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R&D Annual Review

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Report of the Federal Aviation Administration to the United States Congress pursuant to 49 U.S. Code 44501(c)

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The *National Aviation Research Plan* (NARP) is a report of the Federal Aviation Administration to the United States Congress pursuant to 49 United States Code 44501(c). The NARP, related appendices, and the *R&D Annual Review* may be found online at www.faa.gov/go/narp.



CONTENTS

Introduction - 1

R&D Goal 1: Fast, Flexible, and Efficient - 2

- Air Traffic Control Changes in Applying Wake Turbulence Separations - 3
- Increased Data on Wake Turbulence Generated by Heavy Aircraft - 3
- Avoiding In-Flight Icing Conditions in Alaska - 4
- Recommendations for Changes to Air Traffic Control Wake Turbulence Separation Standards - 5
- Next Generation Wake Turbulence Separation Decision Support Tools and Separation Processes - 5
- Flight Management Systems 4-Dimensional Trajectories Downlink for Trajectory Based Operations - 6
- En Route Human-In-The-Loop - 7

R&D Goal 2: Clean and Quiet - 8

- The Aviation Emissions Characterization Roadmap - 9
- Aviation Environmental Design Tool - 10
- Commercial Aviation Alternative Fuel Initiative - 12
- Alternative Aviation Fuel Experiment - 13
- Managing Runoff from Aircraft and Airfield Deicing and Anti-Icing Operations - 14
- Guidance for Quantifying Speciated Organic Gas Emissions from Airport Sources - 14
- Guidebook on Preparing Airport Greenhouse Gas Emissions Inventories - 15

R&D Goal 3: High Quality Teams and Individuals - 16

- Strategic Job Analysis: Selecting the Controller of the Future - 17
- Guidelines for an Aircraft Maintenance Aviation Safety Action Program - 18
- Develop New Practical Color Vision Tests for ATCS Applicants - 20

R&D Goal 4: Human-Centered Design - 22

- Automatic Dependent Surveillance – Broadcast (ADS-B) - 23
- Future En Route Workstation III Simulation - 24
- Future Terminal Workstation – 1 - 25
- Electronic Flight Bags - 26
- Front Line Manager Best Practices - 27
- Dynamic Comprehension: Time on Position and Mental Fatigue - 28
- Surface Moving Maps - 29

R&D Goal 5: Human Protection - 30

- Laptop Computer Fire Extinguishment - 31
- Cargo Fire Control by Depressurization - 32
- Aircraft Battery Safety - 33
- Contaminated Insulation Flammability - 34
- Support of Aircraft Accident Investigation - 36
- Accident Medical Review Program - 37
- Solar Radiation Alert System - 38
- Ensuring Accuracy in the Analysis of Anticonvulsant Medications - 39
- Detection and Prevention of Carbon Monoxide Exposure in General Aviation Aircraft - 40
- Examining Smoking-Induced Differential Gene Expression Changes in Buccal Mucosa - 42
- Standardized Method to Obtain Anthropomorphic Test Dummy Data to Support Analytical Modeling - 44
- Modeling the U.S. Pilot Population - 44

R&D Goal 6: Safe Aerospace Vehicles - 46

- Improved Electrical Wiring Fire Test Method - 47
- Freighter Fire Suppression Cost-Benefit Analysis - 48
- Freighter Fire Detection Certification Testing - 49
- New Advances in Gas Turbine Engine Component Risk Assessment Software - 50
- Engineering Assessments of Fluorescent Penetrant Inspection – Updating of AMS 2647C - 51
- Aviation Fuel and Engine Test Facility Unleaded Aviation Gasoline Program - 52
- Metallic Materials Properties Development and Standardization - 53
- Durability and Damage Tolerance of Bonded Repairs - 54
- Fatigue-Crack-Growth-Rate Testing in the Threshold Regime - 55
- Survey of Repairs, Alterations, and Modifications, for Widespread Fatigue Damage - 56
- Certification Data and Protocols for Certification Guidance - 58

R&D Goal 7: Separation Assurance - 60

- Multi-Purpose Cockpit Display of Traffic Information - 61

R&D Goal 8: Situational Awareness - 62

FAROS - 63

Low Cost Ground Surveillance - 63

Cecil Field Study—A Case Study On Routine Space Vehicle Operations in the
NAS for NextGen - 64

High Altitude Wind Prediction and Measurement Technology Assessment - 66

Temporal Winds Database Considerations for Safety Evaluation of Unguided
Suborbital Launch Vehicles - 68

Weather in the Cockpit Baseline and Assessment - 70

ATM Implications of UAS Operations in Controlled Airspace - 71

R&D Goal 9: System Knowledge - 72

NextGen Towers - 73

NextGen Implementation Modeling and Performance - 74

Acronyms and Abbreviations - 76

INTRODUCTION

The *R&D Annual Review* highlights the 2009 research and development accomplishments of the Federal Aviation Administration (FAA), and serves as a compendium to the FAA's *National Aviation Research Plan* (NARP), 2010 edition. The FAA's research and development (R&D) portfolio assists in achieving the 10 R&D goals described in Chapter 2 of the NARP. This publication presents the accomplishments aligned with the supported R&D goals: Goal 1 - Fast, Flexible and Efficient; Goal 2 - Clean and Quiet; Goal 3 - High Quality Teams and Individuals; Goal 4 - Human-Centered Design; Goal 5 - Human Protection; Goal 6 - Safe Aerospace Vehicles; Goal 7 - Separation Assurance; Goal 8 - Situational Awareness; Goal 9 - System Knowledge; and Goal 10 - World Leadership.

Additionally, the R&D portfolio supports the FAA's core goals to enhance safety, improve efficiency, and increase capacity of the National Airspace System (NAS). In that effort, it continues to lay the groundwork for the Next Generation Air Transportation System (NextGen).

NextGen is a wide-ranging transformation of the entire NAS to meet future demand and support the economic viability of the system while reducing delays, improving safety, and protecting the environment. It is a complex, multilayered, evolutionary process of developing and implementing new technologies and procedures. NextGen is not a single piece of equipment or a program or a system that will instantaneously transform the NAS. It is an evolutionary process, and existing systems must be sustained in the transition. NextGen builds on legacy systems to increase capability in today's airspace system, adds new performance-based procedures and routes, and ultimately delivers programs that will transform the NAS.

How the FAA will achieve that NextGen transformation is detailed in some of the R&D accomplishments found in this issue.

Today, capacity for closely spaced parallel runway operations is dramatically reduced in poor visibility conditions. The R&D portfolio is working on capabilities that allow for continued use of runways during low visibility by providing precise path assignments that permit safe separation between aircraft assigned on parallel paths, restoring capacity, and reducing delays throughout the system.

Increased efficiency with NextGen operations will lead to reduced fuel consumption resulting in lower carbon emissions. The Agency's R&D effort is researching engine and airframe design and alternative fuels that will produce the changes needed to reduce aviation's environmental impact.

These accomplishments begin to tell the NextGen story and provide a glimpse into the future of our nation's world-class aviation system and the immense benefits it will continue to provide to the American people.

FAST, FLEXIBLE, AND EFFICIENT

A system that safely and quickly moves anyone and anything, anywhere, anytime on schedules that meet customer needs.

AIR TRAFFIC CONTROL CHANGES IN APPLYING WAKE TURBULENCE SEPARATIONS

Dependent paired instrument approach procedures are now available for airports to use for their closely spaced parallel runways (CSPR), whose centerlines are spaced less than 2,500 feet apart. This new procedure was approved for use at four airports with CSPR (Lambert – St. Louis International Airport, Philadelphia International Airport, Seattle-Tacoma International Airport, and Boston Logan International Airport) in early FY 2009. Further R&D and airport and data analysis work have added Memphis International Airport and Newark Liberty International Airport as candidates for use of the procedure.

The dependent paired instrument approach procedure is similar to the dependent approach procedure, but has more use restrictions due to the close proximity of the CSPR. A major benefit of the research-developed approach procedure is that it allows airports to continue use of parallel runways when weather or other conditions force a shift to instrument flight rule (IFR) operations. Previously, wake turbulence concerns caused airports to limit use to only one of the CSPR, cutting landing capacity in half. Use of the new procedure with CSPR can provide airports with the capacity to land 10 to 15 more aircraft per hour in these IFR conditions. (Wake Turbulence)

INCREASED DATA ON WAKE TURBULENCE GENERATED BY HEAVY AIRCRAFT



New wake turbulence mitigation separation standards and concepts are under development for NextGen technology air traffic control wake turbulence mitigation processes and procedures. During FY 2009, wake turbulence data collection and analysis activities focused on acquiring more data on wake turbulence generated by Boeing 757 and heavier aircraft (heavier than 255,000 pounds) when approaching and departing airport runways. Wake-measuring instrumentation, along with weather and aircraft data sensing and recording systems, were positioned and operated near airports with a significant

number of heavy aircraft arrivals and departures to support the data collection and analysis work needed for developing standard changes. (Wake Turbulence)

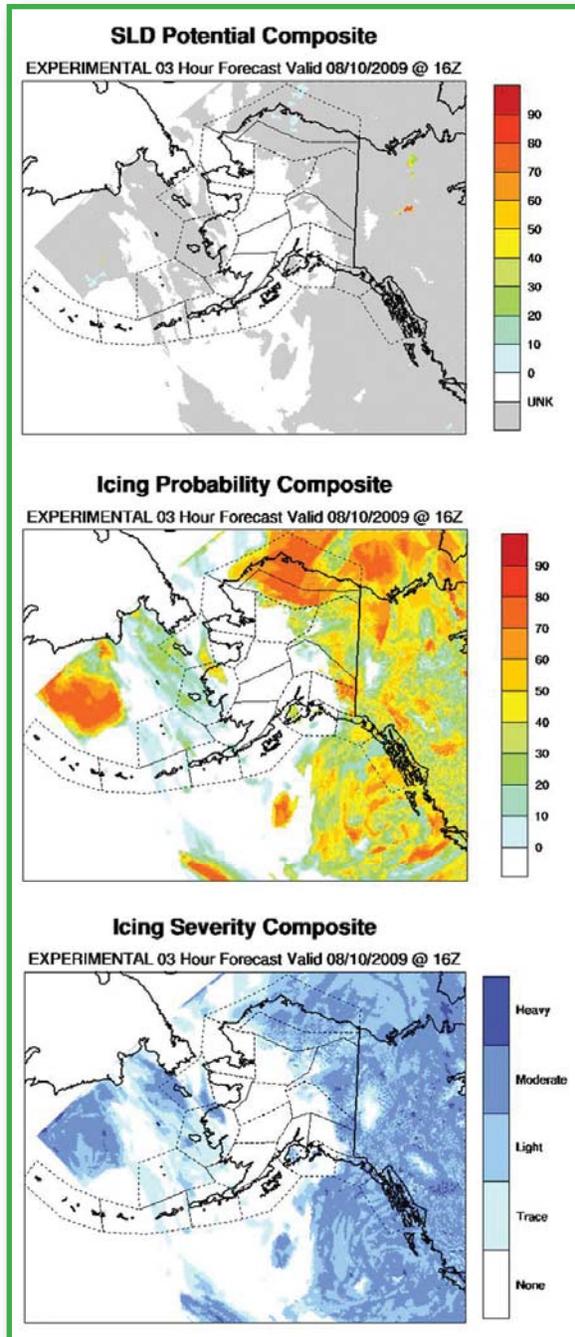
AVOIDING IN-FLIGHT ICING CONDITIONS IN ALASKA

In FY 2009, the FAA approved a Forecast Icing Product (FIP-AK) for test use in Alaska. FIP-AK provides icing severity, probability, and supercooled large droplet fields at a 13km resolution with 1000 foot vertical increments. Outputs are updated hourly with forecasts out to 12 hours. This is an important advancement since in-flight icing is a serious aviation hazard in Alaska. Combine a long coastline, extensive mountainous terrain, and an icing

season that extends throughout the entire year, with relatively sparse observations and inadequate numerical weather prediction models, and there is a real need for an automated forecast capability to provide guidance to Alaska forecasters. Based on National Transportation Safety Board (NTSB) reports, injuries, fatalities, and aircraft damage costs attributed to in-flight accidents in Alaska caused by icing equate to more than \$3 million per year.

A unique feature of the test use will be the use of FIP-AK on the Interactive Correction in Four Dimensions (IC4D) workstation, developed by the National Oceanic and Atmospheric Administration (NOAA), at the Alaska Aviation Weather Unit (AAWU) in Anchorage. The IC4D workstation allows a forecaster to view model fields entering into the icing algorithm, alter them based on observations and experience, and thus provide value-added information to the final forecasts. AAWU forecasters are evaluating the IC4D workstation to determine the benefits derived from this human-in-the-loop (HITL) concept and FIP-AK will be included in the evaluation.

Improvements to icing forecasts will allow users to plan more effective routes of flight that will avoid hazardous icing areas. (Weather Program)



RECOMMENDATIONS FOR CHANGES TO AIR TRAFFIC CONTROL WAKE TURBULENCE SEPARATION STANDARDS

In FY 2009, safety analysis documentation and a proposed change to the air traffic control (ATC) wake separation standards was completed and coordinated. The FAA will publish a turbulence separation standard change in early FY 2010 that will increase runway capacity usage for airports with Boeing 757 aircraft as a major component of their operations. Currently, design takeoff weights for Boeing 757-200 and -300 series aircraft require the FAA to use different ATC wake turbulence separation standards. Analysis of wake turbulence data collected indicates that the wake patterns generated by these aircraft are very similar and that both series of aircraft should be covered by one wake separation standard. Recommendations for an update to international wake separation standards were also developed in FY 2009 by the FAA and EUROCONTROL. These new standards will be submitted to the International Civil Aviation Organization (ICAO) for approval and adoption in FY 2010. (Wake Turbulence)

NEXT GENERATION WAKE TURBULENCE SEPARATION DECISION SUPPORT TOOLS AND SEPARATION PROCESSES

Wake Turbulence Mitigation for Arrivals (WTMA), a NextGen wake turbulence mitigation procedure concept, was further defined in FY 2009. Once the supporting system is developed and deployed, the procedure would allow Boeing 757s and heavier aircraft to be the leader in dependent paired instrument approaches to CSPR. WTMA will require more highly accurate information concerning crosswinds encountered (and predicted to be) along approaches to an airport's CSPR. This technology-enhanced procedure would give air traffic controllers more flexibility in assigning arriving aircraft to CSPR approaches during IFR operations.

In FY 2009, a terminal area CSPR approach design was developed using multiple runway approach paths. Aircraft would use internal navigation capabilities to follow one of multiple precise routes to an airport's CSPR. During FY 2010, the feasibility of the terminal area CSPR approach design will be evaluated in terms of air traffic controller tasks, air crew tasks, and required controller and pilot decision aids.

