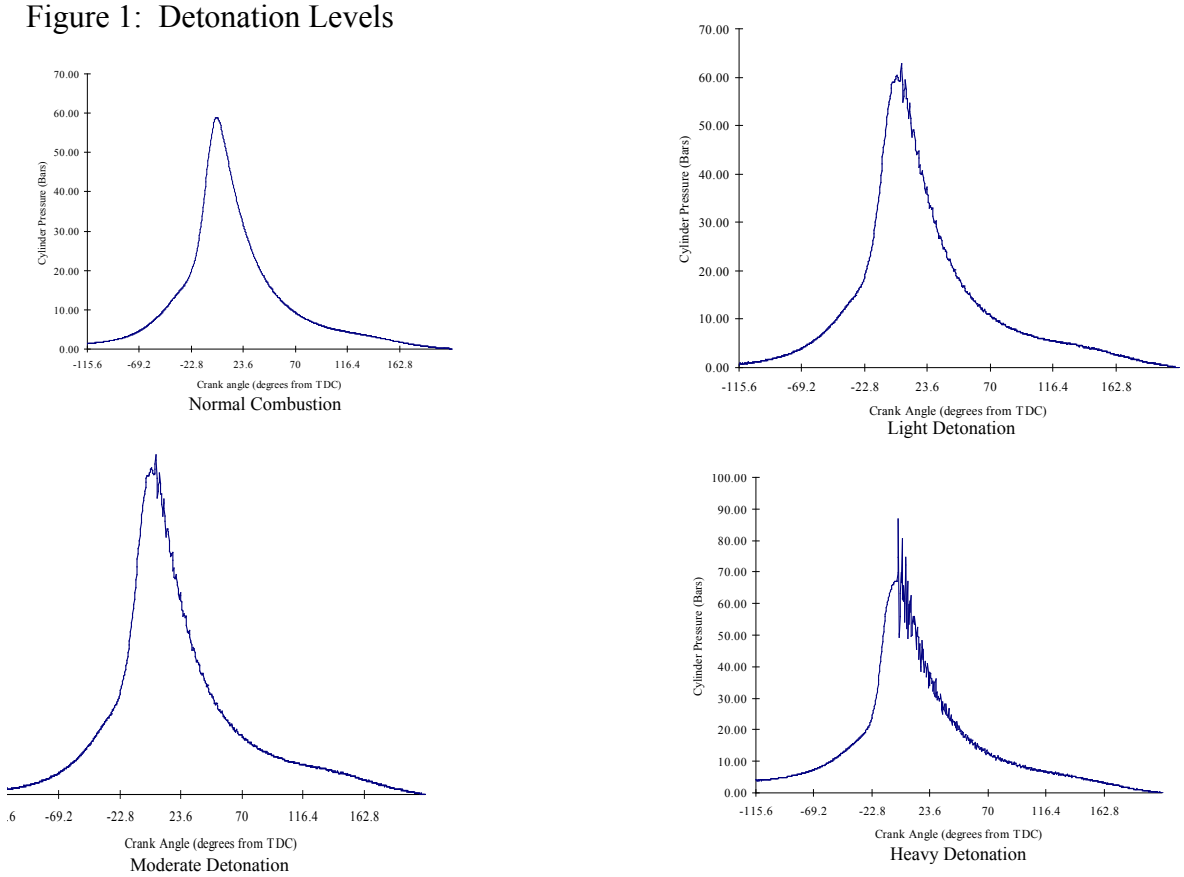
Researchers are working in the laboratory to resolve the difference. Oil companies are sending a new batch of fuels for evaluation at the FAA Small Engine Test Facility, the nation's only lab that tests unleaded gas in full-scale aircraft piston engines for industry standards bodies such as the American Society for Testing and Materials (ASTM). ASTM is the body that sets the specifications for spark ignition, piston aircraft engine fuel, and lubricants.

The Coordinating Research Council (CRC) is submitting the fuel lot for study. In addition to petroleum producers, these contributors include specialty chemical companies, engine manufacturers, airframe manufacturers, aviation associations, universities, and independent consultants. Dave Atwood serves as vice chair of the CRC's Unleaded Aviation Gasoline Development Group. "Our role is to guide the process, and act as the independent testing facility for industry. We're not chemists. We hope somebody takes the data we provide and comes up with the solution for developing different fuels."

Originally, the CRC determined 202 statistical formulations of candidate components for an unleaded fuel. The formulations were narrowed down to 30 different blends, and the FAA Small Engine Test Facility performed full-scale engine detonation testing on them. "From those tests," Atwood says, "some predicting models were developed, where we could say, 'try this much of this chemical, this much of another, and we think the result will react in the engine in this manner.' Now, we're hoping the 45 new blends generated from the previous round of testing, the candidate mixtures being shipped this year, will get us even closer – and will spur further research to come up with something that really works."

Some early formulations gave Atwood and Byrnes hope of coming close to the performance of 100-octane low-lead aviation gasoline. Atwood says, "We can get a fuel ►

Figure 1: Detonation Levels



that works detonation-wise, with about eight percent amine. Basically, that's a hydrocarbon with nitrogen in it. The problem is, the necessary additives are expensive and, at 60 degrees Fahrenheit and below, they sink to the bottom of the tank. So, they don't offer a real solution." (See Figure 1)

The team also considered another product, a highly refined iso-octane, which costs about $11 a gallon shipped. "It didn't solve the detonation problem in large-bore engines," said Byrnes. "Even if iso-octane were perfect, its chances of becoming mainstream are remote. The specialty chemical is a single hydrocarbon, while normal gasoline is made from thousands of hydrocarbon compounds. Iso-octane is not a practical solution, although it may be a good reference fuel."

"So far, there's no additive you can afford to buy that will truly work," maintains Byrnes. "The octane requirement of general aviation planes is higher and more demanding than those chemicals can satisfy. Nothing we've tested works as well as tetraethyl lead in preventing detonation in a piston engine."

"At some point, we're going to exhaust all possibilities," Byrnes concludes. "There may come a time when the industry will have to consider other solutions. Once that happens, the simplest answer might involve researching more advanced engines. When we look at cars – and how their engines compare in horsepower with those of the late 1960s – we know it's possible to come up with a workable technology." R&D Review

For information on the FAA unleaded aviation fuels program, please contact Skip.Byrnes@faa.gov or Dave.Atwood@faa.gov.

Developments in Icing

Studying In-Flight Icing

The newest feature of the FAA-developed Current Icing Product, or CIP, includes a depiction of the probability of icing's occurrence and its severity. Developed at the National Center for Atmospheric Research (NCAR) with FAA funding, this new capability is part of an upgrade to the CIP.

"This is a major advance that will enable dispatchers and, in some cases, pilots to choose flight paths that avoid icing conditions," says Marcia Politovich, team leader of in-flight icing research at NCAR. "The new CIP will help make air travel safer." Commuter pilots at Air Wisconsin, Atlantic Coast, ComAir, and SkyWest tested the technology and gave researchers feedback throughout the development process.

Potentially, ice pellets and cloud droplets that freeze on contact may affect air travel anywhere in the country. Because drag from the build-up of ice on its wings can jeopardize an unprotected aircraft's ability to stay aloft, pilots have sometimes detoured for hundreds of miles. In 2006, the FAA approved CIP as a supplementary tool for meteorologists and dispatchers to use for enhanced situational awareness.

The new version of CIP, which is updated hourly, with selectable altitudes up to 18,000 feet, uses advanced weather prediction models and additional detailed observations. Instead of simply indicating the potential for icing, it quantifies the probability of icing encounters and their likely severity.

A study by the National Transportation Safety Board found that in-flight icing was responsible for dozens of accidents a year, mostly among unprotected general aviation aircraft. More than 800 fatalities occurred in accidents under these conditions from 1982 to 2000, with most accidents occurring between the months of October and March.

Cancellations and delays due to icy weather can cost airlines millions of dollars in a single day. On March 20, 2000, deicing crews at Denver International Airport were overwhelmed by an unusually large number of aircraft that, after circling because of heavy air traffic, landed with heavy ice build-up and then needed deicing treatment before taking off again. As a result, hundreds of flights were delayed and/or cancelled.

CIP will supplement but not replace the information in the National Weather Service AIRMET, the traditional weather alert issued at six-hour intervals. R&D Review

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Readers wanting more information on this promising new technology may contact Marcia Politovich, NCAR scientist, on the Web at: marcia@ucar.edu

R&D in the Community

R&D airport technology researchers Jim Patterson and Nick Subbotin participated in the Boy Scouts of America - South Jersey Chapter Annual Boy Scout Show at the Shore Mall in Egg Harbor Township, NJ. Patterson and Subbotin used the FAA Aircraft Rescue and Fire Fighting Research Program's High Performance Research Vehicle, Crash 9, and smaller truck, Crash 14, to present and demonstrate the 'futuristic' technology installed on both vehicles. Scouts also had the opportunity to 'gear up' in actual airport fire fighting gear. The airport technology R&D branch actively participates in community events to showcase the FAA's ongoing research to ensure aviation safety and efficiency. R&D Review

Q&A

A Few Moments with Earl Stein

Question: Will you tell us a little about your background as a researcher and manager?

When I finished grad school, as an Experimental Psychologist who had also taken ROTC, I thought the Army would place me with all the other psychologists in the Medical Service Corps. The Army, however, sent me to the Signal School at Ft. Gordon, Georgia. After graduating from the school, I served in several units. At the Selection Center at Ft. Jackson, I did research trying to determine how to select the right person for the right Army job. At the Assessment Center at Ft. Benning, I studied whether we could accurately predict performance in the future. My third and last active army assignment was with the Behavioral Science group in the Food Sciences Laboratory in Natick, Massachusetts. For three years, I worked in inter-service projects related to food service worker training and food preferences for soldiers, sailors, and airmen. Primarily, we did field research in places like Norfolk and isolated duty stations in Alaska. I also had a really "tough" three week stint at Pearl Harbor. One advantage of this work was that, under most conditions, I ate really well.

Question: Why did you choose aviation and the FAA?