In FY 2009, a modeling tool was developed using en route and terminal area flight track data collected over a period of time to recreate the current wake separation distances between aircraft that occur in airspace surrounding congested airports. The tool, when fully developed, can be used to evaluate the probability of wake encounters in the same congested airspace under the NextGen high density trajectory-based operating procedures. This work will continue in FY 2010 to include a more representative aircraft wake for each modeled aircraft in the high density NextGen operational scenarios. (Wake Turbulence)

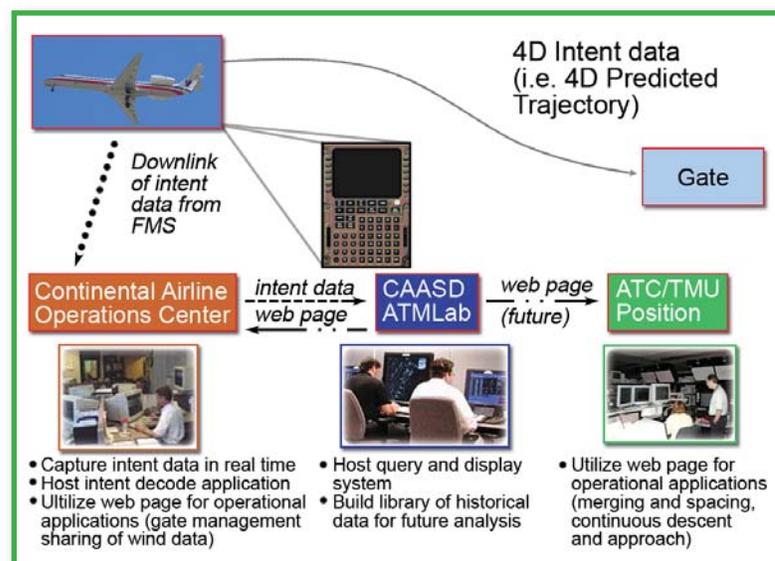
FLIGHT MANAGEMENT SYSTEMS 4-DIMENSIONAL TRAJECTORIES DOWNLINK FOR TRAJECTORY-BASED OPERATIONS

The NextGen Concept of Operations calls for key end state transformations which include the exchange of 4-dimensional trajectories (4DT) between capable aircraft and the Air Navigation Service Provider to enhance trajectory-based operations (TBO). Although current generation Flight Management Systems (FMS) generate 4DT information on board the aircraft to provide the basis for autoflight systems to execute a route from takeoff to touchdown, the utility of this 4DT information in helping meet the operational requirements as envisioned by the NextGen concept for TBO is only now being assessed.

In 2009, to better understand the operational use of the FMS 4DT information, Continental Airlines (COA) and the Center for Advanced Aviation Systems Development (CAASD) researchers worked together to collect and analyze 4DT data from operational flights in the NAS. Four-dimensional (4D) flight intent, which provides latitude, longitude, altitude and time (among other information), was provided by COA Boeing 737NG aircraft equipped with GE Aviation FMS avionics. Currently, 59 Boeing 737-800s are configured to downlink 4DT data using an Aircraft Communication Addressing and Reporting System link to Aeronautical Radio, Incorporated. Data from over 60,000 flights has been collected to date, with approximately 9,000 analyzed thus far.

The analysis helped characterize FMS-generated estimated times of arrival (ETAs) and identified issues that need to be addressed before FMS downlinked 4DT information can be used for air traffic management (ATM) functions. The data were used to analyze parameters of importance for TBO (e.g., ETAs, required times of arrival, and wind interactions); gain operational experience in the use of down-linked 4DT among air traffic specialists and airline operations personnel; and develop and evaluate the utility of 4DT downlink information, including integration with planned ground automation and displays, with all key ATM participants.

Key issues identified in this research include impact of frequent air traffic interventions on ETA predictions; impact of forecast winds as represented and used in the FMS on ETA predictions; and the inaccuracies in ETA predictions due to the discontinuity between the Standard Instrument Arrival and the Instrument Approach Procedure. (CAASD)



EN ROUTE HUMAN-IN-THE-LOOP

The En Route Data Communications (ERDC) Human Factors team conducted a demonstration of prototype ERDC capabilities to refine requirements for the HITL experiment. The ERDC team conducted a HITL experiment with 28 certified professional controllers working in teams of 2. Each controller team worked simulated traffic under 12 different conditions. The ERDC team also conducted a part task that investigated the effect of traffic complexity and the use of Data Communications (Data Comm) on cognitive workload. Functional near infrared imaging provided an objective measure of cognitive workload. (NextGen Demonstrations and Infrastructure Development)



CLEAN AND QUIET

A reduction of significant
aerospace environmental
impacts in absolute terms

THE AVIATION EMISSIONS CHARACTERIZATION ROADMAP

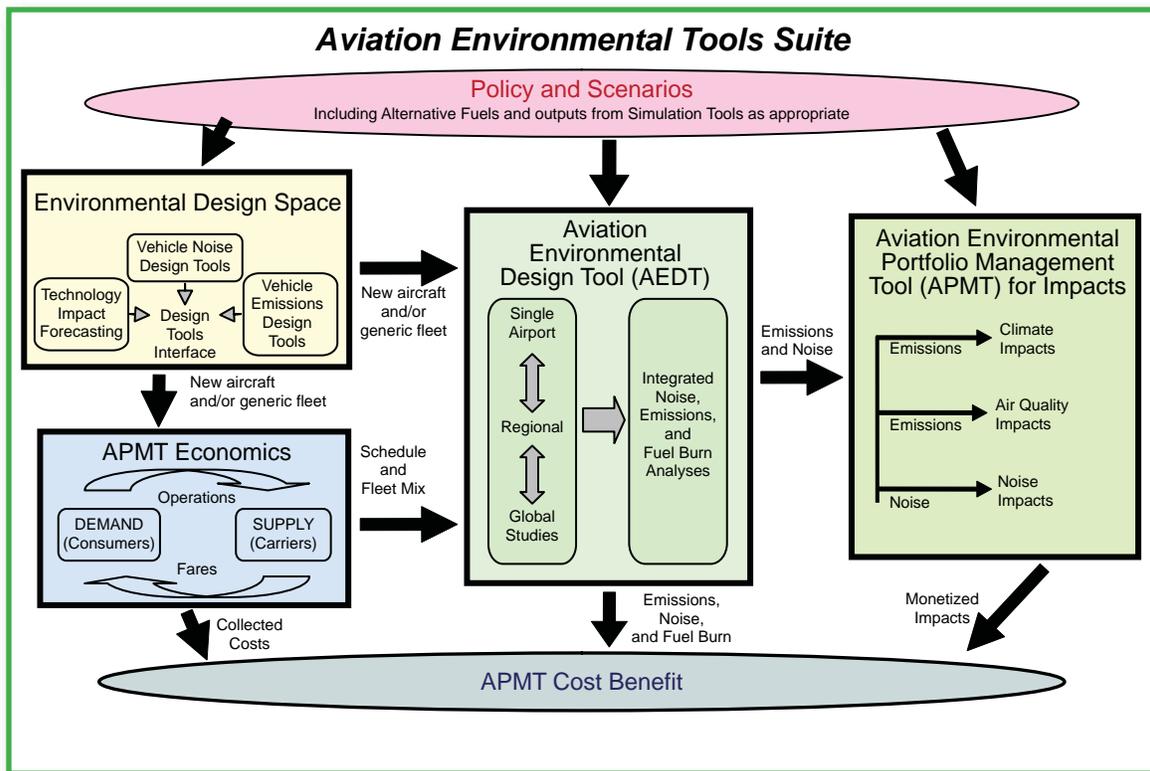
The Aviation Emissions Characterization (AEC) Roadmap is a collaboration of parties interested in R&D and regulatory activities associated with aviation emissions with a particular focus on particulate matter (PM) and hazardous air pollutant (HAP) emissions. Accomplishments during the past year include updating the roadmap which is maintained on the FAA's Knowledge Sharing Network site devoted to AEC Roadmap activities, hosting an intensive two-day meeting reviewing research progress, assessing research direction for the coming year, and identifying knowledge gaps that should be addressed through new research initiatives in the near future. The AEC Roadmap is an external coordinating mechanism providing information to many research programs managed by the FAA Office of Environment and Energy (AEE). In total the roadmap has links into more than 50 research projects, bringing together the knowledge base represented by these projects into a coordinated and focused activity. Through this program, the roadmap is able to leverage research funding, communicate scientific progress, and serve as a conduit to related research in similar fields such as diesel emissions. The AEC Roadmap investigates emissions from aircraft engines, auxiliary power units (APU), ground support equipment, and other emissions sources that may be unique to the aviation industry or other sources present at airports that may not be adequately understood. It is the acknowledged focal point for sharing information and defining broad research requirements for understanding the generation and impact of aviation emissions. Managed by FAA/AEE, the AEC Roadmap includes representatives from the National Aeronautics and Space Administration (NASA), the Department of Defense (DoD), and the Environmental Protection Agency (EPA); engine and aircraft manufacturers, airports and airlines, universities, private research organizations; and technical consulting firms; and a number of representatives from the international community. This extensive participation raises the value of the roadmap as an external coordination mechanism.

The AEC Roadmap's broad objective is to gain the necessary understanding of emissions' formation, composition, and growth and transport mechanisms for assessing those emissions and understanding their impact on human health and the environment, reducing scientific uncertainty to an acceptable level for use in policy setting.
(Environment and Energy)

AVIATION ENVIRONMENTAL DESIGN TOOL

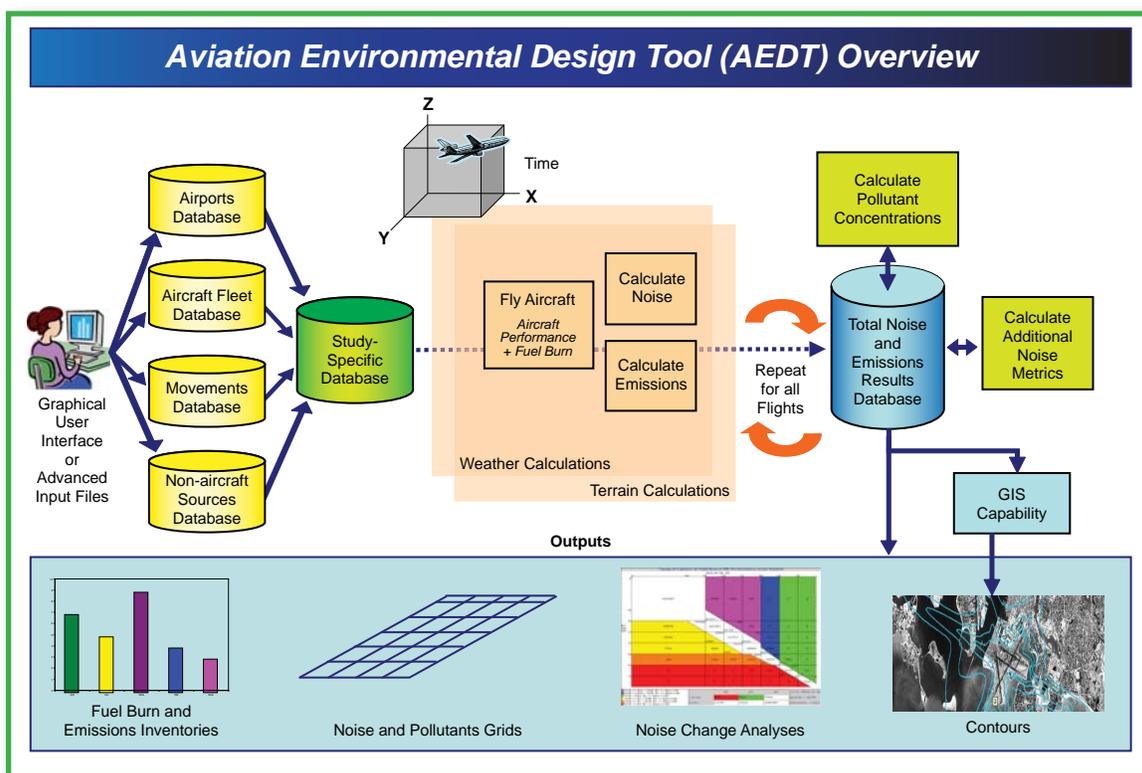
FAA’s development activities of the Aviation Environmental Design Tool (AEDT) continued in a more integrated fashion toward accurately quantifying the interdependent aspects of aircraft fuel burn, noise, and emissions. Interdependent capabilities are critical to the Joint Planning and Development Office’s (JPDO) vision for NextGen as well as the NASA research toward analyzing advanced vehicle concepts in NextGen scenarios. In early 2009, a first alpha version of AEDT was produced for NASA’s analyses, which not only was an important development milestone for AEDT, but also provided seamless integration with NASA’s Airspace Conflict Evaluation Simulator (ACES) tool and FAA’s airspace and airport simulation tool (SIMMOD). Both ACES and SIMMOD are cornerstone planning tools for NextGen and the first alpha version of AEDT was capable of producing the environmental consequences. Success of the first alpha version of AEDT has set the stage for a second alpha version to conduct the environmental modeling in support of JPDO’s Interagency Portfolio & Systems Analysis division to be delivered in early FY 2010.

A prototype version of FAA’s Terminal Area Route Generation, Evaluation, and Traffic Simulation, integrated with AEDT environmental capabilities, was successfully developed as a proof of concept. This critical integration will allow for new navigational procedures to be designed while taking into consideration the effects of fuel burn, noise, and emissions.



AEDT's improved modeling capabilities were used in the analysis of Continuous Descent Arrivals (CDA) and Tailored Arrivals (TA) at several major U.S. airports, and benchmarked against historical dive-n-drive procedures to understand the benefits of reduced fuel burn, noise, and emissions. AEDT was used to model CDA and TA implementations as part of the Atlantic Interoperability Initiative to Reduced Emissions program and NextGen operational scenarios.

In support of the ICAO's Committee of Aviation Environmental Protection, FAA continued to use AEDT to analyze world-wide policy scenarios for setting new nitrogen oxide (NO_x) emissions standards for new certified engines. The modeling effort, also known as the NO_x Stringency Analysis, included modeling the global fleet at reduced engine NO_x levels of up to 20 percent less than what exists today for the implementation years of 2012 and 2016. These NO_x stringency scenarios were then modeled for future forecasted years of 2016, 2026, and 2036 to investigate the overall NO_x emission reduction trends as a result of these policy options. Even though ICAO's focus is on NO_x emission standards, AEDT also produced the interdependent impacts of noise and fuel burn, unlike any other aviation environmental tool in use today to support ICAO policy decisions. Demonstration to properly inform policymakers is the integration of AEDT results with the economic analysis capability in the Aviation Environmental Portfolio Management Tool. (Environment and Energy)



COMMERCIAL AVIATION ALTERNATIVE FUEL INITIATIVE

Commercial Aviation Alternative Fuel Initiative (CAAFI), a coalition of airlines, aircraft and engine manufacturers, energy producers, researchers, international participants, and U.S. government agencies, played a key leadership role in achieving a new specification for synthetic aviation fuel, D7566, a major milestone to introduce alternative aviation fuels. The international standards organization ASTM International (ASTM) approved D7566 in September 2009, allowing the use of a semi-synthetic aviation fuel produced from the FT processes in commercial airliners. These fuels are referred to as FT fuels.



Under CAAFI's coordination, the aviation fuel industry stakeholders worked at an unprecedented pace to achieve the consensus necessary to publish this groundbreaking specification. CAAFI stakeholders also took key steps to advance the acceptance and understanding of alternative aviation fuels produced from biomass by conducting three flight demonstrations on commercial airliners between December 2008 and January 2009. The demonstration flights exemplified the technological readiness of renewable bio jet-fuels and contributed greatly to the public acceptance of these fuels for use in aviation. Important technical data was also generated to be used for the eventual industry qualification of these types of fuels. Other new types of alternative fuels, such as fuels produced from algae or cellulosic material, will be added to D7566 as they are qualified by the industry working group. For more information, visit www.caafi.org. (Environment and Energy)



ALTERNATIVE AVIATION FUEL EXPERIMENT

In 2009, the Alternative Aviation Fuel Experiment (AAFEX) was conducted on engine emissions characteristics at the immediate exhaust location where there is no atmospheric processing, to downstream locations to study plume chemistry and particle evolution. A secondary focus was to look for unique markers that would differentiate aircraft exhaust emissions from those coming from other background mobile and stationary sources. Led by NASA, the FAA participated through PARTNER, with other stakeholders including the EPA, the engine and airframe industries, and the research community. A NASA-owned DC-8 aircraft equipped with CFM56 engines was used during the experiment.

In an effort to minimize the environmental footprint from aviation activities, research is looking at the benefit of using alternative fuels as a way to reduce exhaust emissions from aircraft engines and APUs. While data are still being analyzed, preliminary AAFEX test results showed that the characteristics of PM emissions depend on many factors, among them the variation in ambient air conditions, the engine power settings, the level of atmospheric processing downstream, and most importantly, the type of fuels being used. Notably, FT fuel trends toward lower PM and hydrocarbon emissions. Pure FT fuels tend to yield the most reduction while different mixtures of FT and commercial Jet A fuel yield different reduction levels. FAA is compiling these data in a research database, along with data acquired from previous measurement campaigns, to better assess the impact of aviation emissions. The recent interest in these alternative fuels is also motivated by the need to find renewable energy sources and to lessen the dependence on traditional fuel suppliers. The research was conducted through the AAFEX whose main goal is to determine potential emissions reduction that could be achieved from the use of alternative jet fuels.

The alternative fuels produced using the Fischer-Tropsch (FT) processes that were used in this experiment were derived from two sources: natural gas and coal. FT fuels are particularly attractive for mitigating emissions impact because they have little or no sulfur, which is the ingredient that contributes to the formation of PM, a pollutant that affects the respiratory system. The emissions tests were conducted under simulated aircraft operations, from low power settings, such as those used for taxiing, to intermediate power settings, and to maximum power as for takeoff. The effects of day and nighttime temperature variations on engine emissions were also studied. (Environment and Energy)

MANAGING RUNOFF FROM AIRCRAFT AND AIRFIELD DEICING AND ANTI- ICING OPERATIONS

In 2009, the Airport Cooperative Research Program (ACRP) concluded a study to develop planning guidelines incorporating an array of best management practices (BMPs) for the practical, cost-effective control of runoff from aircraft and airfield deicing and anti-icing operations. These guidelines will assist airports of all sizes and operational levels in designing (or re-designing) site-specific solutions. Also, they will serve as tools for airports to evaluate and select from options and promote the use of sustainable, efficient management systems that reduce the potential presence of airfield deicing and anti-icing fluids (ADAF) in storm water runoff.

U.S. airports face increasing public and regulatory attention and technical challenges in managing runoff from aircraft and airfield deicing and anti-icing operations. This attention, coupled with the consideration of effluent guidelines by the EPA, affects a large community of airports. Of particular concern is how requirements affect smaller airports, which have more limited resources than large hub airports.

Developing successful technical solutions for management of aircraft and ADAF runoff poses significant challenges. Because storm water management regulations affecting airports (e.g., multi-sector general permits, individual state National Pollutant Discharge Elimination System permits, and Phase I and II storm water regulations) are varied and evolving, airports of all sizes need an array of BMPs for controlling ADAF-affected storm water runoff. (Airport Cooperative Research - Environment)

GUIDANCE FOR QUANTIFYING SPECIATED ORGANIC GAS EMISSIONS FROM AIRPORT SOURCES

The AEE recently published on its website a guidance document titled *Guidance for Quantifying Speciated Organic Gas Emissions from Airport Sources* for inventorying HAPs. The guidance was developed for airports to use as a standard approach for estimating emission inventories from all their emissions sources. These inventories are typically triggered by construction projects requiring an environmental impact statement (EIS) or an environmental assessment (EA) as part of FAA environmental documents to address the National Environmental Policy Act.

The document provides guidance on when an inventory is warranted and provides a methodical approach to performing it. This approach covers all airport sources; however, the approach used for aircraft equipped with turbofan, turboprop, and turbojet engines is published in a companion document called *Recommended Best Practice For Quantifying Speciated Organic Gas Emissions From Aircraft Equipped with Turbofan, Turbojet, and Turboprop Engines*. This technical document is also posted on the website listed below.

The guidance is a living document and will be updated periodically to reflect the most accurate emissions indices developed from the latest test data collected from field measurement campaigns, taking into account the uncertainties associated with these indices. It describes step-by-step instructions for preparing sample emissions inventory of airport sources and points to the Emissions and Dispersion Modeling System for performing multiple or complex airport emissions inventories that are required by an EA or EIS. The guidance documents can be found at http://www.faa.gov/regulations_policies/policy_guidance/envir_policy/. (Environment and Energy)

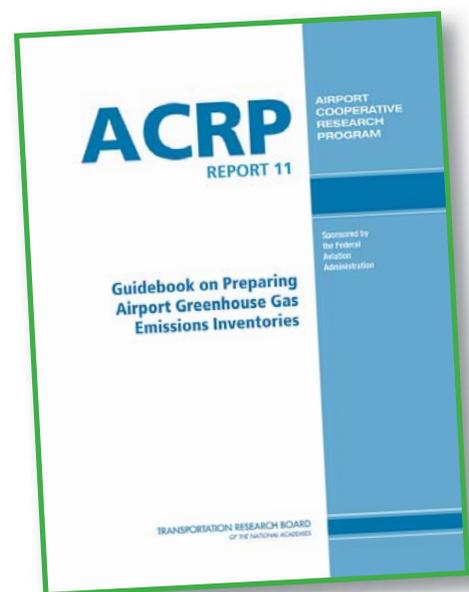
GUIDEBOOK ON PREPARING AIRPORT GREENHOUSE GAS EMISSIONS INVENTORIES

To address increasing concerns about the potential effects of anthropogenic activities on the earth's climate, in 2009 the ACRP developed the *Guidebook on Preparing Airport Greenhouse Gas Emissions Inventories* for airport operators. The report provides airport operators clear and cohesive information and establishes uniform methodology to develop airport source-specific inventories of greenhouse gas (GHG) emissions.

Scientific studies suggest that human activities, including aviation, contribute to increasing atmospheric concentrations of GHG emissions, which are considered to be associated with global warming. According to the United Nations Intergovernmental Panel on Climate Change, aviation activities affecting the atmosphere through the fuel combustion are currently thought to contribute about two to three percent of total global GHG emission inventories and could contribute as much as five percent by 2050.

There are increasing concerns about GHG emissions in the U.S., and some states and municipalities are taking legislative actions and implementing controls. There is no specific guidance or generally applied practice for computing airport-level GHG emission inventories. As a result, there are wide variances and levels of the estimated local aviation contributions which are most likely due to varying methodologies used to quantify emissions rather than actual level or variance in the type of activities.

The report can be found at http://onlinepubs.trb.org/onlinepubs/acrp/acrp_rpt_011.pdf. (Airport Cooperative Research - Environment)



HIGH QUALITY TEAMS AND INDIVIDUALS

The best qualified
and trained workforce
in the world

STRATEGIC JOB ANALYSIS: SELECTING THE CONTROLLER OF THE FUTURE

The Strategic Job Analysis task will assess the probable impact of NextGen concepts of operations, procedures, and technologies on the profile of abilities and other personal characteristics (aptitudes) required to enter the air traffic control specialist (ATCS) occupation. The Strategic Job Analysis (SJA) project has four major elements. First, a Job Analysis Information Database (JAIDB) is being compiled that represents the current work performed by controllers and the profile of abilities and other personal characteristics required to enter the occupation. Second, techniques (cognitive walkthroughs, subject matter expert interviews, and document reviews) will be used to develop hypotheses about far-term changes in controller work and ability requirements. Provisional changes that reflect these hypotheses will be captured in the JAIDB. Third, a similar approach will be used to examine mid-term initiatives, concepts, prototypes and procedures, along with hypotheses about finer-grained changes, generally at the sub-activity and/or task levels of analysis. Finally, near-term initiatives, concepts, prototypes and procedures will be examined to derive changes in personnel selection criteria. While described in stages, the SJA is iterative, with increasingly finer-grained analyses as future concepts of operation mature.

The primary focus in FY 2009 was on the design and construction of two JAIDB prototypes. The first prototype was constructed for the tower cab controller job using Task Architect Pro (v2.0), a commercial hierarchical task analysis application. While the work of a tower cab controller was represented reasonably well in Task Architect, the ability requirements could not be addressed explicitly, and it was not possible to link sub-activities to abilities, as required in selection-oriented job task analysis (JTA) practice and case law. The second prototype, built in Microsoft Access 2003, provided a means for mapping sub-activities and tasks defined in two previous ATCS job analyses to sub-activities and tasks defined in a third job analysis. The prototype provided an explicit linkage between sub-activities and abilities required for successful performance. It also demonstrated the feasibility of linking to other JTA data sources. However, as an Access application, the JAIDB prototype cannot support multiple users. It also does not support multiple instances representing the job-by-ability relationships at different times (e.g., now, mid- and far-term). A market survey of commercial-off-the-shelf (COTS) job analysis applications did not find any viable COTS JTA application.

Understanding the impact of NextGen-related changes on the existing ATCS profile of abilities and other personal characteristics will provide a basis for modifying the Agency's personnel selection criteria for the occupation. This research task will provide a scientific foundation for the continued evolution of ATCS selection procedures. Translating products of the SJA into actual validated selection procedures will require additional research, time, and resources, generally taking between two and five years. Focusing on aptitude requirements about five to seven years out will provide sufficient lead time for the development and validation of selection procedures in advance of implementation of changes in current ATCS selection procedures to reflect changes in the profile of abilities and other personal characteristics linked to near- and mid-term NextGen solution sets and long-term NextGen concepts of operation might be available as early as 2011 or 2012. (Air Traffic Control/ Technical Operations Human Factors)



GUIDELINES FOR AN AIRCRAFT MAINTENANCE AVIATION SAFETY ACTION PROGRAM

In FY 2009, the FAA released *A Practical Guide to Maintenance ASAP Programs* in response to an industry-wide desire for a simple, practical source of information regarding the assessment, development, and operation of Aviation Safety Action Programs (ASAPs) across many areas of the aviation maintenance community. ASAP is a non-punitive, error-reporting program intended to encourage employee groups to report errors so that systemic solutions can be developed and error-inducing conditions can be minimized. In aviation maintenance, safety is dependent on technical reliability of the hardware and human reliability of the maintenance personnel. An ASAP program acknowledges the complexity of this human-machine relationship, as well as the human relationship, and provides a means to address errors that impact the overall safety of aviation maintenance. Over the past several years, the number of ASAP programs has increased significantly (currently 199 for maintenance, pilot, cabin, dispatch, and others). Because of Saint Louis University's extensive ASAP collaboration with airlines and repair stations as well as their experience on a variety of other maintenance human factors research issues, they were asked to develop the FAA Guide. Saint Louis University and the FAA worked with active industry representatives from AAR CORP, American Airlines, JetBlue Airways, Piedmont Airlines, Southwest Airlines, and United Airlines, as well as the International Brotherhood of Teamsters and the Transportation Workers Union, to collect the latest practical thoughts on maintenance ASAP programs. The industry representatives



brought a depth and a breadth of experience to this effort. As the Guide document was developed, it was taken to representative users (FAA, industry, labor) for evaluation and the feedback then incorporated into the revised document.



The Guide was released at the 2009 ATA/FAA Maintenance Human Factors Symposium to over 400 maintenance people and organizations representing most of the world airlines and Maintenance and Repair Organizations. The feedback was extremely positive that this document would be very beneficial in promoting the further development of the ASAP program. The Guide was also released at the 2009 Maintenance, Pilot, and Cabin ASAP Infoshare meeting (over 150 people) where it was similarly

heralded as an extremely important tool to help management and maintenance personnel easily understand the ASAP program and provide a clear roadmap for developing an ASAP program. There are requests for additional copies for distribution. The ASAP Infoshare group is aware of many maintenance organizations with long-standing interests in initiating an ASAP programs and will find the Guide to be a catalyst for them to begin their own formal process to develop an ASAP program. The U.S. Air Force is starting a maintenance ASAP program. (Air Traffic Control/Technical Operations Human Factors)



DEVELOP NEW PRACTICAL COLOR VISION TESTS FOR ATCS APPLICANTS

Research was done to develop a construct-based job-sample test assessing whether an applicant can discriminate the colors deployed for critical tasks in current air traffic displays and the research results were transitioned to operations. A research version of the ATC Color Vision Test (ATCOV) was previously developed and validated. This year, the ATCOV was modified to better comply with the 1978 Uniform Guidelines on Employee Selection Procedures by replacing the three subtests in the original research version ATCOV with five new subtests that more realistically represented targets currently deployed on critical air traffic displays. Display presentation times were also linked with task limitations.

Based on tests comparing results of color vision normal test subjects to those of color vision deficient test subjects, we concluded that the operational version of ATCOV is a true job-sample test, making use of display formats and color values deployed for critical functions on critical displays as defined by a review of published task analyses of ATCS duties. Its items are isomorphic with datablocks, datalines, and weather depictions deployed on Automated Radar Terminal System Standard Terminal Automation Replacement System (STARS), Display System Replacement, and User Request Evaluation Tool displays deployed to Terminal and En Route facilities. The Operational ATCOV was deployed to nine Regional Flight Surgeon Offices and Medical Field Offices in August and September of 2009.