In 1977, I left the active Army and went to work for the Army Research Institute (ARI) in Alexandria, Virginia. Our mission was to develop and evaluate combat simulation training for the infantry, armor, and field artillery as well as for air defense. I spent three years at ARI – more often than not on temporary duty. I went to hot places in the summer like Ft. Bliss, Texas, and cold places in the winter like Ft. Carson, Colorado. We developed the metrics, analyzed data, and wrote up the results for use by the decision makers in the training and doctrine command. We also supported training evaluation by collecting data and teaching military personnel to do the same. My last job with ARI – trying to train people to shoot down aircraft more effectively – involved air-ground engagement simulation. That's how I got into aviation. Coming to the FAA in 1981 represented a cultural change in more ways than one. For example, as a Department of the Army Civilian and former Captain it would not have occurred to me to call senior personnel by their first names. I pretty much still do not.

Question: In what ways does your organization support the FAA mission?

We are part of the ATO-P Human Factors Research and Engineering Group, an organization that supports the ongoing FAA mission. Based in Atlantic City, the Human Factors Team is comprised of engineering research psychologists. We work on research and engineering projects that set near-term and NextGen sponsor requirements. Our sponsors fund us to do this work. All the funding is related to the projects that we agree to accomplish. We take pride in doing what we say we will do, on time and on budget. As long as the sponsor has not increased the scope, we have never gone back and asked for more of anything once we have taken on a project.

Question: Why is human factors research and engineering an important part of the FAA R&D program?

As long as a system includes human beings at any level from operations to maintenance to selection and training, human factors will be a necessary component of development and subsequent modifications. That's why human factors plays a significant role in the Agency's acquisition management system documentation. It is also well represented in various publications on systems engineering as a form of specialty engineering within the overall domain of systems engineering.

If a system is acquired or modified without taking into consideration the people, their strengths and weaknesses, then you will have problems you have not anticipated. Human factors research and engineering is all about finding out the best way to employ people and what they really need to help them do their job. Too often we have seen this brushed off as unnecessary and we have paid and paid. There is an old mechanics' statement which says something like: "You can pay me now, or you can pay me later!" The Standard Terminal Automation Replacement System (STARS) for TRACON controllers, was a case in point. Early intervention and consideration by human factors experts could have saved time and money in the necessary design and unfortunately necessary redesign of graphical user interfaces, which were supposed to have been do-able as a COTS (commercial off-the-shelf) procurement. Up-front human factors support could also have smoothed out the eventual deployment of the resulting system.

Question: What projects are you currently working on?

I should point out that the real answer to that question is what our team is working on. I sort of gave up hope of doing bench-level research when I became the manager of this band of professionals. My job is to get my colleagues the money, materials, and space they need. Then I handle the administrative details that let them accomplish our work.

We are a service organization, and many factors influence the way our projects evolve. At any one time, our eleven psychologists and contract support may be working ten, fifteen, or more projects. Right now two major simulation projects are running. The first is FEWs, or the Future En route Workstation. This is a multi-year effort. FEWS is all about using known technology to increase a controller's capacity to move traffic safety and efficiently. We are finding that you can gain up to 30% or so in throughput by integrating already fielded systems through a straight-forward, technology-based division of labor. When controllers who have access to new advanced data sources work side-by-side with counterparts who currently just handle flight data, it is fascinating to watch how they divide the labor between them. We also are finding that one key piece of technology that is essential for the emergence of this improved efficiency is an effective data com (digital communication) system.

Another project that we have ongoing is the Enhanced Electronic flight Data displays for the tower cab. This involves replacing paper strips with optimized displays of key data elements on electronic displays that can be easily used and seen in the ambient light of the tower cab environment. The data we display is based on input from a subject matter expert group of what tower cab controllers really need to do their job. Our prototype displays are interactive, allowing changes to data elements using traditional keyboards and using touch screen technology. This year we will be building infrastructure to further test the concepts underlying these displays.

Question: What advances in aviation do you foresee over the next five to ten years?

When experimental psychologists are asked to predict the future we tend to be conservative and data-based. We don't always buy into what technologists suggest may or will happen. But when a particular system (or systems) finally reaches a new level of sophistication, some kind of middle ground often emerges – something on which stakeholders can agree. My experience leads me to expect evolutionary, not revolutionary, change. We will continue to modernize our equipment and increase its functionality giving controllers more tools. ►

They will actually use some of these and will ignore or turn off others, if allowed to do so. I personally believe that controllers will still hold the majority of the responsibility for separating aircraft in the next decade.

We anticipate that demands on airspace will continue to grow. But who knows how quickly? Aviation, like so many other service industries, is influenced by forces such as macro-economics – factors that often influence whether folks decide to fly. But controllers must deal equally with large and small aircraft. They are likely to feel the influence of more regional and small private jets. For them, all radar targets with certain capabilities and limitations must enter into their dynamic plan for safely working the traffic to maintain an appropriate level of separation.

Will the benefits of automation influence the air traffic controller's planning process? Probably, but we still will have to ensure that the controller can maintain vital situational awareness. Ultimately, people will always be accountable for system reliability, efficiency, and safety – even as their roles demand they exercise more and more supervisory control over automation. I expect that management by exception – the kind of management that calls for rapid decision making after long hours of air traffic oversight by humans – may create unintended and unforeseen system problems in the future.

Question: What research do you think needs to be accomplished to help ensure aviation's future?

I am only one old psychologist and I have never been known for being a seer. There is no one piece of research or even a group of pieces that will ensure aviation's future. Certainly we need to encourage a positive can-do attitude about building the airspace system of the future. This attitude needs to include a research program that serves as a foundation for the evolution of aviation and not as an afterthought.

Early human factors research and engineering can ensure that we field effective systems and avoid future development costs. Too often human factors research and engineering is seen as "a have to but don't want to" by program managers. In fact, our discipline is one element of good positive systems engineering, and it should be ongoing from concept to fielding of a new system. It is futile to hold program managers accountable for fielding systems on time and within budget regardless of whether the resulting systems are all they can be. Again this is strictly my professional opinion – I am only speaking for myself.

Let me expand on this idea. When we're considering new technologies, we should ask certain research questions as soon as we can. Let's say we're looking at a system that would seem to give controllers so much help working the traffic that they could become much like assembly line workers. We should ask: "What happens when the system starts breaking down?" This question and those underlying it are within current guidance proposed by the Joint Planning and Development office or JPDO.

We tried this, in part, a number of years ago comparing controllers who were actively working simulation traffic and those were passively monitoring while the system or other controllers moved the aircraft. When we stopped the simulation, the passively monitoring controllers simply did not have the picture. They probably could not have jumped in and taken over even though they were fully trained certified controllers. Perhaps we should evaluate how this would work in simulation so that we could avoid problems in the future. To do this type of research, we will need the sponsorship and funding essential to get the job done. Doing the research always competes with other often more salient priorities for limited resources. Keeping the system operating safely and efficiently has to take priority. Having the vision to invest in human factors research and engineering for the future is essential and requires priorities of its own.

Question: What advice would you share with people considering a career in aviation?

If you are thinking about human factors engineering as a profession, then aviation is one cool place to work. There is always something going on and there will likely always be work to do that pays a livable wage. The key here is getting the education you need to be competitive. It does not hurt at all if you are also a licensed pilot, but many of us are not. You need at least a master's degree – and preferably a Ph.D. or a Psy.D. – from an accredited university. Your undergrad degree can be in psychology, engineering, computer science, or any other major science including math. Get all the math and science credits you can and load up on computer science, which did not really exist when I was an undergraduate.

In grad school, you should be looking for a degree in experimental psychology, human factors, or possibly industrial engineering with a subspecialty in human factors. If you can get an internship with an organization that is aviation-related, that is a plus. It doesn't have to be with the government. The more you know about aviation the better, but we would be interested in someone with good research skills first and aviation knowledge second. Applied research experience will give someone a real leg up if that person is looking for a human factors job in aviation. It will also give you the opportunity to publish. A publication list as part of an application package is a very positive indicator of someone who has the skills we need.

Question: Is there anything else you would like our readers to know about you?

I have a current state professional license as a psychologist. I took the board while stationed in Massachusetts and have kept the license current since 1975. My wife and I have been together for over forty years having met at the University of Maine in 1963. I have two children, a daughter who was once a Clinical Social Worker and a son who is a police officer in Columbia, Pennsylvania. He has two sons of his own, my grandsons Asher and Spenser. R&D Review

Yielding Results

Joint FAA/NASA Wake Turbulence Research Program

The FAA and NASA are jointly conducting a multi-phased research and development program to increase capacity while maintaining or reducing the risk posed by wake turbulence at certain U.S. airports. This research program is also supported by the U.S. Department of Transportation at its Volpe National Transportation Center, MITRE at its Center for Advanced Aviation System Development, the Massachusetts Institute of Technology at its Lincoln Laboratory, and others.

The near-term research phase addresses arrival capacity at airports with closely spaced parallel runways, here referred to as CSPRs, during less-than-visual conditions. Mid-term research is looking into the potential of applying wind-dependent procedures to improve departure operations from these runways. The long-term research phase will develop new technologies, for installation on the ground and in the flight decks of aircraft by 2025, to deal with additional weather variables that affect wake behavior and to achieve many of the capacity goals sought for the Next Generation Air Traffic System (NextGen).

The aerodynamic effects of air passing under a moving aircraft's wing, or "lift," make flight possible. In the trail of the aircraft, however, lift remnants degenerate into localized patterns of turbulence somewhat like the wake generated by a water craft. While this wake phenomenon occurs when aircraft operate at any altitude, it poses the greatest risk to aviation during takeoffs and landings – times when aircraft are typically operated most closely to one another and to the ground. For this reason, past and present air traffic control standards define the allowable separation between aircraft that are taking off or landing.

Separation standards have been designed conservatively. As a result of this conservatism, and because the full standards have routinely been enforced when aircraft were operating under instrument flight rules, wake turbulence has never caused a fatal accident in the U.S. Some of the standards may be relaxed during good visibility when the trailing pilot can observe the lead aircraft, assume separation responsibility and apply wake mitigation procedures. The goal of the wake turbulence research program is to find additional opportunities for the safe reduction of wake turbulence separation standards – to increase the capacity of the national airspace system.

The Wake Turbulence Research Program is looking into the varied effects of ambient weather conditions on wake turbulence (or wake vortex) behavior. For example, under conditions with calm prevailing winds, wake vortices from recently arrived aircraft can linger near the "threshold," the section at the end of the runway first encountered by arriving aircraft. With moderate crosswinds, these swirling eddies can be blown out of the arrival corridor entirely. With increasingly strong crosswinds, the "life" of each individual wake decreases and this wake decay becomes an important additional mitigation factor. Placing precise bounds on the limits of wake behavior is the first step in knowing when it is safe to relax the current standards and capture capacity gains in the system.

Arrival capacity at airports with CSPRs, runways spaced closer than 2500 feet, is reduced to that of a single runway in weather that is less than visual conditions. The controller handbook, 7110.65, requires controllers to treat CSPR runways as a single runway under those conditions due to collision risk and wake turbulence considerations. Until the weather improves, arrival capacity is effectively cut in half at these airports – and a ripple effect can be felt throughout the aviation system as a result. A promising solution has been found.

A new concept known as simultaneous offset instrument approaches (SOIA) can now keep some of these facilities operating at a higher capacity in bad weather. Under SOIA rules, controllers at an approved facility are relieved from providing the same in-trail separation between two aircraft arriving on parallel runways as is required between two aircraft arriving to the same runway. Instead, new "laterally offset" patterns provide continual separation of 3100 feet or more between aircraft that effect a critical portion of their final approach to the parallel runways from slightly different angles. The Precision Runway Monitor, a one-second update radar, also helps to ensure collision avoidance between these independent approaches until the aircraft descend below the ceiling and can continue on visual approaches to the runways. One aircraft then continues straight onto one runway and the other aircraft performs a small S turn from the 3100 feet offset approach to line up with the other parallel runway. The slightly longer path associated with the small turn also helps ensure the second aircraft will not overtake the first aircraft. ►

Image Courtesy of © Ben Wang and www.airliners.net

Researchers used wind anemometers, a pulsed lidar, and sodar, or sonic detection and ranging system is to measure remotely the vertical turbulence structure and the wind profile of the lower layer of the atmosphere over a two year period to collect more than 250,000 aircraft wake data tracks at San Francisco International Airport. Data analysis demonstrated that wakes from leading small and large aircraft pose no unacceptable risk to the trailing aircraft along the visual segment to the parallel runway from 750 feet away virtually up to its threshold. Rare instances were noted when wakes from Boeing 757 and other heavy aircraft transported to the adjacent approach at SFO. But the research further showed these wakes could safely be avoided if the trailing aircraft were kept within a single nautical mile behind the lead aircraft during the parallel approach. This pairing window, however, is somewhat dependent on the strength of the crosswind. Investigation is underway to determine whether a new decision support tool is needed to support the controllers in customizing a safe pairing window.

A wake behavior model based on the SFO data has been integrated into Flight Standards Airspace Safety Assessment to create a promising new toolset that facilitates the goals of Airspace Simulation and Analysis (ASAT) for Terminal Instrument Procedures (TERPS). Combined with other findings at SFO, use of this tool has led to the approval and implementation of SOIA at the Cleveland Hopkins and Lambert Saint Louis International airports. Thresholds displaced 1,700 feet or more create sufficient lateral and vertical separation to ensure wake avoidance from all aircraft types leading on the lower approach, so no pairing windows were required for these configurations. The parallel runway separations at these facilities are 1,241 feet and 1,300 feet respectively.
At Ted Stevens Anchorage International Airport (ANC), some operational configurations require heavy aircraft to depart from one CSPR runway in the opposite direction of departure operations from the other CSPR runway. The controller handbook requires a three-minute wait after the heavy departure before an operation can be conducted on the CSPR runway. Using the wake model and ASAT, Flight Standards found that ANC could safely waive the 3 minute separation standard when crosswinds were no greater than 15 kilometers and it could be assured that the heavy departure did not lift off until it was abeam of or beyond the departure point for the opposite direction traffic.

Lambert Saint Louis International is about to implement another of the research program's findings, a reduced separation standard for dependent parallel approach operations to closely spaced parallel runways. Under the current rules, when flying in less-than-visual conditions on parallel approaches to runways spaced 2,500 feet or farther apart, aircraft of all aircraft weight categories, including heavy and Boeing 757 aircraft, must maintain 1.5 nautical miles of diagonal separation. This separation standard is overly conservative for the bulk of the traffic (large and small aircraft) served at many CSPR airports.

The goal of the wake program is to develop reduced separation standards that consider the weight category of the leading aircraft in a pair, the runway centerline separation, as well as the threshold displacement between the two parallel runways.
(continued on page 36)

Safety First

Modeling Engine Debris Damage

"Engine disk failure, although rare, is one of the leading propulsion related safety hazards in aviation," explains William Emmerling, FAA propulsion researcher. "Fan disk failures, in particular, pose a significant threat because they are large heavy parts that rotate rapidly. If one of these high-energy disks cracks and fails, it can exit the engine case leading to an uncontained failure. This type of failure can turn catastrophic because the resulting fragments can exit the engine at high speeds and in many directions." Although uncontained engine failure events involving fatalities are very uncommon, uncontrolled high-energy fragments pose a serious risk to passengers, crew, and airframe integrity.

Analysis of rotor bursts is complex. To minimize the damaging effects from such a failure, FAA researchers are working with Naval Air Warfare Center (NAWC), Weapons Division, China Lake on engineering analysis approaches that can identify critical components put at risk during an uncontained event and thus allow the designer to relocate the components to an area of lower risk before the design is finalized. The Uncontained Engine Debris Damage Assessment Model (UEDDAM) is one weapon in the FAA's growing arsenal.

Adapted from an analysis package originally developed by the Department of Defense, the modifications and enhancements the FAA has funded are now applicable to the certification of civil aircraft. UEDDAM incorporates fragment penetration, system-level hazard assessment, and multiple fragment analysis to shed light on risks to airframe systems during a rotor-burst event. The model closely recreates the aircraft geometry, system dependencies, and debris (threat) characteristics to allow an analyst to visualize an uncontained engine failure. As a design tool, UEDDAM can provide early insight into probable hazards created by an engine rotor burst. As a proposed alternate means of compliance, it provides a standardized approach that can aid officials in assessing and minimizing rotor-burst hazards.

The UEDDAM software employs a Monte Carlo statistical analysis technique to assess an aircraft's hazard probability. Researchers integrated existing models in UEDDAM to determine the ballistic impact of projectiles. Together with debris definition and aircraft geometry, the tool draws upon the military's Fast Shotline Generator (FASTGEN) geometric modeling to develop debris fragment trajectories through the aircraft. A modified version of another military model – Computation of Vulnerable Area and Repair Time (COVART) – provides vulnerability assessment based on these trajectories and debris characterizations, and then summarizes the component contribution to the aircraft hazard level. The developers of UEDDAM modified COVART to include penetration equations more suited to engine disk and blade fragments than existing equations for munitions. Penetration equations were developed through a series of tests including full-scale blade fragments impacting a fuselage section at NAWC China Lake.

UEDDAM accumulates the results from COVART for multiple possible fragment trajectories associated with a single-release origin, multiple-release origins about the circumference of the rotor disk, and the multiple rotor stages in the engine. The tool then generates the hazard probability for each event in summary format, and provides details of the critical component contribution for each execution of the Monte Carlo analysis. The analysis can simulate fragment impacts to recreate a real event and can randomly repeat itself many times to develop the cumulative probability of hazard associated with the event. UEDDAM also tabulates risk angles for each critical component or event. It may be used to assess debris types independently or debris types may be combined in a single evaluation of the hazard for a specified uncontained event. ►

A visualizer presents a graphic depiction of the complex data and information generated from a UEDDAM run. This tool provides analysts and researchers with a powerful means to "see" the integrated effects of aircraft geometry, debris hazard zones, debris trajectories, probability plots of hazard levels, and translational risk angles.

Although the FAA does not yet use the model for commercial certification, the U.S. Air Force has used an earlier prototype to validate design of a large transport aircraft. In a 2004 description of its C5 re-engine program, the Air Force reported, "In a unique approach to the problem, we were able to answer both LFT&E (live fire test and evaluation) and safety issues by using the latest Federal Aviation Administration endorsed methodology. The use of UEDDAM allowed the program to realize large cost savings while answering vital questions about the safety and vulnerability of the upgraded engines due to cascading damage."

FAA researchers continue to work with their counterparts at the Naval Air Warfare Center to enhance UEDDAM. In September 2006, they released Version 3 of UEDDAM. One improvement includes the ability to assess aircraft decompression hole size as an output of the hazard analysis. Other significant enhancements involve user-defined inputs that allow manufacturers to insert data from their proprietary materials into the code. The research team finalized the new release after incorporating recommendations from a November 2005 UEDDAM training session. To encourage transition of this technology into commercial use, the FAA has hosted training and user feedback sessions with personnel from Boeing, Embraer, Pratt Whitney, General Electric, and the Department of Defense.

"We consider the UEDDAM vulnerability assessment tool a major accomplishment toward our goal of enhancing the safety of commercial aircraft," states Emmerling. "By automating threat analysis, this tool allows us to examine the threat posed by uncontained engine debris and determine the best steps to mitigate that threat. Version 3 addresses industry requests for changes to the code, and planned Version 4 improvements will take advantage of available code improvements the Department of Defense is currently making and will also improve the output options and user feedback during execution of the code." R&D Review

For additional information on UEDDAM, please contact William Emmerling via e-mail at william.emmerling@faa.gov.

Solutions Today for Tomorrow's Challenges

FAA's En Route Workstation

FAA's Future En Route Workstation

The capacity of our national airspace system is limited by current technologies, procedures, and air traffic controller workload. Aviation analysts forecast more than one billion passengers by 2015 and 1.2 billion by 2020. New aircraft will increase the airspace complexity by mixing very light jets, large aircraft such as the Airbus A-380, and unmanned aerial systems all operating within the same high-density airspace.