The Color Assessment and Diagnosis (CAD) test was deployed to the same locations. In contrast to a job-sampled and validated test, this approach attempts to more precisely measure the color capabilities of a person and map color perception to a standard (International Commission on Illumination; CIE 1931) color space. CAD scores precisely quantify an applicant's range of color perception ability. The CAD may allow us to improve the selection process and to seek standards for color use in future air traffic displays. It will document the color perception abilities of those CAD ATCS candidates who pass and fail the ATCOV, using a high-precision clinical test. In turn, a critical envelope defined by color vision perception capacities of those who can perceive current display characteristics could become the occupational standard and constraints on future use of color could become the display standard. (Air Traffic Control/Technical Operations Human Factors)



HUMAN-CENTERED DESIGN

Aerospace systems that adapt
to, compensate for, and
augment the performance
of the human

AUTOMATIC DEPENDENT SURVEILLANCE – BROADCAST (ADS-B)

In 2008, RTCA SC-186 on ADS-B formed the Cockpit Display of Traffic Information (CDTI) Symbology Ad Hoc Working Group (CSAHWG). The goal of the working group was to create and execute a plan to address symbology-related issues that arose during review of a draft standards document. The CSAHWG determined that research was needed to understand what was known about the design of traffic symbols and to address gaps in knowledge to help develop more specific symbol recommendations. The Volpe Center supported this effort by conducting a broad literature survey in the summer of 2008. Later that year, the Volpe Center worked with CAASD and the FAA to design a study, conducted in FY 2009, in support of the CSAHWG.

The Volpe Center conducted an online CDTI symbol study in coordination with CAASD. The study assessed pilots' ability to learn and remember traffic symbols that may be shown



on a CDTI. Three aspects of using the traffic symbols when presented in isolation on a static display were evaluated: intuitiveness, ease of learning, and ease of remembering the symbols. Four symbol sets were tested, each with approximately 22 symbols. Each participant saw only one of the four symbol sets. The sets used different visual features of the traffic symbol to represent different information about the target, such as directionality, data quality, air and ground status, and alert level.

A total of 623 pilots with a broad range of experience participated in the main portion of the study. Results showed that while some conventions are well understood, such as the use of red and yellow for warnings and cautions (respectively), other conventions may be confusing and should be avoided. Two examples of confusing conventions are (a) using more than one visual feature (e.g., two different shapes) to represent the same traffic information, and (b) using similar visual features (e.g., two different outlines) to represent different traffic information.

Results of the study were considered by RTCA SC-186 in developing sample symbols for RTCA DO 317, Minimum Operational Performance Standards for Aircraft Surveillance Applications Systems, which was published in April 2009. A conference paper on the study was submitted for the 2009 Digital Avionics Systems Conference. Volpe Center also began preparing a full technical report on the CDTI symbol study that includes more information about the data and analyses. (Flightdeck/Maintenance/System Integration Human Factors)

FUTURE EN ROUTE WORKSTATION III SIMULATION

FAA researchers at the William J. Hughes Technical Center developed the Future En Route Workstation (FEWS) interface to support controller management of increased traffic levels. FEWS modifies the en route workstation to make information available to the controller when and where it is needed and automates some housekeeping tasks (e.g., data block management). Earlier simulations found benefits for FEWS, including better situational awareness, reductions in workload and display complexity, better sequencing of traffic, and fewer controller data entries.

In FEWS III, researchers made additional modifications to the workstation simulation to support use of Area Navigation (RNAV), self-spacing, and aircraft grouping procedures. The simulation assumed ADS-B capabilities and used three-mile lateral separation standards in all conditions. Scenarios included very high (2 to 3 times current) traffic levels in which 70 percent of the aircraft were equipped with Data Comm. Weather was also a factor in some conditions. Eleven controllers from five en route facilities participated in the simulation. They used two systems to evaluate the concepts: a baseline system simulating the En Route Automation Modernization system and the FEWS system.

Results showed that controllers managed more aircraft and reported lower workload when using the FEWS system than when using the baseline system. The participants also held or redirected traffic outside their sector much less frequently when using FEWS. They reported that FEWS was easier to use and better supported control efficiency, sector operations, control strategies, and their ability to determine which aircraft were using the self-spacing procedure. Other results showed that the participants managed more traffic when the aircraft were flying RNAVs that had both lateral and vertical conformance constraints (Full RNAVs) than when the aircraft had to be descended on the RNAV arrivals. Regardless of system, there were significantly fewer voice communications when aircraft were flying Full RNAVs. The aircraft also spent more time and traveled a greater distance in the sector when Full RNAVs were used, indicating that the participants tended not to intervene as much when aircraft were adhering to more constrained route structures. However, the workload was higher in conditions that incorporated the self-spacing and grouping procedures. Overall, the participants rated the self-spacing procedure favorably, but reacted negatively to the grouping procedure.

These results indicate that FEWS and the use of Full RNAVs allow controllers to safely and effectively manage a much larger volume of aircraft in a sector. The researchers presented a preliminary briefing of these findings to personnel at FAA Headquarters in June. They are currently completing the data analyses and writing a technical report summarizing the simulation and its results. (Air Traffic Control/Technical Operations Human Factors)

FUTURE TERMINAL WORKSTATION – 1

NextGen will bring substantial changes to operational concepts, procedures, and technology used in the terminal domain. It is not known how these changes, combined with higher traffic complexity, will affect controller performance, decision-making, or workload. It is also not known how the information necessary to support NextGen in the terminal domain should be presented to controllers and integrated into their workstations. The Future Terminal Workstation (FTWS)-1 simulation was developed by researchers at the William J. Hughes Technical Center to evaluate a prototype workstation for the terminal domain that incorporates much of the technology needed to support NextGen. In 2009, researchers created the first FTWS prototype and accompanying simulation scenarios. The FTWS prototype was used to conduct human factors research on NextGen operational concepts and procedures. It is designed to follow human factors best practices, keep controller workload at manageable levels, and reduce the likelihood of human error. The prototype builds on research, lessons learned, and designs created for other projects, systems, domains, and countries. The prototype and scenarios served as the platform for a HITL simulation and will serve as the platform for further simulations in 2010 and beyond.

Researchers developed the FTWS platform using the Distributed Environment for Simulation, Rapid Engineering, and Experimentation. The FTWS-1 simulation contained three sets of functionality and user interface designs, known as “skins,” and evaluated the skins using scenarios reflecting 2008, 2020, and 2025 traffic and equipage levels. The skin emulated STARS as it currently exists in the field. The STARS skin included all the core air traffic functions and capabilities. The STARS+ skin also emulated STARS with major new capabilities added, including ADS-B as a surveillance source, controller-pilot Data Comm, advanced route functions, and spacing tools. The full FTWS skin added new user interface designs to the STARS+ skin, including interactive data blocks and a different keyboard and pointing device.

Data was collected using the simulation during May and June 2009. Seven controllers or supervisors from field sites participated in three, two-week sessions. Participants completed numerous training and data collection scenarios followed by interviews with human factors personnel. Preliminary analyses of the data indicate that having aircraft fly on RNAV routes with a conformance monitoring tool greatly reduced controller workload even under 2025 traffic levels, thus potentially allowing them to manage more aircraft safely and efficiently. However, interdependencies were observed between the various tools that were developed independently. For example, when the controllers used Data Comm messages to vector aircraft flying an RNAV, the system needs to inform the conformance monitor of the change. Researchers also observed that participants continued to employ a vector mindset even with the advanced capabilities and determined that controllers will need to transition to a trajectory-based mindset to achieve maximum benefit.

Initial data analysis for the FTWS-1 simulation is complete. Technical reports for the simulation will be delivered in FY 2010. (Air Traffic Control/Technical Operations Human Factors)

ELECTRONIC FLIGHT BAGS

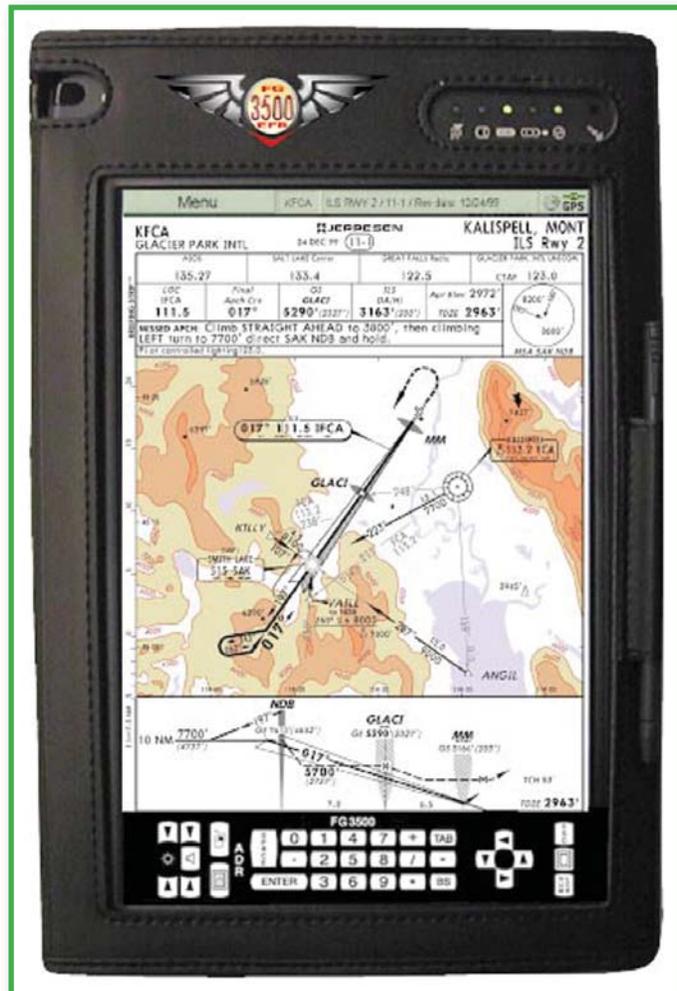
The Electronic Flight Bag (EFB) industry has grown rapidly since the FAA issued Advisory Circular (AC) 120-76A in March of 2003. A variety of models are being purchased and deployed by all types of operators. The purpose of this research is to examine what, if any, safety impacts EFBs are having as the industry matures and units are deployed more widely. In 2008, EFB-related safety reports were gathered from the Aviation Safety Reporting System (ASRS). In addition, the NTSB database was searched for EFB-related accidents. A total of 37 ASRS reports were determined to have EFB-related issues and 2 relevant accident reports were discovered.

A conference paper was prepared based on the data gathered in 2008 and presented at the International Symposium on Aviation Psychology in April 2009. The most commonly reported EFB issues concerned: (a) configuring the chart display so that both detailed and global information is appropriately accessible, and (b) use of EFBs by new users.

An expanded search of the ASRS database was completed in August 2009. This search identified over 100 additional reports related to the use of laptop computers in performance calculations. The new reports were reviewed in detail with the net result that approximately 30 new events are expected be added to the original 37 in the technical report. Most of the new reports involve flight deck procedures for when and how to do the performance calculations.

Results of the research will be published in a technical report that will be made available on the Volpe Center website.

In addition, EFB human factors workshops are planned for FY 2010 for the FAA inspectors and others involved in the evaluation of EFBs. The workshops will inform FAA staff involved in evaluating EFBs about the current state of the industry and about tools previously developed by the Volpe Center to aid in their evaluations. A similar workshop was conducted in September 2009. (Flightdeck/Maintenance/System Integration Human Factors)



FRONT LINE MANAGER BEST PRACTICES

The Air Traffic Organization's Offices of Safety and of NextGen and Operations Planning initiated a series of projects to determine the relationship between high performing Front Line Managers (FLM) and losses of separation. Current thought maintains that operational FLMs may be able to influence the reduction of this risk through various supervisory skills or techniques that prevent the occurrence of reportable errors. In support of this effort, two independent, consecutive studies were done in the tower and en route environments. The third, and last, phase in the Terminal Radar Approach Control (TRACON) environment was conducted in 2009.

The first study applied a methodology in the en route environment addressing the gap between existing performance management training and people skills critical for helping controllers avoid errors. The second study performed in the tower environment focused on specific contributing factors such as communication breakdown, memory, and coordination to determine practical strategies for managing and improving controller performance.

This third phase provided data-driven results in conjunction with lessons learned from the prior phases to identify additional FLM best practices that positively affect safety. Focus was placed on reviewing existing research data and performing an operational error analysis based on various contributing factors such as weather, training tasks, and implementation of new equipment and procedures. All of the facilities chosen for this phase had a history of low error rates and the participating FLMs had been identified as high performers in those facilities. TRACON facility interview results and information analyses produced an integrated set of FLM Best Practices encompassing the Tower, En Route, and TRACON environments. These were used to develop a comprehensive set of best practices for the *FLM Best Practices Quick Reference Guide* that will be distributed to all Air Traffic Control FLMs within the FAA in FY 2010. (Air Traffic Control/Technical Operations Human Factors)

DYNAMIC COMPREHENSION: TIME ON POSITION AND MENTAL FATIGUE

In FY 2009, research was done to provide an empirical basis for establishing minimum and maximum times on position for en route controllers. No empirical research was available that would enable the FAA to determine the minimum amount of time a controller should be on position before being relieved without compromising safety. An experimental approach was used to determine the amount of time it took to develop dynamic comprehension of the traffic situation following a position transfer under varying workload conditions. Three experiments were conducted. Experiment 1 examined the use of oculomotor measures and an adaptation of the Situation Present Assessment Method to detect changes in controllers' attention and dynamic comprehension. Experiment 2 calibrated scenarios based on levels of subjective workload. Experiment 3 assessed the vulnerabilities associated with controllers' memory and planning and decision making immediately following a position transfer.

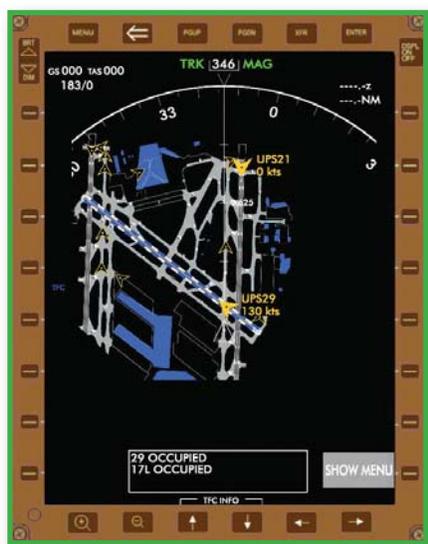


Experiment 1 failed to demonstrate the value using oculomotor measures to detect changes (units of seconds) in controllers' attention associated with the development of dynamic comprehension. Experiment 2 successfully calibrated four 20-minute scenarios based on the subjective workload experienced by controller participants. Segments of these scenarios were used to create six five-minute scenarios that formed the stimuli for the revised Experiment 3. The results of Experiment 3 suggested that controller participants needed between 5-10 seconds per aircraft to understand the traffic situation and develop a tactical plan for controlling traffic following a position transfer. This range forms an empirical basis for estimating the minimum amount of time a controller needs before he/she can make an informed decision about the traffic situation and, hence, be able to give an informed position relief briefing. Also, contrary to the notion that controllers memorize traffic situations prior to assuming position control, controller participants did not memorize all aircraft locations and their corresponding altitudes, states of climbing or descent, and headings. Instead they focused on only those aircraft that mattered (i.e., require immediate action). Experiment 3 also demonstrated that controllers underestimated the number of control actions (and hence the amount of time) necessary to implement their traffic management plan once they assume position control. Thus, controllers are vulnerable to being in a time crunch, even if the traffic situation is manageable following a position transfer.