The FAA's ultimate goal is to reduce the time and steps necessary for controllers to interact with pilots and other controllers, thereby enabling them to focus on separating aircraft and moving aircraft through the airspace. The FAA Air Traffic Organization Operations Planning (ATO-P) Human Factors Team in Atlantic City created a prototype en route controller workstation to test their theories. The team is using the Future En-route Work Station (FEWS) to reduce controller workload and discover how much traffic can be handled in the future using integrated information displays and automation with currently available data sources.

Background

As Russ Chew, former FAA Air Traffic Organization (ATO) Chief Operating Officer, explained at the 2006 ATCA conference, "by the middle part of the next decade, we have a problem. We have an en route airspace problem . . . We're never going to reach two to three times [capacity] by 2025 . . . Because we can't scale that anymore. When you reach the limit, you can't just shove more airplanes down a human being's throat and say, 'just handle it.' You've got to do something . . . You have to actually integrate from end to end . . . Otherwise you don't get more capacity."

"Current approaches to air traffic control simply cannot meet the increasing demands and complexity of the future system," echoes Dr. Terry Allard, FAA ATO Operations Planning Manager of Human Factors Research and Engineering. "To meet future needs, FAA human factors experts are developing and testing new, integrated information displays that decrease the workload of air traffic controllers, enabling them to handle increasing air traffic levels now and in the next generation air transportation system. We are finding practical and potentially low-cost solutions to overcome capacity challenges." Dr. Earl Stein, manager of the FAA ATO-P Human Factors Team based at the FAA William J. Hughes Technical Center in Atlantic City, explains that "our specialists are collaborating with Air Traffic Organization service units to conduct human-in-the-loop simulations and live tests to identify which concept alternatives work most effectively for the people who will use them. Our job is to ensure these considerations are systematically integrated at each critical step in the design, testing, and acquisition of any new technology introduced into the national airspace system. Technology innovation and human factors must be considered together to meet new capacity demands safely and efficiently."

FAA human factors specialists at the Tech Center are conducting research that will enable controllers to meet increasing demands in the near-term. "Many of the more advanced en route controller tools that we have introduced over the last decade have had separate development cycles," says Dino Piccione, FAA technical lead for the FAA ATO and ATO Technical Operations Service Unit research and engineering program. "As a result, the Agency has deployed separate systems with automation functions that could be integrated in the controller workstation. For example, efficiency could be increased and controller workload decreased if some aspects of the User Request Evaluation Tool (URET) are incorporated into the En Route Automation Modernization (ERAM) system. We are aware of the challenges integrating diverse technologies will create. Part of our human factors mission is to develop concepts and approaches to getting the job done quickly and effectively."

The Future En-Route WorkStation (FEWS) concept

The national airspace system (NAS), as it currently exists, already contains a wealth of data sources and systems supporting aircraft separation, the primary safety and capacity function of air traffic management. Many of these data sources and systems were developed and deployed independently over time without taking into account how they would be used together or what impact multiple systems would have on air traffic controller workload and decision-making. "In the first phase of the FEWS project," says project lead Ben Willems, "we are looking at how the time and effort controllers need to exchange relevant information can be streamlined by better information presentation, information integration, automation, and by changing the scope of controller operations."

The FEWS goal is to integrate and automate many of the information functions that already exist and to see what new technologies and approaches are needed in order to meet future capacity requirements. The human factors team is using what is already available, and integrating it in a way that helps controllers. Willems adds, "Our focus is on providing support for primary air traffic control tasks, while decreasing secondary often mundane tasks wherever possible. ▶

We are attempting to allow the controllers to go back to basics -- to control air traffic." (See Ben Willems, "Future En Route Air Traffic Control Workstation: Back to Basics," Proceedings of the 23rd AIAA/IEEE Digital Avionics Systems Conference, pp. 5.A.3.1-12; Piscataway, NJ: IEEE.)

Data display integration and automation make it possible for controllers to focus their efforts on moving traffic. For example, the FEWS automation approach allows for:

- Full data block drop-off
- Dragging of full data blocks - instead of using the cardinal orientations that are linked to the numeric keypad layout
- Handoff acceptance
- Route display on a click on the controller's information display - currently route display requires an entry that involves the keyboard
- Preferred orientations of the leader lines based on a fix and destination - currently leader line orientations are only based on the direction of flight

In today's en-route systems, two people manage an airspace sector when traffic and complexity necessitate such staffing. The radar controller, who is in charge of the sector, talks with pilots, and the data controller helps to maintain situational awareness by coordinating with neighboring sectors and updating the computer systems. If the sector gets really busy, the data controller gets pulled into a tactical mode, and acts as a second pair of eyes, often looking over the radar controller's shoulder to help manage the traffic.

To avoid that situation and enhance teamwork and communication, the FEWS prototype provides identical displays for the two controllers. Under this new concept, the data controller – if certified to perform radar separation – can contribute more easily without distracting the radar controller. With the new improvements, a controller can right-click a screen call sign sending a clearance, and, at the same time, highlighting the action on the other controller's display. The actions of the second controller are not interrupted or interfered with in any way – something that is impossible under the current system.

The paired controllers will be able to communicate without actually talking to each other. Of course, controllers can still verbalize any development if they want to, but freeing them from voice communications should help them manage their sector more efficiently.
If repetitive responsibilities can be programmed, controllers will be free to focus on their real job – keeping airplanes safely separated.

FEWS Test and Validation

FAA researchers and engineers are validating the FEWS concept by human-in-the loop tests in a simulation environment in the Human Factors Lab at the FAA William J. Hughes Technical Center. The research team tests the FEWS approach directly with certified professional en-route controllers in realistic air traffic scenarios where the traffic level is varied beyond current levels.

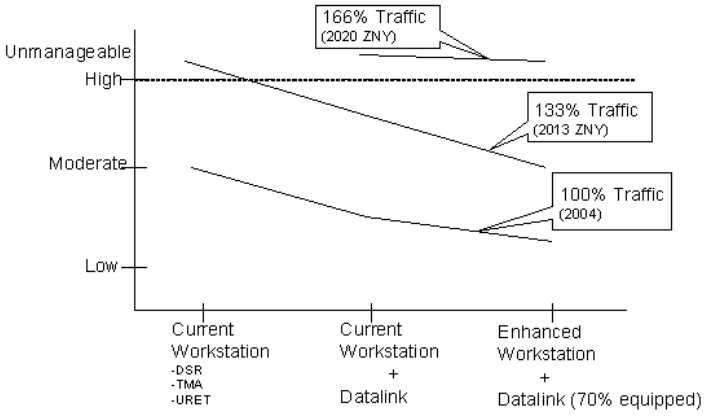
The researchers found that 30 percent of controller task load is what they termed as basic housekeeping -- required, but not contributing to productivity. Automating these tasks will improve productivity and efficiency. The team also discovered that the verbal communication workload will constrain operations in the near future. Data communications may be the best option to overcome this constraint.

FAA human factors specialists are testing new types of screen displays and procedures. In the future, for example, controllers will be able to double-click call signs to bring up flight details without going to the computer keyboard. They will instead use the mouse to bring up the electronic flight strip and direct the pilot to change the plane's route, thus uplinking instructions to the aircraft directly from the radar display.

In the first simulation, researchers calculated the time and number of events necessary for the controller to separate traffic. The en route controller volunteers worked simulated air traffic with a half dozen aircraft in a generic sector, gradually moving up to today's capacity – 21 planes. Researchers gradually increased the number to the 133-percent level, or 28 aircraft, and then ramped up to 166 percent, or 35 planes, then on to 40. Under one condition in the experiment, 70 percent of the simulated aircraft used data communications in addition to the normal radio contact.

During the simulation, researchers analyzed controller moves using eye-tracking equipment. The equipment lets the researchers measure the scanning pattern. They found that with 35 aircraft in the sector, the human eye could not pick up all the information necessary to control the traffic. (See Figure.)

Figure: Controller Workload Limits



Solutions Today for Tomorrow's Challenges *continued from page 21*

These applied research studies verified that a number of human factors constraints must be overcome for controllers to handle projected traffic levels in the near-term. Those limitations include voice communication, data entry, situation assessment, comprehension, and projection.

The Future for FEWS

Significant increases in air traffic capacity will be possible with the addition of data communication (datacom) systems datalink that further reduce the need for controller-pilot voice communications. Controllers at the future workstations will move away from text-based information and voice commands. Instead of taking the time to key the microphone and tell the pilot to descend to a specific altitude, the controller would send a message to the aircraft with just the click of a mouse. The pilot would confirm receiving the message, and the controller's screen would show the aircraft's response.

As a result of this initial work, the FEWS project team determined that data entry and visual scanning of individual targets on the controller displays will be the primary obstacle to increasing sector productivity once the voice communication roadblock is reduced through data communication systems. The current "one controller on one aircraft at a time" method of air traffic control simply will not work in the future. The researchers hypothesize that grouping aircraft into "chunks," i.e., one controller handling multiple aircraft simultaneously with the use of automation tools could significantly increase the amount of traffic one controller can manage.

The FEWS project team is working with the ATO Operations Planning and En Route and Oceanic service units to explore how these results can be incorporated into current and future ATO modernization plans such as the En Route Automation Modernization (ERAM) system. Implementation of some of the features studied in the laboratory environment may be straightforward enough to include in future releases of the en route automation system. *R&D Review*

For information on the future en route workstation project, please contact Ben Willems at ben.willems@faa.gov.

Excellence in Aviation Research Award

The FAA presented its 2006 Excellence in Aviation Research Awards to the Department of the Navy's Terrain Awareness Warning System (TAWS) Team in a ceremony at the Patuxent River Naval station on December 21.

"This technology is saving lives," said FAA R&D Director, Joan Bauerlein. "The Navy's research and development efforts on the terrain awareness warning system are dramatically improving the safety of military aviation and helping to meet safety goals for the national aviation system."

The Naval Air Systems Command Terrain Awareness Warning System, developed by the Air Combat Electronics program office led by Captain Gregory Silvernagel, is a patented software safety backup system for tactical aircraft that warns aircrews who have lost situational awareness of impending Controlled Flight into Terrain (CFIT). The Navy's TAWS software determines when to provide aural and visual warnings to the pilot.

Commercial off the shelf solutions for CFIT protection are effective for military transport aircraft, but do not work for tactical aircraft, such as the F/A-18. These aircraft are required to operate at very low altitudes and high speeds to accomplish assigned missions. Because commercial systems are ineffective in that environment, the Navy developed a software solution that provides predictive warnings of imminent CFIT to U.S. Navy and Marine Corps aviators.

The Navy developed the TAWS system at a cost of approximately $10.8 million over 4 years. The F/A-18 aircraft that it protects cost approximately $80 million, and the lives that it saves are priceless.

This is the tenth year that the prestigious Excellence in Aviation Research Award has been presented. The FAA presents the awards annually to individuals and/or institutions outside of the FAA whose research contributions have resulted in a significantly safer, more efficient airspace system.

For additional information on the award, please contact Dr. Terry Kraus at terry.kraus@faa.gov.

Normal Operations Safety Survey

"FAA human factors researchers are working with their international counterparts to help improve safety in air traffic management (ATM)," says Dr. Paul Krois, acting Operations Planning Research & Development manager. "NOSS, or Normal Operations Safety Survey, is a safety management tool being developed for ATM following the success of Line Operations Safety Audit (LOSA), a method for capturing the ways in which threats to safety are managed on the flight deck. Premised on the concepts of Threat and Error Management (TEM), NOSS provides a means of collecting safety data during normal operations."

In 2004, the International Civil Aviation Organization chartered the NOSS Working Group to develop a methodology to collect safety data during normal air traffic control operations. This panel of international experts immediately began work to create the NOSS framework. They believe that by conducting a series of targeted observations of air traffic control operations over a specific period of time and then analyzing the data, they can provide air traffic managers an overview of the threats, errors, and undesired events that air traffic controllers must manage on a daily basis. With this information, a facility or organization can make proactive changes to its safety process.

NOSS requires a multifaceted approach. We see measuring, analyzing, and predicting safety as the three keys to success with NOSS. "Conducting human factors analysis of air traffic management services," explains Dr. Krois, "will help us to improve the interface between people and the tasks they perform, the equipment they use, and the physical and organizational environment in which they work – all with a goal of increasing safety."

NOSS observations are uniquely different from data routinely collected, such as staffing levels, training programs, time-in-position, workload, complexity, and supervision. With its focus on normal everyday operations, a NOSS observation stops when a loss of required separation occurs for which mandatory reporting mechanisms apply. By analyzing data in all of these categories, NOSS will help identify safety concerns and lead to solutions to improve safety including how routine ATC operations adjust to transitions to NextGen capabilities.

In February, the FAA Human Factors Research and Engineering Group hosted the 2nd ICAO Global Symposium on Threat and Error Management and Normal Operations Safety Survey in Air Traffic Control in Washington, DC. Ninety representatives from thirty-six countries attended the conference to discuss NOSS developments and exchange ideas and ongoing research information.

Kathy Fox, Vice President for Operations at NAV CANADA, provided the keynote address at the symposium. She championed the use of the Threat and Error Management model and the NOSS methodology as part of a robust and proactive safety management system. Captain Don Gunther from Continental Airlines provided valuable insights from ten years flight deck experience with the Line Operations Safety Audit, the forerunner to NOSS.

Briefings by ICAO experts and University of Texas researchers explained the Threat and Error Management model and its application to air traffic control operations. In particular, they discussed characteristics of constant threats stemming from the aerodrome environment that occur beyond the influence of the controller and require constant human attention to maintain the margins of safety. Examples include runway crossings, shift handovers or position relief, similarities in call signs, differences in the ways pilots perform, and ever-changing weather conditions.

The presenters noted that controller errors are actions or inactions that lead to deviations from the intentions or expectations mandated by organizations or controllers themselves. An "undesired state" is any operational condition that results when some unintended traffic situation poses a reduction in the margins of safety. Most such threats and errors are normally handled successfully; but if unmanaged, they do have the potential to turn into operational incidents. The briefers also related the workings of the NOSS methodology to established observation protocols and the ten key characteristics emphasized by ICAO.

Representatives from Airservices Australia, Airways New Zealand, NAV CANADA, and EUROCONTROL (through its work with the Finnish Air Navigation Service Provider) presented findings and lessons learned from their individual and combined NOSS trials. Collectively, these researchers reported a range of five to eight threats occurred along with a rate of two to three errors per hour of observation, resulting in one undesired operational state for every two to three hours of observation.

Introducing the panel discussion, Stuart Matthews, former head of the Flight Safety Foundation, addressed key challenges involving protection of NOSS safety data, including anonymity of observed controllers and confidentiality of data. Panelists also discussed the safety change process and additional uses of NOSS data. The panel provided a lively interactive discussion with symposium participants.

Captain Dan Maurino, ICAO Coordinator for Human Factors and Flight Safety has made Symposium presentations available at: www.icao.int/anb/humanfactors and www.icao.int/anb/safetymanagement.

Currently, the FAA is defining a research study on how NOSS might be used to identify leading indicators to operational errors. R&D Review

For further information, contact Dr. Paul Krois at 202-493-5310 or paul.krois@faa.gov.

Clearing the Air

The Impact of Particulate Matter

FAA researchers are clearing the air about jet engine exhaust. Their studies of atmospheric emissions are leading to new ways to understand, estimate, and lessen pollution from aircraft. "Even as the aviation industry continues to expand," says Dr. Lourdes Maurice, "we are finding ways to reduce its contribution to pollution relative to other sources."

As Chief Scientific and Technical Advisor in the FAA Office of Environment and Energy, Maurice leads efforts to identify the impact of aircraft emissions on air quality. "In total, airplanes account for only two or three percent of the fossil fuels burned in the United States and contribute only a fraction of a percentage to pollutant inventories," she continues. "But these totals do not tell the whole story. The impacts of aviation on the environment vary locally, regionally, and globally. We must learn to analyze each of these impacts according to its own scale and, if necessary, find different solutions to different problems so that the industry can expand responsibly."

The Government Accounting Office reports that before 2003, data on one important air pollutant was simply not available for commercial aircraft. Maurice admits that, "Not long ago, calculating the aviation portion of particulate matter, or PM, remained an elusive goal. But recently, FAA analysts have found ways to glean valuable insights from new emissions studies undertaken by PARTNER, a dynamic consortium of government organizations and universities."

PARTNER, or the Partnership for AiR Transportation Noise and Emissions Reduction, is one of seven active Centers of Excellence established by the FAA. This Center draws additional support from NASA and Transport Canada.

"We have developed a living methodology based on the hard-core research provided by PARTNER," explains Ralph Iovinelli, research analyst in the FAA Office of Environment and Energy. "Given certain indicators, we can approximate aviation particulate matter emissions based on these studies."

In the NASA and PARTNER collaboration called Aircraft Particle Emissions eXperiment (APEX), engineers used sampling probes to record PM emissions from engines on small regional jets and large commercial aircraft under varied weather conditions. Testing in locales as diverse as the NASA Dryden Research Center in the California desert; Atlanta, Georgia; Oakland, California; and Cleveland, Ohio produced highly specific results. Probe locations within the exhaust plume ranged from 1 to 50 meters downstream from the engines, and the sensors took readings of engine power settings from idle to maximum thrust. The FAA simultaneously measured ambient PM loading and meteorological conditions surrounding the sample site so that results could be corrected for existing levels of pollution. Last fall, NASA recognized the FAA with an award for participating in this field research.

Iovinelli says the field emissions studies, albeit limited to a few commercial engines, yielded data that improved the first order approximation (FOA) methodology used to quantify particulate matter from all certified commercial engines. "The FAA had help in developing this valuable FOA methodology. We worked alongside a panel of experts within the International Civil Aviation Organization's Committee for Aviation Environmental Protection (ICAO/CAEP). We made some assumptions and together we succeeded in developing a series of mathematical expressions to quantify – in a conservative manner – the PM in aircraft exhaust." The new version, called FOA3, gets scientists closer to accounting for the triggers in producing PM. ►

Each driver of PM emissions identified through the FOA3 technology can be analyzed separately depending upon whether it is expressed as a primary or secondary pollutant. Iovinelli explains: "Primary PM comes directly out of the hot exhaust as black carbon soot or some nonvolatile substance. The secondary portion of pollutants result when the hot gasses cool in the atmosphere, changing from a gaseous to a solid phase. That secondary particulate matter, the volatile portion, is often chemically active in the air."

Secondary PM formation is believed to be driven by three processes. First, the sulfur in the emissions gasify into sulfur dioxide and sulfur trioxide, and finally the materials cool and condense to become sulfates. The resulting sulfate particles are very tiny. In fact, when measured according to the criteria expressed as PM2.5 by the Environmental Protection Agency, they are less than 2.5 microns (one micron equals one-thousandth of a millimeter) in diameter.

Fuel organics constitute a second part of volatile aviation PM that break down in the combustion process, gasify, and condense out as they cool in the atmosphere. The third driver of the formation of volatile PM, and the fourth component overall of the FOA3 methodology, is the least understood. Researchers suspect some lubricant oil from engines also gets released in one of two ways depending upon engine manufacturer and design considerations. It appears these oil-based substances may be introduced directly into the hot exhaust from a port in to core exhaust flow, or they may become entrained into the exhaust plume from a port located on the side of the engine. Iovinelli believes the influence of lubricant oil on PM formation warrants further research.

"Of the four categories, we've developed expressions for three, which certainly accounts for the lion's share of PM," Iovinelli declares. ICAO/CAEP has endorsed the FOA3 methodology to estimate emissions of landing and takeoff cycles at specific airports. As a result of this endorsement, says Iovinelli, FOA3 can become the interim global standard for predicting PM emissions from commercial aircraft engines. Following these developments, the FAA has incorporated the FOA3 methodology into the latest version of its Emissions and Dispersion Modeling System (EDMS), a tool developed to assess air quality impacts of various airport emission sources, both in the air and on the ground.

Already, the FAA Office of Environment and Energy is looking into that fourth part of the methodology, lube oil, on which FOA4 may focus. "Every time we tweak the FOA, we are standing on the shoulders of giants," Iovinelli says, borrowing a centuries-old phrase to describe the groundbreaking scientific research that supports the development of emissions methodologies. "Researchers around the world are taking measurements and analyzing the microphysics and microchemistry. It's our mission to take their work and factor it into our methodologies to advance our predictions capabilities."