Controllers commonly state that it takes time to develop a feel for the traffic once they assume position control. The results of this study suggest that the feel that controllers are referring to may be associated with calibrating their internal (mental) time clock with the actual time it takes to execute their plan. Controllers may have a plan when they assume position control, but they may initially underestimate the amount of time it will take to

execute that plan. Since the calibration occurs during the first few minutes following a position transfer, this may create unexpected time crunches within an otherwise well-organized plan of action. Position changes that occur before the outgoing controller has had time to adapt (i.e., develop a feel or calibrate internal time with external time) to the traffic situation simply pass on this period of vulnerability to the next incoming controller. This study suggests that it takes between 5-10 seconds per aircraft for controllers to adapt to the traffic demands of their sector once they assume position control. This range serves as an initial basis for estimating the minimum amount of time controllers should be on position before being relieved. (Air Traffic Control/Technical Operations Human Factors)

SURFACE MOVING MAPS



It is generally accepted that the use of a surface map improves the flight crew's situation awareness and increases safety in taxiing on the airport surface. The intended function for this application is to assist flight crews in orienting themselves by enhancing the pilots' awareness of ownship position on the airport surface and to improve pilot position awareness with respect to taxi operations. Several advanced functions are also being considered (e.g., indications or alerts of potential runway incursions, integration of air traffic control instructions for taxi) for surface map displays. The FAA is charged with approval of surface map displays for installation and operational use in aircraft. The approval process will require an understanding of how the application will be used by crews and the implications for operational procedures.

Two main activities were conducted in FY 2009. First, the Volpe Center provided human factors support for an FAA-sponsored operational evaluation to assess the impact of a surface moving map with ownship position on a Class 2 or Class 3 EFB. The Volpe Center coordinated with participating airlines, CAASD, and the FAA to develop three surveys to gather data on the human factors and pilot interface aspects of the EFB as well as issues associated with their operational use and safety. Second, the Volpe Center published an industry survey describing what information is depicted on surface moving map displays and what functions are being implemented. Thirteen manufacturers and six research organizations participated. Of particular interest in the survey are how the ownship is depicted, whether a traffic function is available, and whether any visual or auditory indications or alerts are planned.

The results of this research are intended to support the development of guidelines and approval criteria for surface moving maps depicting ownship position. This research also intends to provide information to identify what additional guidance is needed for establishing minimum standards and best practices to support advanced functions proposed for this application. (Flightdeck/Maintenance/System Integration Human Factors)

HUMAN PROTECTION

No fatalities, injuries, or
adverse health impacts due
to aerospace operations

LAPTOP COMPUTER FIRE EXTINGUISHMENT

Laptop computers and other battery-powered electronic devices can pose a significant fire hazard when carried aboard passenger aircraft. The lithium-ion batteries may malfunction and overheat, often occurring during the charging process. This can cause the battery pack to catch fire. Laptop computer batteries contain up to nine lithium-ion cells and become dangerous when the internal temperature reaches 350 degrees Fahrenheit. At that temperature the cell goes into thermal runaway. The cell gets extremely hot, then overpressurizes, releasing flammable liquid electrolyte, and may explode. A single cell in thermal runaway generates enough heat to cause adjacent cells to also go into thermal runaway, a chain reaction process.



The FAA, in conjunction with the airline industry, embarked on a series of tests to determine the optimum procedure for fighting a laptop computer fire on board an aircraft. Halon 1211, the typical fire extinguisher installed in passenger aircraft, was effective in extinguishing the burning electrolyte, but did not prevent adjacent cells from going into thermal runaway and catching on fire. It was determined that water was the most effective agent in cooling the remaining cells and stopping the chain reaction. A training video, developed by the Fire Safety Team, illustrates effective

and practical methods to extinguish a cabin fire involving lithium batteries in a laptop computer. The video, “Extinguishing In-Flight Laptop Computer Fires,” may be viewed at the Fire Safety Team website: www.fire.tc.faa.gov.

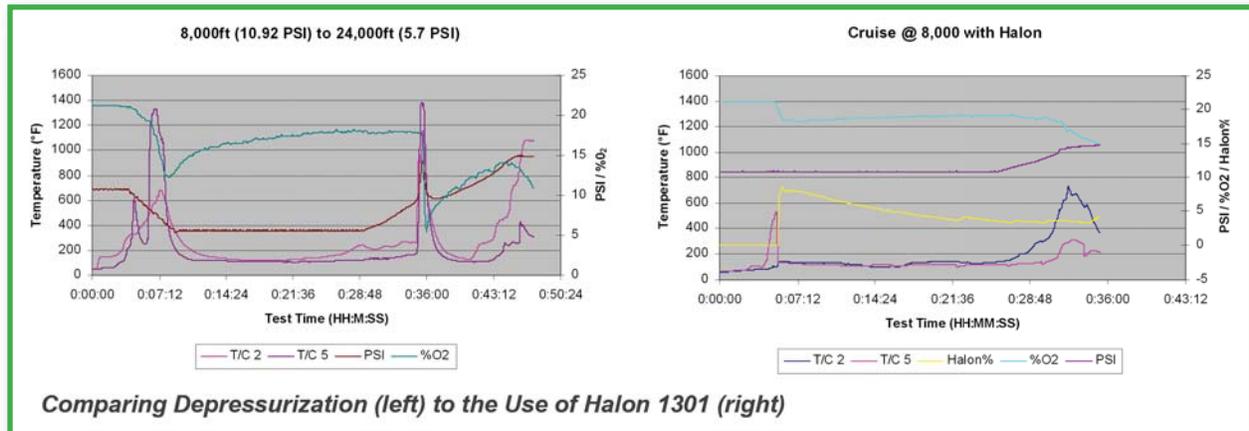
The FAA issued a Safety Alert for Operators (SAFO) (SAFO 09013, June 23, 2009) entitled *Fighting Fires Caused by Lithium Type Batteries in Portable Electronic Devices*. The SAFO recommends procedures for fighting fires caused by lithium type batteries in portable electronic devices. Based on testing by the Fire Safety Team of the FAA William J Hughes Technical Center, the SAFO recommends a two phase procedure: (1) extinguish the fire and (2) cool the remaining cells to stop thermal runaway. Halon 1211 or water fire extinguishers are effective at extinguishing the fire and preventing its spread to additional flammable materials. After extinguishing the fire, dousing the electronic device with water or other non-alcoholic liquids cools the device and prevents additional battery cells from reaching thermal runaway. The SAFO references the FAA training video, “Extinguishing In-Flight Laptop Computer Fires,” for additional information and demonstration of the fire fighting techniques. (Fire Research and Safety)

CARGO FIRE CONTROL BY DEPRESSURIZATION

In FY 2009, a test program was conducted in a pressure vessel to examine the effectiveness of aircraft depressurization, an FAA-accepted procedure for controlling fires in freighter (all cargo) aircraft, in response to an NTSB recommendation following a destructive freighter fire. Two series of test were conducted. In the first series, several scenarios with different fire sources were tested at varying altitudes to measure the effect of altitude (ambient pressure) on fire source intensity and burn time. For each scenario, the variation in mass weight loss versus time at different altitudes or the burn rate versus altitude were examined. The results demonstrated that cargo fires suppressed in this manner may re-ignite as the aircraft descends and ambient pressure rises. For the second series, tests were performed to determine the effect of varying altitude after a cargo fire was detected. Four flight scenarios or profiles were tested. Testing commenced for each flight profile at 8,000 ft, which corresponds to the normal aircraft pressure in flight. Once a rapid temperature rise was observed, indicating that the cargo had ignited, a descent was simulated by increasing the pressure in the vessel over a 20-minute period of time. At the end of the 20 minute descent, the pressure vessel was brought back to a sea level condition.

Series one test results showed a reduced burn rate for all materials tested as the altitude increased (pressure decreased). The decreased burn rate was nearly linear, slightly greater than a reduced rate of two percent per 1,000 feet. Lithium metal and lithium ion batteries are a fire safety area of concern for all transportation modes; but testing showed that altitude had little or no effect on the reaction. However, the time needed to heat the batteries to the point of reaction was increased, because of the reduced burn rate of the fuel supplying the heat, as altitude was increased (pressure reduced).

Series two test results showed that, although depressurization reduced the initial burning, the fire intensity on descent was greatly accelerated. The highest depressurization altitude evaluated (25,000 feet) produced the best initial results but the largest fire on descent. The results of the depressurization tests were compared to the use of Halon 1301 under similar conditions. Halon 1301 is used to suppress cargo compartment fires in passenger-carrying airplanes. The use of halon provided much greater control of the fire. An FAA technical report for public distribution was drafted describing the findings. (Fire Research and Safety)



AIRCRAFT BATTERY SAFETY

Tests were performed at the William J. Hughes Technical Center by the FAA Fire Safety Team to examine the fire safety hazards that cylindrical lithium-ion and lithium-ion polymer batteries may pose on aircraft. Tests were conducted on individual, manufacturer-supplied battery cells to determine how the cells would react in a fire situation. Tests were also conducted to determine what potential fire hazard the battery cells themselves may pose and to determine the effectiveness of a typical handheld extinguisher on a fire involving the battery cells. The battery cells that were tested were all COTS products that are being considered by manufacturers for aircraft-power-related usage. In recent years, there has been an increase in the use of lithium batteries for aircraft applications.

The results of the tests showed that both the cylindrical and polymer-type battery cells can react violently when exposed to an external fire. The cylindrical cells vented such that the electrolyte would spray out forcefully and ignite, accompanied by a rise in temperature and pressure. The polymer battery cells did not have any vent locations. Instead, they were designed with a seam around the perimeter of the cell



Prototype aircraft battery cells

that would open thereby exposing the flammable electrolyte. The failure of the polymer-type battery cells greatly fueled the existing fire as the full amount of the electrolyte was exposed instantaneously to the fire source. In both single- and multi-cell tests, the lithium polymer battery cells, which consist of a different chemical reaction and possess a much higher energy density and power capacity, resulted in significantly higher temperature and pressure increases compared to the cylindrical cell types. Tests conducted with a handheld Halon 1211 fire extinguisher showed that the halon was able to extinguish all three types of battery fires. However, for the polymer battery cells, even after several attempts, the halon extinguishing agent was not able to prevent the cells from reigniting.

The tests on lithium battery cells provided much insight into the potential hazards that these new battery technologies may pose. The results can be used to determine what requirements and safeguards need to be placed on the battery packaging system that house these cells. Such safeguards include proper vent placement and sizing, overcharge and thermal protection circuits, and barriers between cells to prevent thermal propagation from one cell to the adjacent cells. The next step will be to conduct tests on prototype lithium batteries for aircraft. (Fire Research and Safety)

CONTAMINATED INSULATION FLAMMABILITY

The fire resistance of aircraft thermal-acoustic insulation is critically important because most serious aircraft in-flight fires originate in hidden areas lined with insulation. In 2005, an FAA regulation requiring a more stringent flammability test method for thermal-acoustic insulation, developed by the Fire Safety Team, went into effect. Another aspect of the flammability of insulation is the effect of contamination that may accrue on the surface from various sources during service. FAA recommends that the insulation blankets be examined periodically to remove any contamination.



Igniting a highly contaminated blanket



***Highly contaminated blanket
Time = 1 minute***

Thermal-acoustic insulation blankets having visible contamination were removed from a commercial passenger airplane which had experienced an in-flight smoke incident. The level of contamination on the polyester film encapsulating the fiberglass insulation was weighed, ranked by visual inspection, and characterized by microscale combustion calorimetry to determine the thermal combustion properties and fire hazard. The areal weight of the visible contamination was as high as 167 grams per square meter of film surface and its average heat of combustion was 13 kJ/g. Previous analysis by the aircraft

manufacturer had determined that the contamination consisted of dried liquid corrosion inhibiting compounds and PM that included glass fibers, synthetic and natural fibers, animal hair, cotton fibers, mineral particles, plastic, Styrofoam, metal fragments, and insects.

Pictured above: Contaminated thermal-acoustic insulation fire tests



Uncontaminated blanket
Time = 1 minute

The 2009 study determined that the inert/mineral component of the contamination accounted for about one-third of the weight and was mostly broken glass fibers. The pyrolyzable (volatile) component accounted for the remaining two-thirds of the contamination weight and the specific heat of combustion of these volatile compounds ranged from 19-28 kJ/g, which is comparable to the polyester film. Insulation blankets and films were also tested for flame resistance and flame spread using the less stringent FAA regulatory standard in effect when the airplane was certificated. Tests were also conducted with a voluntary

standard employed by industry. All samples of insulation blankets passed the 12-second vertical Bunsen burner flame resistance requirement of Federal Aviation Regulation (FAR) 25.853 and FAR 25.855, but highly contaminated blankets failed the non-regulatory (voluntary) screening test for flame spread using a cotton swab ignition source. Numerical modeling of the burning rate using the FAA-developed ThermaKin code suggests that the flame-spread on contaminated samples tends to be erratic and may be associated with the non-uniform combustion properties of the contamination. Moreover, it was determined that insulation blankets with the highest levels of contamination would not be compliant with the current stringent FAA fire test requirement. (Fire Research and Safety)



Moderately contaminated blanket
Time = 1 minute

Pictured above: Contaminated thermal-acoustic insulation fire tests

SUPPORT OF AIRCRAFT ACCIDENT INVESTIGATION

Turkish Airlines Flight No. TK 195, a current generation Boeing 737 – 800, crashed at Amsterdam’s Schiphol Airport on 25 February 2009. Of 134 passengers and crew on board the aircraft, 9 occupants were killed and over 50 injured. A research engineer from Civil Aerospace Medical Institute (CAMI), Aerospace Medical Research Division, was called to the accident site in Holland by the U.S. accident investigation team to assist the Dutch Safety Survivability Board in the accident investigation. This accident was of particular interest to both accident investigators and researchers because the relatively new model Boeing 737 was equipped with 16G seats rather than the 9G seats that are standard equipment in the earlier model Boeing 737 aircraft. The designation “G” is the unit of measure for acceleration; thus, 16G represents 16 times the earth’s gravitational pull. The 16G seats are safer than 9G seats, which date back to 1950’s technology, because they are stronger and do a far superior job of protecting the occupant in the event of a survivable crash. 9G seats undergo only a static pull test with a load of 9G (1540 lbs) held for three seconds. In the static tests, a pelvic block (hips only) is used to represent the occupant. 9G seats are not evaluated to any defined occupant protection criteria. 16G seats must pass a 9G static test plus two dynamic sled tests - a vertical test of 14G and a longitudinal test of 16G. A 170 pound anthropomorphic test dummy (like those used in automobile crash testing) must be used during dynamic tests to represent the occupant. The 16G seats also must pass other occupant protection criteria that contribute to its improved occupant protection.