Iovinelli outlines how different FAA environmental models will fit together. "We're midway through our six-year development plan, which involves integrated noise and emissions models. Over the next three years, the FAA will merge the EDMS capabilities to analyze emissions with the capabilities to analyze noise provided by the Integrated Noise Model. SAGE (System for Assessing Aviation's Global Emissions) and MAGENTA (Model for Assessing Global Exposure to the Noise of Transport Airplanes) will merge to better assess global emissions. By 2010, the emerging capabilities of the Aviation Environmental Design Tool (AEDT) will bring those four components together."

"Research on aviation particulate matter will result in the metrics and models to understand the impact of aviation PM, and if warranted to develop the technology to improve our environment," says Dr. Maurice, "We hope our work results in cleaner, more efficient airplane engines." R&D Review

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Get more details about the FOA methodology and EDMS at http://www.faa.gov/about/office_org/headquarters_offices/aep/models/edms_model/. For more information about PARTNER, visit http://www.partner.aero/

Continuous Improvement

Halon Replacement

The Halon-based fire extinguishing agents that have been used for decades to protect aircraft engine nacelles (and auxiliary power units) are known to damage the environment. In late September, the FAA drafted minimum performance standards to guide the search and regulate the performance testing needed to identify new, less harmful agents. In accordance with the new standards, full-scale fire tests must be conducted in a simulated engine fire environment to demonstrate that the new agents are equivalent in fire extinguishing effectiveness to the Halon compounds (short for halogenated hydrocarbons) in current use.

Nacelles are the cylindrical covered housings on aircraft, separate from the fuselage, that contain the engines and related equipment. The fire protection standards for these components are the final performance document for Halon replacement agents in civil aviation. Previously, similar performance standards were developed for use with lavatory extinguishers, hand-held extinguishers, and cargo compartment fire extinguishing systems. Each of the standards was a cooperative undertaking involving FAA and the aviation industry, including agent suppliers, extinguishing system manufacturers, airframe manufacturers and other interested parties. The work was completed under the auspices of the International Aircraft Systems Fire Protection Working Group (IASFPWG), a permanent advisory body chaired and administered by the FAA's Fire Safety Branch.

This achievement is a credit both to FAA fire safety researchers and the environmental values of the aviation community. First developed in 1948 by the Army Corps of Engineers, Halon quickly gained wide acceptance as a highly effective, non-toxic fire-extinguishing agent. The gas became a staple in many high tech environments, including aviation. Ironically, however, "people-safe" Halon proved dangerously unfriendly to the global environment.

In 1987, the United States signed the Montreal Protocol, the first major international agreement to curb the threat of global emissions that deplete the earth's fragile ozone layer. This agreement was undertaken as part of the United Nations Environmental Program, and has been amended twice since its signing. It established a list of problem chemicals, including Halon, and bound nations to ban their production by 1993 in the developed world and by 2010 in developing countries. Although its production has been banned in the United States since 1993, aircraft manufacturers have been allowed to pay a tax to recover, recycle, or reclaim basic Halon from old extinguishers used in various non-aviation applications. While the release of these reclaimed blends depletes the ozone layer at a rate of up to 16 times that of CFC-11, a common refrigerant, their continued "critical" use has been permitted because they protect vulnerable aircraft fleets and passengers.

Since 1993, the FAA has worked with industry and other agencies participating in the IASFPWG to certify an effective and safe Halon replacement. However, some agents that either have been adopted for use in non-aviation applications or that appear promising have been shown to have serious deficiencies when subjected to the complex and demanding engine nacelle fire extinguishing environment. The testing was conducted at the William J. Hughes Technical Center in a unique engine fire simulator that simulates a range of flight conditions and fire threats.

A separate IASFPWG subgroup has generally dealt with technical details related to the protection of engine nacelles and auxiliary power units. This subgroup initially undertook a large-scale, multiphase program run by the U.S. Air Force with participation from industry and other military branches. A three-phase process known as "Halon Replacement For Aviation" resulted. With this phased approach, researchers narrowed three promising Halon replacements down to a single agent, HFC-125, and slated it for follow-up research. Unfortunately, as noted above, subsequent realistic full-scale fire tests did not give promising results.

The IASFPWG engine subgroup later focused a new plan on the needs of transport category aircraft. This document, "Minimum Performance Standard for Engines and Auxiliary Power Unit Compartments," provided the basis for the FAA's new Halon replacement standards. Both FAA and the aviation industry are committed to finding effective and practical replacement agents for civil aviation engine fire extinguishing systems. FAA will continue to make its unique engine nacelle fire extinguishing test facility available to Airbus and Boeing, who have targeted the A350 and B787, respectively, for engine nacelle halon replacement agents. R&D Review

Interagency Cooperation Enhances Aviation Safety

When passengers board an aircraft the one thing they probably never think about is the airplane's wiring. They simply take it for granted. Nervous fliers are more apt to worry about the unlikely event of an engine failure or a wing falling off. But, there are miles of aging wiring, intertwined within complex wire bundles, located behind the side panels of an aircraft fuselage. Failure of these wires can potentially cause serious safety hazards. An intermittent electrical short due to frayed insulation can make lights blink and air conditioning falter. In rare circumstances, wiring failures can contribute to fatal accidents, as happened with SwissAir 111 or TWA 800.

FAA researchers, working in cooperation with their counterparts at the Department of Energy Sandia National Laboratories, have developed a new technology for improving the electrical safety of aircraft. They developed this newly patented and licensed innovation – called PASD, for Pulse Arrested Spark Discharge, to find an aircraft wiring fault so airline mechanics can take corrective actions before that fault can become a serious safety hazard. This work is so important to the aviation industry and the flying public that the Federal Laboratory Consortium for Technology Transfer recently awarded the team its first ever Interagency Partnership Award. The award recognizes the efforts of agency and/or laboratory employees from at least two different agencies who have collaboratively accomplished outstanding work in the process of transferring a technology.

PASD is the world's first wiring diagnostic tool that can detect and locate defects such as breached insulation, chaffing, and physically small insulation cracks. It is highly immune to line impedance variations – a necessary property in commercial aircraft – and does not harm the electrical insulation materials on the aircraft. Because of the simplicity of its underlying concept, the low energy PASD pulser and diagnostics technology is readily implemented into a portable diagnostic system and can be applied to a number of nonaviation wiring systems.

Tech Transfer

Improving aviation safety is the number one objective of the FAA. As part of the strategy to meet this goal, the FAA conducts a broad array of research with a number of external partners to leverage the expertise of other agencies, universities, and the ►

aviation community. The Aging Aircraft/Continued Airworthiness Research Program contributes to the FAA's strategic safety goal by reducing the number of accidents associated with failure of aircraft structure, engines, and systems. The program develops technologies, procedures, technical data, and performance models that help prevent accidents and mitigate accident severity related to airframe, engine, and system failures as a function of the age and usage of civil aircraft.

Following the tragic accidents of TWA Flight 800 and Swiss Air Flight 111, the FAA led an international effort to conduct a comprehensive review of aircraft electrical wiring design requirements and examined how to ensure the continued airworthiness of the wiring through the operational life of the aircraft. Among other things, the aviation community recognized that aircraft wiring is not simply a means for connecting one point of a system to another, but rather a highly complex system of interconnections. If strung end-to-end, the wiring in a transport aircraft might extend to one hundred, two hundred, or more miles. Much of the wiring is bundled together into complex harnesses that travel throughout the aircraft. As it travels through various sections of an aircraft, wiring may be exposed to extreme environments. It became clear to the aviation community that aircraft wiring requires care throughout the aircraft operational life, and that inspection of aircraft wiring is an essential part of this care.

As a result, the FAA expanded the scope of its Aging Aircraft/Continued Airworthiness Program to include research on aircraft electrical wiring. Research objectives included developing non-destructive inspection methods for aircraft wiring. As part of this work, the FAA began evaluating all possible technologies that might be suitable for wiring inspections. During this review process, FAA researchers became aware of the PASD technology being developed by Sandia.

Sandia's team originally conceived PASD for DOE applications involving facility control and power systems. FAA researchers quickly discovered that Sandia's expertise in pulsed power and high voltage sciences could help transform the PASD concept for use in inspecting the complex electrical wiring environment found in commercial aircraft. Recognizing the potential of PASD, the FAA initiated an aggressive three-year contract with Sandia to adapt and improve PASD for commercial aviation.

The joint research team successfully developed and prototyped PASD ahead of schedule. The FAA subsequently fostered a strategic and highly successful commercial partnership between Sandia Laboratories and Astronics. This technical relationship led to development of an advanced commercial product on March 30, 2006 – within nine months of the executed license. This partnership was of paramount importance in transferring PASD technology from the lab environment into production with all the capabilities needed to address a complex commercial market.

After concluding successful prototype testing, the FAA and Sandia transferred PASD technology to the private sector. In December 2006, its developer and manufacturer, the Astronics Corporation, made this technology commercially available as the ArcSafe® - AS1216 Arc Fault Detection System. As a result of this organizational cooperation, PASD is now in commercial use and is helping to prevent in-flight fires.

PASD can be connected to aircraft-installed wire harnesses, 40 wires at a time, to check them for the very small insulation breaks associated with intermittent faults. These sporadic short circuits occur where two exposed conductors, or a conductor and aircraft frame, make temporary contact during flight. Vibrations caused by turbulence may cause wires to touch, interrupting power to sensitive electronics and possibly damaging wires. These conditions are tricky to diagnose when the aircraft is stationary (on the ground) because the shorting wires often have shifted back to a non-shorted state. The pinhole-sized insulation gap of these breaks also may make them nearly invisible to the naked eye, like a fine cut from a razor blade. Traditional wire-test systems can not detect, much less locate, such defects.