The FAA, along with other groups -- NTSB, NASA, U.S. Army, General Aviation Safety Panel, etc. -- have done extensive research and studies over the last few decades to determine how best to raise the level of safety for seating systems for passengers and crewmembers in the event of a survivable aviation accident. The results of this research culminated with the FAA issuing very well-defined rules in 1988 to make sure the seats could endure the new higher 16G dynamic testing and protect the occupant in that seat. This actually means running an airplane seat with a test dummy down a track much like tests seen in automobile crash tests. Among other criteria, those rules specifically address maximum leg, spine, and head trauma injury levels which all 16G seats must prevent an occupant from experiencing.

There have been very few survivable airliner accidents in newer model aircraft that are equipped with the 16G seat; thus, the TK 195 accident represented a unique opportunity for investigators and researchers to assess the safety implications of the 16G seat relative to occupant survival and injury. While the results of the accident investigation have not been released, it is thought that the absence of a post-crash fire and possibly the 16G seat contributed to the high number of survivors. (Aeromedical Research)



Investigators at the scene of the Turkish Airlines Flight No. TR 1951 accident at Amsterdam's Schiphol Airport, 25 Feb 2009.

ACCIDENT MEDICAL REVIEW PROGRAM

The CAMI autopsy acquisition program was initially developed by the FAA Office of Aerospace Medicine to move the responsibility for the acquisition of autopsies from the Regional Flight Surgeons' offices to a centralized office at CAMI. This move not only met requirements to obtain autopsies for accident investigators, but it facilitated collaboration between the autopsy acquisition team and medical research. This collaboration led to the development of a medical accident review program that provided accident investigators and FAA Headquarters safety personnel with near real-time accident data. This information was transmitted to the users via email or telephone. The Autopsy and Medical Teams worked the accidents on a seven-day-per-week basis; however, contact and information availability was generally limited to normal duty hours. Team members determined that 24/7 availability of accident information would be valuable for investigators and safety personnel and initiated an effort to determine the optimum method to provide accident data in a timely manner. It was also recognized that in addition to real-time information, the accident information needed

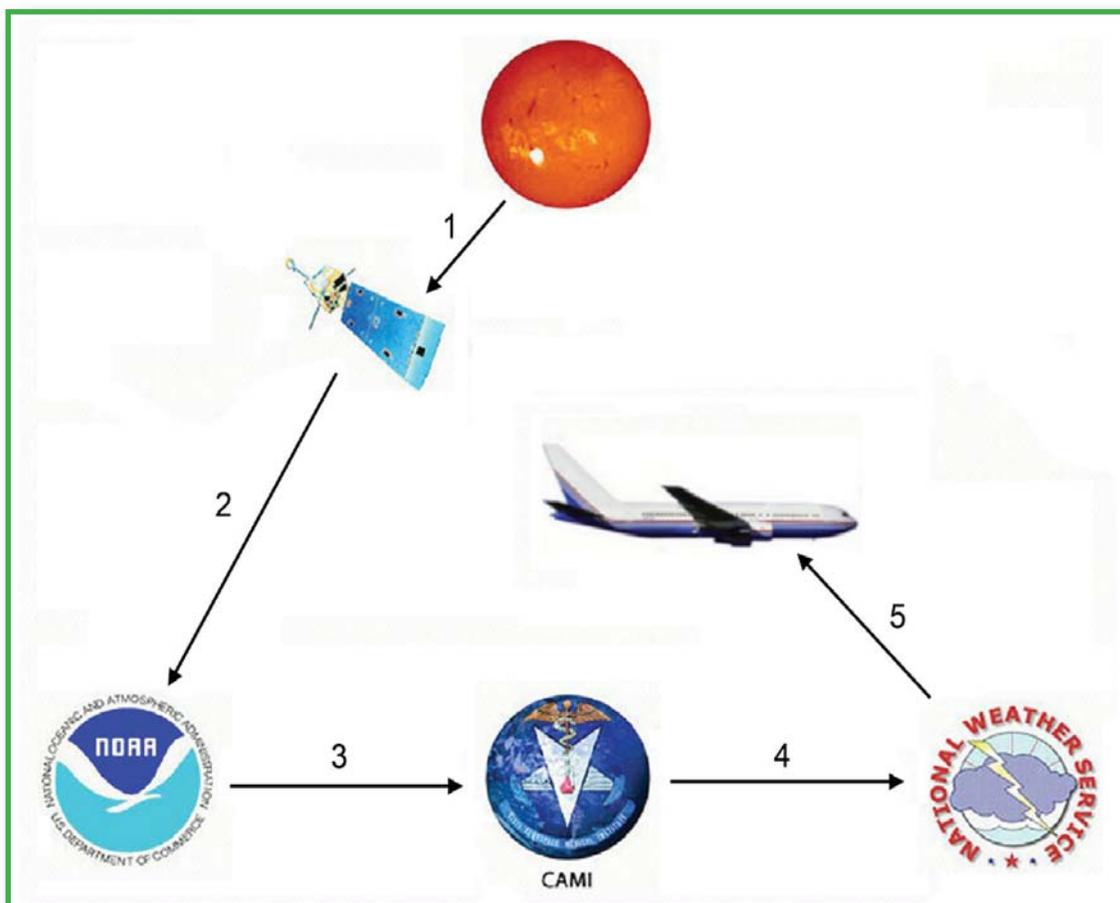
to be presented by geographical location, contain linkages to other essential data sources, and present the information in a user-friendly, human-centered format. The team found that a Google Map/Google Earth format would best portray the information. Using Google Maps, the geographical location of the accident could be identified with a pin marker. The geographical information was important to the Autopsy Team to assist it in locating the medical examiner

that was responsible for the accident and to find other local offices that may be involved in the investigation. Using the bubble identifier supports the attachment of linkages to other sources of information. Linkages to NTSB data provides that accident synopsis and, for the medical aspects of the investigation, linkages to the medical analysis, toxicological findings, and autopsy findings provided needed data to investigate the mishap pilot's medical status. When established, the supporting databases may be searched and shown in the Google format to highlight items of interest. The data could be shown by FAA region, state, or any other desired geographical area. Similarly, the data could be shown by date or other relevant time period for individual users. Marker pins may be color coded to represent other important accident information. In short, the use of map/bubble presentation technology provides a timely and efficient method for accident data transfer. The concept was briefed at the 2009 Safety Line-of-Business managers meeting and generated significant interest as a valuable tool for multiple users. (Aeromedical Research)



SOLAR RADIATION ALERT SYSTEM

During air travel, aircraft passengers and crew are usually exposed to ionizing radiation at higher dose rates than members of the general population. The principal ionizing radiation for air travelers is galactic cosmic radiation, a main source of which is supernovae (exploding stars). Occasionally, a disturbance in the sun leads to a large flux of solar protons with sufficient energy to penetrate earth's magnetic field, enter the atmosphere, and increase ionizing radiation levels at aircraft flight altitudes. The Solar Radiation Alert (SRA) system continuously evaluates measurements of high-energy protons made by instruments on Geostationary Operational Environmental Satellite (GOES). If the measurements indicate a substantial elevation of effective dose rates at aircraft flight altitudes, the CAMI issues an SRA via the NOAA Weather Wire Service. If the measurements indicate a substantial elevation of effective dose rates at aircraft flight altitudes, the CAMI issues an SRA via the NOAA Weather Wire Service.



Solar Radiation Alert system:

(1) Occasionally, a disturbance in the Sun (solar flare, coronal mass ejection) leads to a large flux of high-energy particles in the vicinity of the Earth. (2) Instruments on a GOES satellite continuously measure the radiation and the information is transmitted to NOAA. (3) From there it is sent to CAMI. A computer at CAMI analyzes the measurements. (4) If the measurements indicate the likelihood of a substantial elevation of ionizing radiation levels at aircraft flight altitudes, a Solar Radiation Alert is issued to the NOAA Weather Wire Service. Estimated effective dose rates for 30-, 40-, 50-, 60-, and 70-thousand feet are included and updated at 5-minute intervals for the duration of the alert. (5) The National Weather Service distributes alerts and updates via the NOAA Weather Wire Service and the Internet.

Office of Aviation Medicine report DOT/FAA/AM-09/6 describes the revised SRA system that replaced the system described in the 2004 report DOT/FAA/AM-05/14. The new system replaced the older system in 2008. SRA issue criteria remain the same but significant improvements have been made in the calculations. The solar proton fluence to effective dose conversion coefficients for specific altitudes are based on hundreds of millions more Monte Carlo simulations of radiation showers. The shape of the <10 MeV secondary neutron spectrum is now accounted for down to 100 eV. The flux correction based on spectral index has been revised to smooth the flux spectrum of solar protons. Estimates of the >605 MeV spectral shape have been improved by the addition of correction factors for the differential interpretation of the >700 MeV integral flux channel. Estimates of galactic cosmic radiation background count rates in the GOES data are now median rather than mean values.

Comparisons with dose rates calculated by more sophisticated methods (unsuitable for near-real time indicate use) indicate that dose rates generated by the revised SRA system, which uses easily and rapidly available data, are good estimates at aircraft flight-altitudes at polar latitudes. (Aeromedical Research)

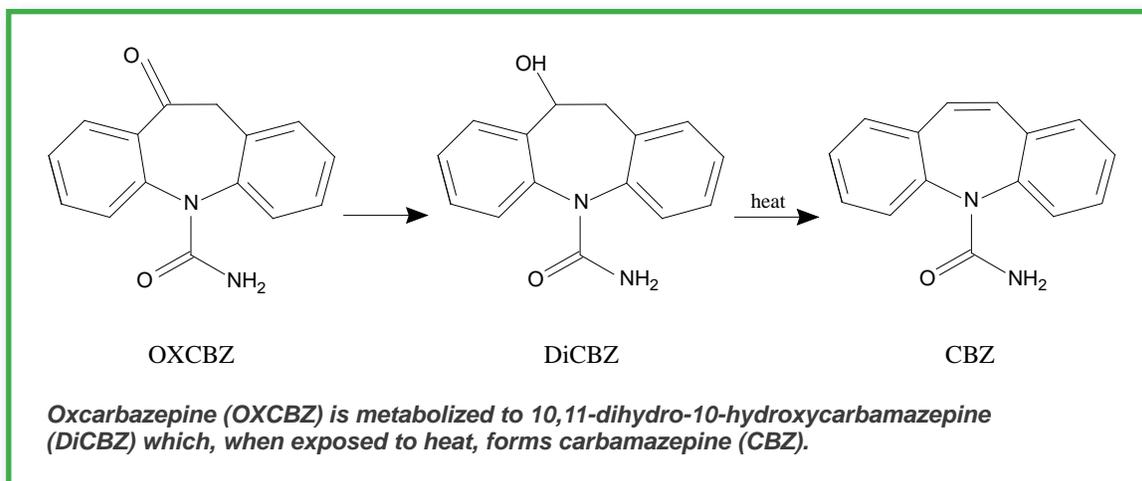
ENSURING ACCURACY IN THE ANALYSIS OF ANTICONVULSANT MEDICATIONS

Anticonvulsant medications are commonly prescribed for the treatment of epilepsy. These medications also act as mood stabilizers and are prescribed in that function for the treatment of bipolar disorder. Such conditions, and medications to treat such conditions, are disqualifying for airmen medical certification. Two of the most common anticonvulsant medications are carbamazepine (Tegretol®) and oxcarbazepine (Trileptal®). These compounds are nearly identical structurally.

A case recently received by CAMI screened positive for the anticonvulsant medication carbamazepine by gas chromatography/mass spectrometry (GC/MS). The carbamazepine found during the routine screening procedure was subsequently confirmed using a carbamazepine-specific GC/MS procedure. Concurrently, it was discovered that the accident victim had been prescribed oxcarbazepine.

Specimens from the victim were reanalyzed by GC/MS to confirm and quantify both oxcarbazepine and its active metabolite, 10,11-dihydro-10-hydroxycarbamazepine. While analyzing analytical standards of these compounds by full-scan GC/MS prior to analysis, it became evident that carbamazepine was present following the injection of 10,11-dihydro-10-hydroxycarbamazepine.

The percentage of carbamazepine formed at various injector port temperatures was found to be 2.4 ± 0.3 percent (n=4), 4.8 ± 0.2 percent (n=4), 12.8 ± 0.3 percent (n=4), and 26.6 ± 1.4 percent (n=4) at GC injection port temperatures of 200, 225, 250, and 275°C, respectively. All three compounds were quantified in nine fluid and tissue specimens from the case in



question. The carbamazepine initially found in this case was ultimately due to the thermal breakdown of 10,11-dihydro-10-hydroxycarbamazepine (oxcarbazepine metabolite) in the heated GC/MS injector port.

The findings from this 2009 study clearly demonstrate the thermal transformation of 10,11-dihydro-10-hydroxycarbamazepine to the structurally related carbamazepine during analysis. Chemical degradation or transformation is particularly disconcerting in cases resulting in either a false negative or a false positive analytical finding. If the compound formed is readily available and commonly prescribed, the analytical result obtained following analysis would most likely not be questioned. Therefore, it is prudent to be aware that such transformation or degradation can occur during or prior to drug analysis and for a laboratory to maintain a high degree of quality assurance so that such occurrences can be detected if and when they do occur. (Aeromedical Research)

DETECTION AND PREVENTION OF CARBON MONOXIDE EXPOSURE IN GENERAL AVIATION AIRCRAFT

Exposure to carbon monoxide (CO), which is formed by the incomplete combustion of carbon-containing materials such as aviation fuels, is associated with headache, dizziness, fatigue, and, at elevated doses, death. Exhaust system failures in General Aviation (GA) aircraft can result in CO exposure. When this occurs in an aircraft, the end result could be an accident. This research on detection and prevention of CO exposure in GA aircraft addressed the following objectives: to identify exhaust system design issues related to CO exposure; to identify protocols to quickly alert users to the presence of excessive CO in the cabin; and to evaluate inspection methods and maintenance practices with respect to CO generation. These objectives were accomplished by review of the scientific literature on CO incidents and accidents, current CO detector technology and determination of the best placement location for CO detectors in the cabin, industry maintenance practices, Advisory Circulars, and FAA regulations with respect to GA exhaust systems, and current industry inspection practices on exhaust systems in GA aircraft.

A total of 71,712 accident cases between 1962 and 2007 were reviewed from the NTSB accident and incident database. Review of these cases revealed that the CO-related accidents occurred throughout the year; however, accidents caused by leakage in the muffler or exhaust system were more prevalent in the colder months. Furthermore, it was shown that the majority of the CO-related accidents caused by leakage had muffler usage greater than 1000 hours.