The Team

Larry Schneider led the Sandia PASD team that included researchers Mike Dinallo, Steve Glover, and R. Kevin Howard. The technology enabling their PASD concept is both simple and highly effective. PASD uses a high voltage pulse to "interrogate" the insulation on wiring. Described in layman's terms, because the pulse lasts for a mere ten billionths of a second, like a static charge that builds up when one walks across a carpet, it cannot damage the wiring conductors or insulators. ►

The voltage involved, however, is quite high, causing harmless energy to jump from the smallest insulation break to the bulkhead or to another nearby damaged wire. That jump — again like static electricity moving from a hand to a doorknob — sends a unique signal back down the wire, in effect lighting up the damaged spot. Automated test equipment analyzes the amount of time it takes for the signal to return to its source, showing within inches how far the defect is from the test entry point.

As the FAA project leader, Mike Walz developed the system requirements in conjunction with team member Cesar Gomez. While the Sandia team refined the PASD concept, the FAA team brought requisite aerospace application experience to the project. Through this coordinated research, Walz and Gomez characterized the types of wire defects the technology needed to target to serve commercial aviation needs. Along with the Sandia team, Walz and Gomez developed the test protocols necessary to evaluate the performance of the PASD technology.

Walz also had responsibility for ensuring that the PASD technology would be safe for use on aircraft. This interagency team of engineers worked hard to minimize the potential for electrical discharges. PASD actively creates an electrical discharge in locating wiring defects, making it essential for the team to assess fully any potential safety hazards to aviation. The FAA team led the effort to identify the potential hazards and to conduct the analyses and tests necessary to assess the hazards. They then worked with the Sandia team to refine PASD, making sure that the energies released during a PASD test would not create a safety hazard.

The FAA team recognized the value of teaming Sandia with a product development company to make PASD suitable and accessible for use by the aviation community. Gomez and Walz worked together with Sandia to find corporate sponsorship, restructure contracts, and facilitate transfer of PASD technology the benefit of the aviation community and flying public. The FAA team recognized the strengths of matching the Sandia researcher's capabilities with the product development know-how of the Astronics team, moving PASD from the lab to a product in the aviation community.

The simple PASD technique should make it financially feasible for airlines to quickly diagnose and locate intermittent ►

Interagency Cooperation Enhances Aviation Safety *continued from page 35*

faults that have plagued the industry and cost millions of dollars in lost revenue due to aircraft downtime. By enabling airline mechanics to efficiently and accurately locate and repair a wiring fault, disruption to the aircraft and downtime are minimized. In the words of Astronics team leader Mike Ballas, "We really value PASD technology. We licensed it, turned it into a practical portable test unit targeted for the aviation industry to find intermittent faults, and we believe it's the best way now to do the job." Says Robert Pappas, FAA program manager for aging aircraft research and the first to recognize the value of Sandia's original research proposal in 1998, "It would have been unfortunate if PASD had been developed and then remained stuck in a lab. Integration of the technique with others offered by Astronics' ArcSafe is a real success story." R&D Review

Yielding Results *continued from page 22*

At Lambert Saint Louis International, the CSPR runways are 1,300 feet apart and there are 1,700 feet of displacement at the end of Runway 30 and 3,035 feet of displacement ending Runway 12. Wake data was collected at multiple locations on approach and over 150,000 wake data tracks from large aircraft were analyzed. Coincident wind, ceiling and visibility data were also collected and analyzed, along with aircraft position data from an expanded multi-lateration system.

After analyzing the data, supplemented with Monte-Carlo techniques using the ASAT tools, the research team concluded that 1.5 nautical miles was a safe minimum diagonal separation behind a large or small aircraft on the lower approach. This procedure can be used down to CAT I minima and therefore can complement arrival procedures like SOIA, which have higher ceiling and visibility minima. Some of the other CSPR airports (e.g., Cleveland Hopkins, Boston Logan International and Philadelphia International airports) have similar or larger runway separation and threshold displacement and are likely to support similar wake avoidance solutions. The goal of the program is to develop a national standard by 2008.

The joint program is also developing Wake Turbulence Mitigation for Departures, a wind-dependent departure solution for closely spaced parallel runways. This work builds on the procedural solution of the near-term and introduces part of the ground automation needed to meet initiatives required by the Next Generation Air Transportation System. The new protocols allow for the elimination of a departure wake restriction under specific wind conditions, thus improving capacity. The program currently is developing a prototype system to be placed at George Bush Intercontinental. There are at least ten airports where data indicate the use of the system would improve capacity.

The joint program has also applied its near-term research findings and models to support the development of separation standards proposed by the International Civil Aviation Organization for the Airbus 380 aircraft. Separation standards work has begun for Very Light Jets as well as other new large aircraft, such as the Boeing 747-800. Also, the research efforts in the U.S. and Europe are being coordinated through the FAA/Eurocontrol Cooperative Research and Development Action Plan 14 and are beginning to form around a wake avoidance solution for single runway departures.

The sequence of wake avoidance solutions is structured to build incrementally on the program's developing knowledge of wake behavior and its experience in applying that knowledge in an operationally effective way to increase capacity and maintain or improve the level of safety in the national airspace system. In pursuing these initiatives, this effort is building the research infrastructure necessary to achieve future operational improvements as well as the evolutionary improvements in the mid-term that form transition steps to NextGen. R&D Review

Hot off the Press!

FAA's Latest Technical Reports

ANALYSIS OF RESIDUAL STRENGTH OF FLAT AND CURVED PANELS, WITH AND WITHOUT STIFFENERS, WITH MULTIPLE-SITE DAMAGE (DOT/FAA/AR-06/37)

Multiple-site damage (MSD) is a typical problem for aging aircraft. Flying great numbers of fuselage pressurization cycles may cause fatigue cracking at multiple rivet locations in the lap joints of an aircraft structure and thereby reduce overall structural integrity. The residual strength of a panel with a leading crack and MSD cracks is known to be lower than that of a panel that has a similar leading crack but lacks MSD cracks. Considerable research in the testing and development of models has been conducted in recent years to assess the residual strength and predict linkup of stiffened flat panels with both a leading crack and MSD. Because differences exist between the models in terms of definitions and criteria used to assess crack growth and linkup, researchers set out to verify the output of available models. In the process, they used experimental data, available from public literature, and not data from direct experiments.

For this project, researchers developed a new model to predict linkup and residual strength in various panels. Some panels were flat and others were curved, all had both a leading crack and MSD cracks, and some were fitted with stiffeners while others were not. The model employed the strip yield (as implemented in the NASGRO software), J-integral, and compatibility methods. The stresses and deformations at the crack tips were first calculated using the strip yield method, and these values were then used in the calculations of the J-integral values at the crack tips. The effect of the stiffeners on the deformation behavior of the panels was measured by the displacement compatibility method, and bulging factors were used in modeling the panel curvature. Finally, the model was verified with experimental data obtained from testing the flat and curved panels, either with or without stiffeners.

STATISTICAL LOADS DATA FOR THE BOEING 777-200ER AIRCRAFT IN COMMERCIAL OPERATIONS (DOT/FAA/AR-06/11)

FAA-funded researchers are developing new and improved methods and criteria for processing and presenting large commercial transport airplane flight and ground loads usage data. The scope of activities for this study include: (1) defining the service-related factors that affect the operational life of commercial aircraft; (2) designing an efficient software system to reduce, store, and process large quantities of optical quick-access recorder data; and (3) reducing, analyzing, and providing processed data in statistical formats for the FAA to reassess existing certification criteria. Equally important, the new data will enable the FAA, the aircraft manufacturers, and the airlines to better understand and control factors that influence the structural integrity of commercial transport aircraft. This report presents Boeing 777-200ER aircraft operational usage data collected from 10,047 flights, representing 67,000 flight hours, recorded by a single international operator. The aircraft usage data include statistics on aircraft weights, flight distances, altitudes, speeds, and flight attitudes. Flight loads data include statistical information on gust and maneuver load factors, derived gust velocities, and ground-air-ground cycles. Ground loads data include statistics on lateral, longitudinal, and vertical load factors during different ground operational phases. Systems operational data include statistics on flap usage, thrust reverser usage, and engine fan speed.

The B-777 airplane sensors – which measure vertical, lateral, and longitudinal acceleration – are located in the cockpit area. The estimates of the center of gravity (c.g.) accelerations are computed in the Air Data Inertial Reference Unit, a device that converts the measured crew station accelerations to accelerations at the c.g. For some dynamic and ground load conditions, inaccuracies could exist in these filtered c.g. time history measurements. Operators and inspectors who use the recorded B-777 acceleration values as maintenance action triggers or Flight Operational Quality Assurance events should recognize the possibility of these recorded Digital Flight Data Recorder acceleration inaccuracies. ▶

INVESTIGATIONS OF PERFORMANCE OF PNEUMATIC DEICING BOOTS, SURFACE ICE DETECTORS, AND SCALING OF INTER-CYCLE ICE (DOT/FAA/AR-06/48)

This report represents the results from collaborative icing wind tunnel and flight test investigations of pneumatic deicing boot deicing performance. The tests were performed by FAA, NASA, Goodrich Aerospace Corporation, the University of Illinois at Urbana-Champaign, Empresa Brasileira de Aeronautica S.A (EMBRAER), and other airplane manufacturers. The report includes the results of icing wind tunnel investigations into ice accumulations prior to activation of an ice protection system, scaling of intercycle ice accretions, and detection of ice accretion aft of the deicing boots using commercially available surface ice detectors. For these investigations, researchers used a 36-inch chord hybrid model of the National Advisory Committee for Aeronautics 23012 airfoil, with leading-edge ordinates of a 72-inch, full-scale airfoil.

Researchers documented ice shapes with photographs, video recordings, tracings, and ice thickness measurements. They also made molds from ice castings for subsequent aerodynamic testing and other purposes. They performed icing wind tunnel tests at a true airspeed of 170 knots (195 miles per hour), which is representative of maneuvering and holding airspeeds used by turbopropeller regional air transports. Flight testing of the deicing boots intercycle ice using a fully instrumented EMBRAER EMB-120 aircraft showed lift losses of 25 to 27 percent at the airplane angle of attack for the control column pusher. The lift losses are greater at the aerodynamic stall angles of attack.