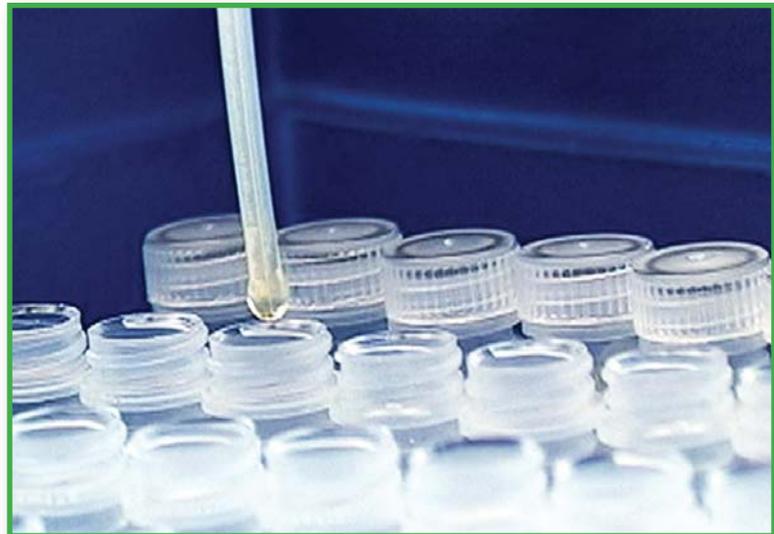
The research on the specifications of CO detectors resulted in a list of performance specifications regarding the use of CO detectors in GA aircraft. Some of the characteristics considered important for GA application include high accuracy, quick response time, inherent immunity to false alarms, and low power consumption. Taking these characteristics into account, it was concluded that CO detectors using electrochemical sensors may be the most suitable for use at this time in a GA environment. Electrochemical CO detectors available on the market that are likely suitable for use in a GA environment range in price from \$175 to \$200, possess good battery life (2000 to 2600 hr), and have quick response times (12s to 35s). A database of available CO detectors on the consumer market was developed, which, along with categorized performance parameters, can help pilots make informed decisions on CO detector selection.

A limited field test using portable electrochemical CO detectors was conducted on two GA aircraft models to determine the best location for a CO detector. The results indicated that the majority of CO detected in the cabin was below 10 parts per million (ppm), well below the FAA standard of 50 ppm. However, a small percentage of CO that was detected in the cabin was above 50 ppm. Based on the analyses of limited collected CO data, the instrument panel appeared to be the best location for CO detector placement. To increase the probability of being able to detect at least 50 ppm anywhere in the cabin and to reduce the occurrence of false alarms, it appears that the CO detector should be set at a lower alarm threshold of 35 ppm.

FAA regulations and guidance documents indicated that the maintenance and inspection of GA aircraft exhaust systems is generally carried out by means of visual inspection. While there is no lifetime limit on mufflers in FAA regulations, the NTSB accident and incident database review showed a strong relationship between the lifespan of a muffler and its failure. Performing a thorough visual inspection and air pressure test with soapy water increased the chance of finding cracks, damage, and developing deterioration in exhaust system components. This maintenance practice, together with an imposed lifetime limit for mufflers (recommended by respective manufacturers), should be considered as a primary prevention method for CO exposure in GA aircraft. Placing a suitable CO detector at the instrument panel would serve as the secondary prevention method to further prevent CO exposure. Familiarity with the signs and causes of exhaust system failures can facilitate the identification and prevention of CO exposure at its sources. This information is summarized in the form of checklists to help pilots and mechanics identify and remedy potential exhaust system failures. (System Safety Management)

EXAMINING SMOKING-INDUCED DIFFERENTIAL GENE EXPRESSION CHANGES IN BUCCAL MUCOSA

Gene expression changes resulting from conditions such as disease, environmental stimuli, and drug use, can be monitored in the blood. However, a less invasive method of sample collection is of interest because of the discomfort and specialized personnel necessary for blood sampling especially if multiple samples are being collected. Buccal mucosa samples (cheek swabs) are easily collected and may be an alternative sample material for biomarker testing. A limited number of



studies, primarily in the smoker and oral cancer literature, address this tissue's efficacy as an ribonucleic acid (RNA) source for expression analysis. The study was undertaken to determine if total RNA isolated from buccal mucosa could be used as an alternative tissue source to assay relative gene expression.



In this study Quantitative Polymerase Chain Reaction (q-PCR) and microarray analyses were used to evaluate gene expression in buccal cells. Initially, q-PCR was used to assess relative transcript levels of four genes from whole blood and buccal cells collected from the same seven individuals at the same time. The RNA isolated from buccal cells was degraded but was of sufficient quality to be used with Reverse Transcription-q-PCR to detect expression of specific genes. Second, buccal

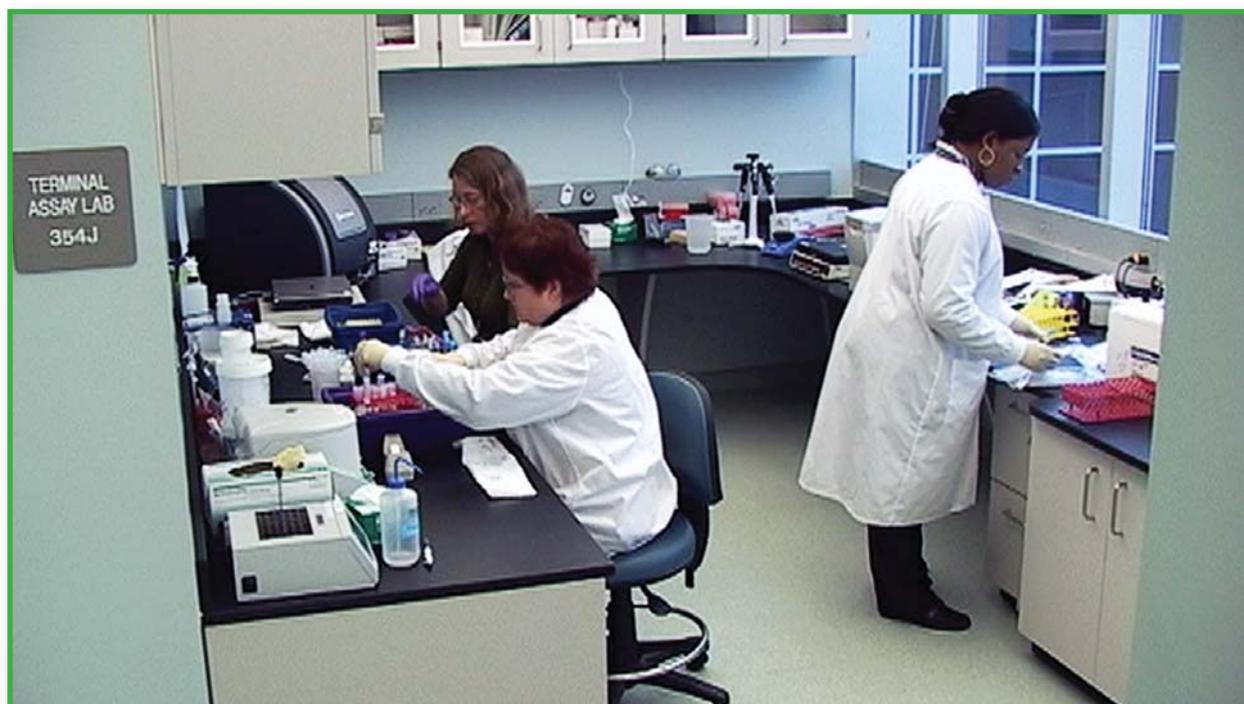
cell RNA was used for microarray-based differential gene expression studies by comparing gene expression between smokers and nonsmokers. We report here the finding of a small number of statistically significant differentially expressed genes between smokers and

nonsmokers, using buccal cells as starting material. Analysis confirmed that these genes had a similar expression pattern to results from another study.



Scientists at CAMI collect buccal mucosa samples in support of gene expression research (photo: Westmoreland Co PA)

The results suggest that despite a high degree of degradation, RNA from buccal cells from cheek mucosa could be used to detect differential gene expression between smokers and nonsmokers. The amplification protocol allowed use of 150-fold less buccal cell RNA than had been reported previously with human microarrays. However the RNA degradation, increase in sample variability, and microarray failure rate found show that buccal samples should be used with caution as source material in expression studies. This study advanced the search for an alternative tissue source for gene expression research and supports aviation safety goals by providing easier methods to obtain samples. (Aeromedical Research)



Pictured on pages 42 and 43: The FAA's Functional Genomics Group is working to discover gene and protein expression markers for aerospace medical factors such as fatigue and hypoxia.

STANDARDIZED METHOD TO OBTAIN ANTHROPOMORPHIC TEST DUMMY DATA TO SUPPORT ANALYTICAL MODELING

The development and certification of aircraft seats currently involve the use of full-scale sled tests in the design and certification process. Aircraft manufacturers and operators are under constant pressure to reduce the time and associated costs and satisfy regulatory and user requirements. FAA AC 20-146 allows for the use of analytical techniques to help meet these requirements. However, a basis for the development of numerical models lies in establishing evaluation parameters to define the kinematic and biodynamic properties of anthropomorphic test dummies (ATDs).

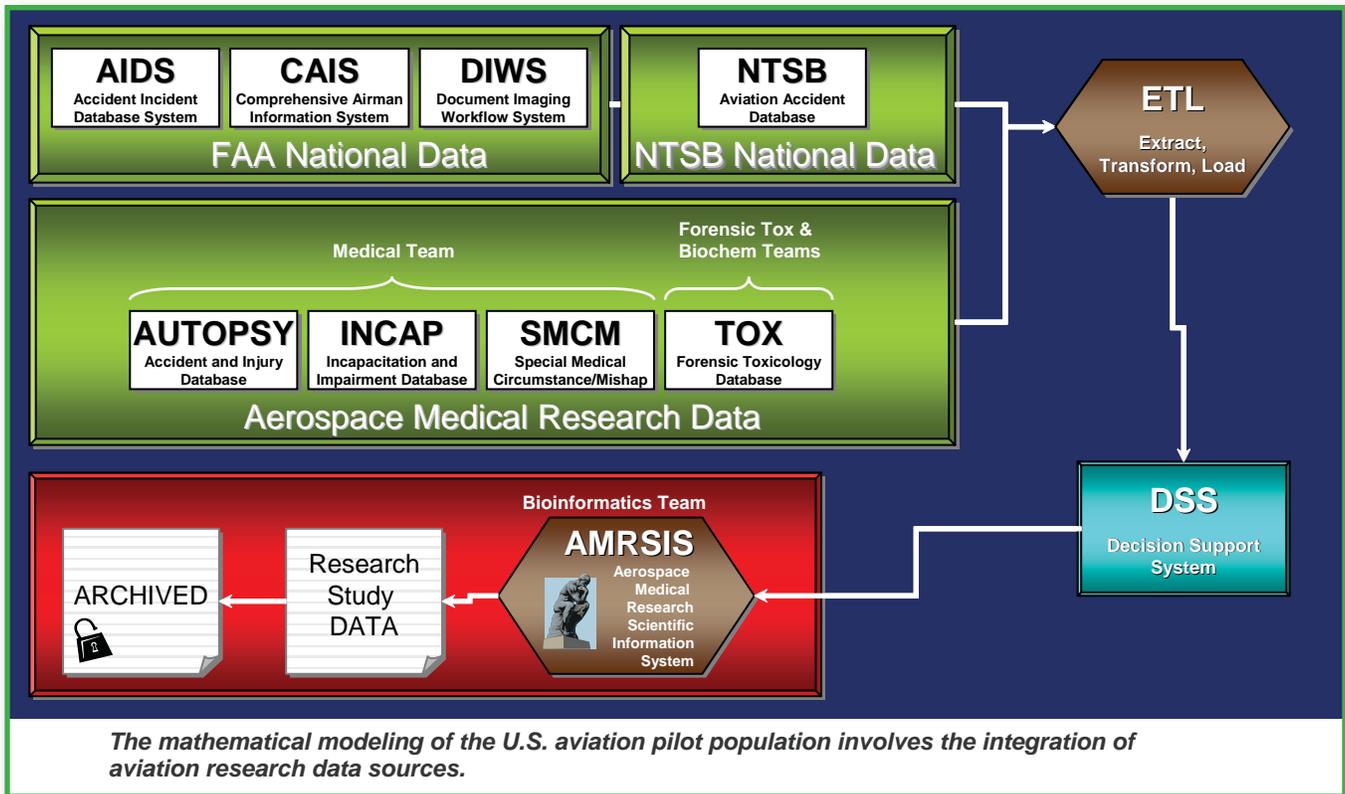
Industry, government, and academic entities worked together to develop a standardized method to obtain ATD sled data and define a set of ATD evaluation parameters. The effort involved manufacturers of ATDs, seats, and aircraft to assure that all aspects of the requirements were integrated into the resulting protocols. These parameters will be used in the development of numerical ATD models leading to the design and certification of aircraft seats.

This information has been submitted to Society of Automotive Engineers (SAE) for incorporation in an Aerospace Recommended Practice for analytical methods for aircraft seat design and evaluation. The development of the standardized seat test, evaluation parameters, and validation metrics represent a cumulative effort by subject matter experts throughout the world. (Advanced Materials/Structural Safety)

MODELING THE U.S. PILOT POPULATION

The size of the U.S. civil aviator community has been of interest to researchers, policy makers, and special interest groups. A strict definition for membership in the U.S. pilot population was used that was based on Scientific Information System principles. This approach provides methods for scientists to describe, quantify, and predict changes in this population over the 23-year study period. The Bioinformatics Research Team at CAMI analyzed and modeled the counts of the U.S. pilot population using a segmented linear regression model.

A dataset was constructed, based upon the methods prescribed by Scientific Information System principles of data construction, from 1983 to 2005. This methodology was selected since the data represent the entire population of pilots, rather than just a sample. Thus, the statistical results are population parameters, rather than estimates, and are not subject to sampling error. The airmen population was constructed and examined for each year of the study period. The criterion for membership of the U.S. civil pilot population is based on the medical examination that each airman must pass to hold a pilot certificate. A segmented linear regression model was chosen because of its flexibility in accounting for any policy changes that occurred over the 23-year study period.



The CAMI Scientific Information System provided the foundation to build a segmented linear regression model pertaining to the counts of the U.S. civil pilot population; from these results it was possible for the first time to explain the changing frequencies over time and make fact-based predictions concerning future population numbers. The capability now exists to categorize the population by gender, medical class, age, and experience over a two-decade time period, which may provide hints at some of the changes taking place within the aviation community as a whole.