Using the Ruff method for scaling test conditions, intercycle ice roughness measurements obtained on a model one-half the scale of the hybrid model compared well with those obtained on the hybrid model. However, tests with the smaller model tended to produce smoother ice than that obtained through the hybrid model. In addition, the tests often did not reproduce the large-scale roughness elements seen during the hybrid model tests. These differences may have occurred because the model's pneumatic deicers were not scaled from what would have been installed on the full-scale airfoil. The surface ice detector test results indicated the potential for use of a local surface ice detector for finding ice accretion aft of a lifting surface's leading-edge ice protection system.

EVALUATION OF A NEW LIQUID FIRE-EXTINGUISHING AGENT FOR COMBUSTIBLE METAL FIRES (DOT/FAA/AR-TN06/26)

For this study, researchers evaluated a new liquid agent designed to extinguish fires involving combustible metals. Aircraft rescue fire fighters may confront metal fires, produced by materials such as magnesium and titanium, in aircraft brake assemblies, landing gear components, aircraft engines, and other structural components of aircraft. A burning combustible metal fire could be a possible ignition source or a continuing source of ignition in an aircraft fire. The standard method for extinguishing combustible metal fires consists of using sodium chloride dry powder to smother the burning metal.

Researchers used FEM-12 SC in hand-held extinguishers to determine the optimum chemical formulation and best extinguishing method. A further evaluation included aquatic-toxicity testing of FEM-12 SC. In this instance the extinguishing performance of FEM-12 SC was compared to that of sodium chloride dry powder in accordance with the parameters set forth in the American National Standards Institute/Underwriters Laboratories Incorporated 711 "Rating and Testing of Fire Extinguishers," Section 10.2, Magnesium Fire Tests, Section 10.2.28, Magnesium Casting Fire Tests.

The tests determined optimum chemical formulation, FEM-12 SC and the best extinguishing method using 240 pounds per square inch, high-pressure extinguishers in a straight-stream configuration. The extinguishing performance comparison results showed that sodium chloride extinguished a magnesium fire in an average of 102 seconds – twice as fast as FEM-12 SC. However, due to the experimental agent's inability to cool the metal, it created a potential long-term fire hazard that could redevelop into a fire if the sodium chloride-covered metal were disturbed. FEM-12 SC provided better cooling than sodium chloride, so that the magnesium could be handled with bare hands within minutes of extinguishment. However, when FEM-12 SC came into direct contact with the burning magnesium, violent flare ups of the fire and flying magnesium sparks created potential fire hazards. Once the fire was extinguished, the fire hazards were eliminated.

POLYUREA PAINT MARKING MATERIAL STUDY (DOT/FAA/AR-TN06/46)

Pavement markings must endure the harsh airport environment. Standard waterborne, epoxy, methacrylate, and solvent base markings require frequent repainting, a procedure that significantly increases life-cycle costs. An elastomer material used on highways, called polyurea, is a potential alternative to existing standard pavement marking materials.

Researchers undertook this study to determine: (1) the effectiveness of the polyurea marking material for use on airport surfaces; (2) if retro-reflective beads are compatible with the polyurea marking material; (3) if grading or sieving the beads during application results in a better retro-reflectivity; and (4) how well polyurea marking material bonds to the pavement if a seal coat is applied first. ▶

Researchers applied three different products on asphalt as well as concrete surfaces at the FAA William J. Hughes Technical Center and Newark Liberty International Airport. They applied the polyurea marking material at a thickness of 20 mil on each test surface. The Four types of beads applied to the polyurea marking material during the evaluation included: Type I - 1.5 Index of Refraction (IOR); Type III - 1.9 IOR; Ceramic - 1.8 IOR; and Plus 9 - 1.9 IOR. During the one-year test period, researchers conducted retro-reflectivity, chromaticity, pull-off strength, friction, and water recovery tests.

The results showed that:

- Polyurea was ineffective in a high-traffic area either on asphalt or concrete surfaces when using Type III beads based on retro-reflectivity. Polyurea tested on concrete with Type I beads was still effective after six months, based on retro-reflectivity.
- Ceramic beads were not compatible with polyurea marking material in a high-traffic area. Plus 9 beads were found to be compatible with polyurea marking material when installed in a low-traffic area.
- Sieving the beads did not improve the retro-reflectivity.
- Polyurea marking material did not bond well to pavements when a seal coat was applied first.

IN-FLIGHT RADIO FREQUENCY SPECTRUM MEASUREMENTS OF COMMERCIAL AIRCRAFT CABINS (DOT/FAA/AR-06/41)

This report summarizes the results of a promising testing program. The aviation community's focus on the risk posed by portable electronic devices carried onboard commercial flights continues to intensify. Recent measurements and analyses have been useful in developing a better understanding of the issues, but they have not supported firm conclusions about what is happening in today's revenue flight environments. An instrumentation package was developed, and tests were performed in commercial aircraft cabins involving select in-flight radio frequency (RF) spectrum measurements on revenue flights. Research objectives for this study included: identifying cellular in-flight calls and activity rates, assessing maximum levels of received power, and identifying areas that deserve further research.

The research team including investigators from two major U.S. airlines observed 37 Boeing 737 and 1 Airbus 320 flights between September 23, and November 19, 2003. This study provided the first reported characterization of the RF environment in the cabins of commercial airline flights. The researchers found considerable in-flight cellular telephone call activity, discovered signal activity in the aviation critical frequency bands at field strengths capable on causing interference to onboard avionics, and witnessed onboard spectral activity at flight critical phases. These findings carry implications for both future research and public policy. Before the industry moves forward with policy changes, significantly more field measurement and analysis of the potential for interference is urgently needed. These studies should include a consideration of the implications of having many onboard transmitters and the potential risks posed by intermodulation.

MICROPROCESSOR EVALUATIONS FOR SAFETY-CRITICAL, REAL-TIME APPLICATIONS: AUTHORITY FOR EXPENDITURE NO. 43 PHASE 1 REPORT (DOT.FAA.AR-06/34)

Progressively complex microprocessors originally developed for consumer, automotive, and industrial uses are being used in aviation applications. These microprocessor devices reduce the size, weight, and power requirements of a product and, by use of advanced design and dense component packaging techniques, add capability. However, evolving microprocessor architectures include concepts, such as caching and pipelining, that can affect system predictability and safety. This is especially true as more complex microprocessors are being used, more complex hardware is integrated, and fully partitioned systems are being implemented. Thus a defined process for microprocessor evaluation and acceptance is needed.

This research focuses on current microprocessors being proposed on aircraft and establishes evaluation criteria. The project documents potential safety concerns when using modern microprocessors on aircraft and proposes potential approaches for addressing these safety concerns. In the study, researchers also consider issues of modern microprocessor architecture and related system architectures and their use in integrated modular avionics. As well, they provide practical techniques for use by aircraft manufacturers, avionics developers, certification authorities, and other stakeholders. The project also identifies criteria for a new approach for scaling the criteria depending on the functional criticality of the processor. The results will be used by the FAA to develop policy, regulations (if deemed needed), and guidance materials for industry. The output may be expanded upon in the future to address other commercially available complex devices.

This project is being performed in two phases by a combination of avionics system developers (BAE Systems, The Boeing Company, and Smiths Aerospace) and FAA organizations responsible for aircraft safety research and development.

SPARK IGNITION AIRCRAFT ENGINE ENDURANCE TEST OF AVIATION-GRADE ETHANOL 85 (DOT/FAA/AR-06/43)

In 2004, the FAA funded South Dakota State University in a multiyear effort to research the use of aviation-grade ethanol 85 (AGE-85), a blend of at least 85% ethanol denatured with 2% automotive gasoline, less than 1% biodiesel, and pentane isomerate. In a parallel effort, FAA researchers evaluated AGE-85 in an overhauled Lycoming IO360-C, four-cylinder, spark ignition, piston aircraft engine. The ▶

engine is type-certificated to operate on either 100 or 100 low-lead (100LL) American Society for Testing and Materials D 910-grade aviation gasoline. The engine fuel control servo was modified with an oversized main metering jet and the fuel distribution nozzles were enlarged to allow increased fuel mass flow. The engine ignition timing was retarded by 5° to 15° before top dead center (BTDC).

Researchers obtained test fuel from sealed drums containing less than 0.2% water on a volume basis. Under the conditions of this test, they found no excessive wear on any of the high-contact, high-stress parts of the engine except for the hammered effect on the exhaust valve faces and seats. These findings may have been a consequence of operating the engine at the 5° retarded timing. There were minimal piston face and valve deposits and moderate intake valve deposits and minimal fuel system deposits and engine varnish and sludge buildup.

Prior to the start of the endurance test and at the completion of the endurance test, researchers ran a series of power baselines using both AGE-85 at the 15° BTDC ignition timing and isooctane (ISO) at the standard ignition timing of 20° BTDC. The engine produced an average of 4.3 (2.8%) more peak horsepower when operating on the AGE-85 than it did when operating on ISO. However, peak power required 39.7 lb/hr (56.5%) more fuel mass flow with the AGE-85 than with ISO – equating to an average increase of 5.6 gal/hr (35%) fuel volume flow. These operating conditions reduced the efficiency from an average peak power brake-specific fuel consumption (BSFC) of 0.470 lb/break horsepower (bhp) hr for ISO to 0.716 lb/bhp hr for AGE-85. The AGE-85 produced 1.8% more power at best economy fuel mixture than 100LL but required 55.8% more fuel mass flow. Operating under these conditions reduced the average best economy BSFC from 0.415 lb/bhp hr for ISO to 0.640 lb/bhp hr for AGE-85. Average exhaust gas temperatures were 20°F higher with AGE-85 than with ISO at the best power mixture. Using AGE-85 would increase fuel weight by 9% above 100LL values due to its 6.4 lb/gal mass density versus 5.87 lb/gal for 100LL and would reduce engine range by 35%.

This testing showed that without significant modifications to existing engine design beyond retarding the ignition timing – modifications such as increasing cylinder compression ratios, changing valve timing, and derating engine power – adjustments to the fuel schedule for a 100- or 100LL-certificated engine would be required to provide upwards of 57% more fuel mass flow or 35% more fuel volume flow. Future tests will compare the detonation performance of AGE-85 at standard engine ignition timing to 100LL in a 100/100LL-certificated IO360-A e