The model constructed showed a decline in the overall U.S. civil aviator community. This decline is most evident in second- and third-class medical certificate holders. The percentage of women in the largely male-dominated population remained relatively stable over the study years. The age composition of both men and women changed substantially from the beginning of the study in 1983 to the end in 2005. Both segments of this population have grown significantly older. As a group, men were older than women over the study period. Therefore, when average flight time was calculated and categorized by medical class and gender, men were shown to have more flight experience. The study's results are described in Report No. DOT/FAA/AM-09/9, *An Analysis of the U.S. Pilot Population From 1983-2005: Evaluating the Effects of Regulatory Change*. (Aeromedical Research)

SAFE AEROSPACE VEHICLES

No accidents and incidents due
to aerospace vehicle design,
structure, and subsystems

IMPROVED ELECTRICAL WIRING FIRE TEST METHOD

Flammability tests on non-aviation communication cable comparing current FAA test method with improved test method



Current FAA 60-degree test method; cable passed test, incorrect result



Improved FAA test method; cable failed test, correct result

Serious aircraft in-flight fires usually occur in hidden areas, such as above the cabin ceiling, behind the side wall, or beneath the floor, where it is difficult for the crew to locate and extinguish a fire. In hidden areas the most abundant materials are thermal-acoustic insulation, air condition ducting, and electrical wiring and cable. The FAA's Fire Safety Team has been developing more stringent and realistic flammability tests for these three types of materials to provide a much higher level of fire resistance in hidden areas and enhanced in-flight fire protection. Improved flammability tests for insulation and ducting are now available from this work. The FAA adopted a regulation requiring the improved test standard and criteria for insulation that went into effect in 2005.

The current test requirement for aircraft electrical wiring is the 60-degree test, which is described in Title 14 Code of Federal Regulations Part 25, Appendix F Part I (b)(7) and Chapter Four, "60-Deg Bunsen Burner Test for Electric Wire," of the Aircraft Materials Fire Test Handbook (FAA report DOT/FAA/AR-00/12). During large-scale fire tests it was determined that wiring compliant with the current FAA flammability requirement could allow a fire to propagate when subjected to a moderate ignition source (FAA Report DOT/FAA/AR-TN04/32), further emphasizing the need for an improved and more stringent flammability test method for wiring.

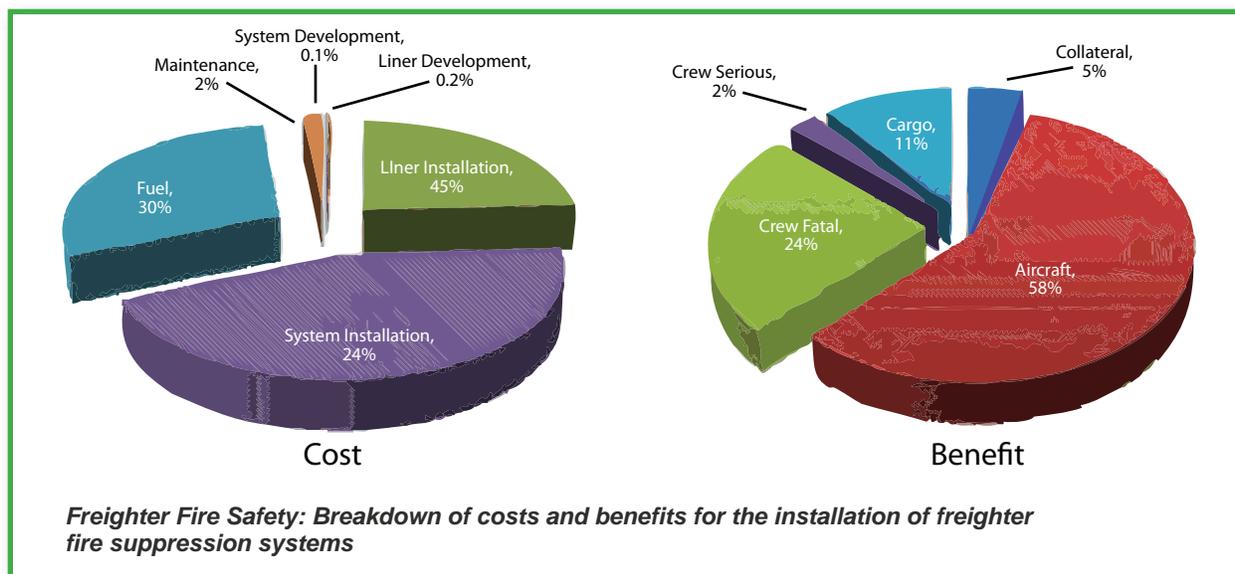
Beginning in 2008, the Fire Safety Team embarked on this effort, coordinating industry stakeholders who are members of the International Aircraft Materials Fire Test Working Group, which is also chaired and administered by the Fire Safety Team. The goal was to develop a test method capable of providing an equivalent level of fire safety as the previously developed test methods for insulation and ducting. After 12 months of evaluation work and hundreds of tests, ranging from small- to large-scale fire tests, an improved fire test method capable of meeting the project scope and objectives was determined. The key condition was that the new flammability test gave a good correlation, in terms of the ranking of materials for their relative flammability, with large-scale fire test results for a wide variety of aircraft wiring materials. An FAA technical report for public distribution was drafted describing the findings. (Fire Research and Safety)

FREIGHTER FIRE SUPPRESSION COST-BENEFIT ANALYSIS

After a fire gutted a United Parcel Service DC-8 freighter in Philadelphia, the NTSB recommended the installation of fire suppression systems in the main cargo compartment of freighter (all cargo) airplanes. Currently, FAA does not require fire suppression systems in freighters and fire protection is provided mainly by early detection and aircraft de-pressurization. To develop a response to the NTSB recommendation, a cost-benefit analysis was conducted for the installation of on-board fire detection and extinguishment systems in freighter aircraft.

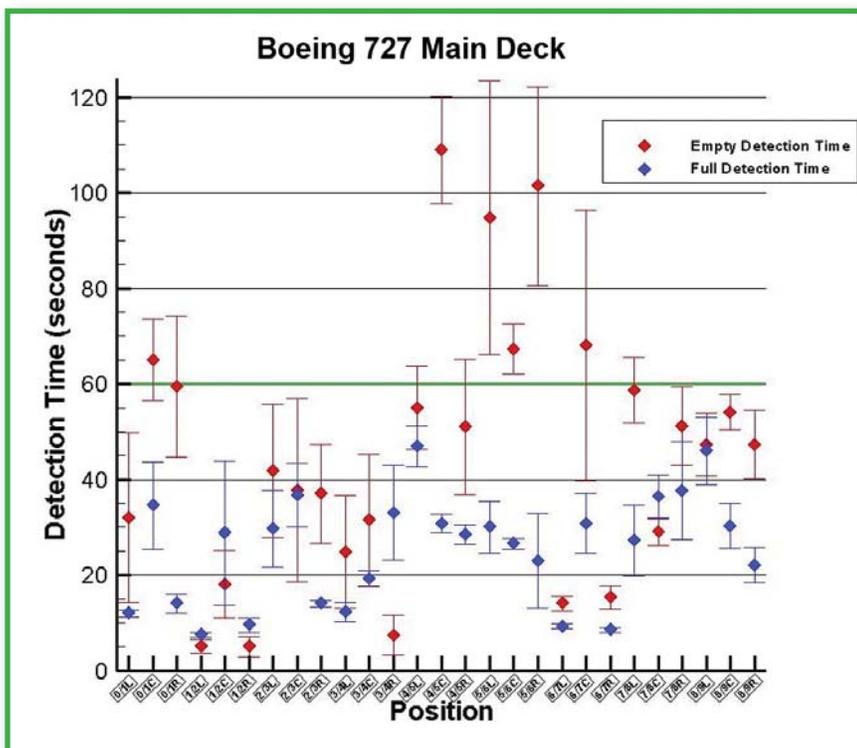
Potential benefits would result from a reduction in fatalities and injuries to crew members, a reduction in the damage incurred to the aircraft and its cargo, and a reduction in the loss of life and to property on the ground. Potential costs are associated with the installation of the fire suppression systems and the operation of the aircraft with the systems. A mathematical model was developed to assess the benefits. The model used statistical distributions derived from data on in-service airplanes and accident information. Cost assessments were made for the installation of a halon total-flooding fire-suppression system, similar to the type installed in the cargo compartments below the cabin floor in passenger-carrying airplanes.

The study showed that crew fatalities and injuries and the loss of the aircraft and cargo are likely the significant factors in the benefits. Collateral ground damage did not appear to contribute significantly to the prediction of benefit. It was concluded that a halon total-flooding fire-suppression system is unlikely to be cost beneficial for the cargo compartments of freighter aircraft. However, the study provided useful baseline data that can be used as a goal for the design of a cost-effective system. This work will commence in FY 2010 and should provide more information to reply to the NTSB recommendation. FAA report DOT/FAA/AR-09/17, *A Cost-Benefit Analysis for the Installation of Fire Suppression Systems in Cargo Compartments of Cargo Airplanes*, has been published and is available on the Fire Safety Team web site, www.fire.tc.faa.gov. (Fire Research and Safety)



FREIGHTER FIRE DETECTION CERTIFICATION TESTING

FAA regulations require cargo compartment fire detection systems to alarm within one minute of the start of a fire and under all approved operating conditions. To show compliance with this regulation in the past, in-flight tests were conducted using a variety of actual or artificial smoke sources. Traditionally, these tests have been conducted in empty cargo compartments with the smoke source placed in what was assumed to be the most difficult location to achieve detection.



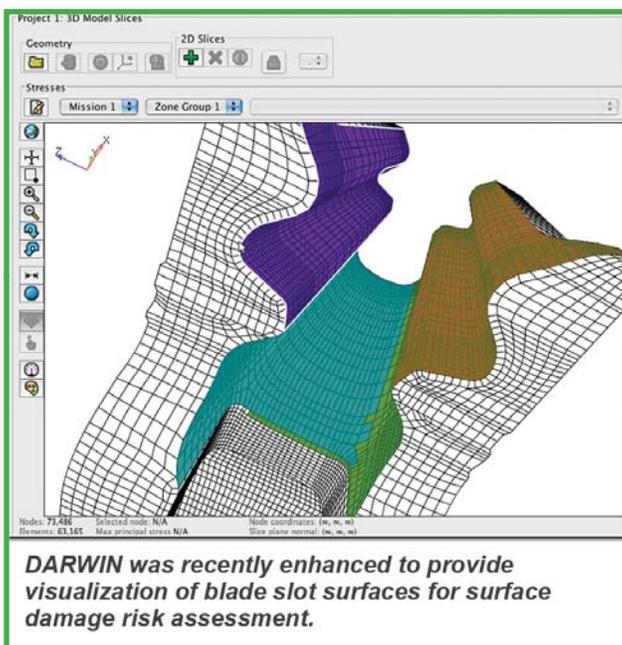
This project was conducted in response to an NTSB recommendation based on the investigation of an in-flight main deck cargo fire on a freighter aircraft in 2006. NTSB determined that a significant amount of time had elapsed between the time the flight crew first smelled smoke and the time the smoke detectors alarmed. The recommendation requested that the FAA determine the influence of main deck cargo containers on smoke detection times. The Fire Safety Team conducted over 300 tests on the main deck of a Boeing 727 freighter aircraft and in the below-floor aft cargo compartment of a Boeing 747SP.

The same quantity of smoke was introduced into these cargo compartments at the location of every container position when they were both completely empty and fully loaded with cargo containers. Each test condition was repeated four times to account for the expected variability inherent in the transport of artificial smoke throughout the cargo compartments.

The results of these tests showed that detection times were typically faster in fully loaded compartment, than in empty ones. This confirmed that the historic method of conducting certification tests in empty compartments generally represents the worst case scenario for smoke detection times and is a more conservative approach. An FAA technical report for public distribution was drafted describing the findings. (Fire Research and Safety)

NEW ADVANCES IN GAS TURBINE ENGINE COMPONENT RISK ASSESSMENT SOFTWARE

Aircraft gas turbine engine components may contain rare anomalies that can potentially lead to uncontained engine failure. Several recent or pending FAA ACs address life-limited engine parts (AC 33.70-Y), induced surface damage anomalies from manufacturing, maintenance (AC 33.70-X), or titanium rotors with inherent material anomalies (AC 33.14-1). The associated risk of fracture can be predicted using Design Assessment of Reliability With INspection (DARWIN®), an award-winning probabilistic fracture mechanics software code developed by Southwest Research Institute and funded by the FAA. A new version of DARWIN (7.0) was recently released to the industry steering committee for detailed review.



DARWIN 7.0 includes several new stress-intensity factor (SIF) solutions for improved assessment of fracture risk. New univariant and bivariant weight function SIF solutions for an embedded crack in a plate are also included in DARWIN 7.0.

The DARWIN graphical user interface (GUI) significantly reduces the time required to assess the risk of fracture, but the accuracy of the assessment is still dependent on the skill and judgment of the analyst. A new algorithm automatically determines (without user input) the orientation, size, and stress input for a fracture model that will produce accurate life results, given only the finite element model and the initial crack location. Additional algorithms are planned for future versions to automate the generation of probabilistic fracture mechanics models.

DARWIN 7.0 also includes several new features for risk assessment associated with surface damage. The GUI was enhanced to provide visualization of blade slot surfaces in three-dimensional finite element models. Risk assessment of turned surfaces in two-dimensional models was enhanced to include treatment of stress concentrations such as hole features. A new capability to allow the user to apply manufacturing process credits (defined in AC33.70-X) to surface-damage risk-assessment results was added. DARWIN 7.0 also includes a new report form that provides the essential assessment data applicable for an FAA review.

DARWIN 7.0 has a number of other general enhancements, including bivariant shakedown, enhanced filtering of finite element models, improved crack growth life interpolation, enhanced stress gradient search, and improved display of GUI warning messages. (Propulsion and Fuel Systems)

ENGINEERING ASSESSMENTS OF FLUORESCENT PENETRANT INSPECTION – UPDATING OF AMS 2647C

Fluorescent penetrant inspection (FPI) is a nondestructive test (NDT) method that relies on careful adherence to process parameters to reliably detect surface breaking cracks in metal aircraft structures. Widely used, it is estimated that over 90 percent of an aircraft's metal components are inspected by FPI and that a typical U.S. commercial air carrier will have over 30,000 parts in their inventory requiring FPI. Failure of the FPI process can be catastrophic as evidenced by the uncontained-turbine-engine-failure accidents of United Airlines Flight 232 (Sioux City) and Delta Air Lines Flight 1288 (Pensacola). NTSB recommendations resulting from these accidents called for research to improve the FPI process.

In response to these recommendations, the FAA initiated a major research program in 2002 to study and improve the reliability of this important NDT method. The program, Engineering Assessments of FPI, assembled an international team comprised of academia, industry, and government personnel to identify and study key FPI processes. Led by researchers from Iowa State University (ISU), the team consisted of representatives from aircraft and engine manufacturers (Boeing, Pratt & Whitney, GE Aircraft Engines, Rolls Royce, Honeywell), airlines (United and Delta), penetrant manufacturers (Sherwin, Met-L-Check, Magnaflux), and technical experts from the NDT community (D&W Enterprises).

The technical approach for the program consisted of defining factors for which engineering FPI data was either not publicly available or deficient and then conducting engineering studies to target those factors and obtain quantitative assessments of performance over a range of controlled parameters. Specific studies were completed using ISU labs or airline shop facilities as appropriate.

Studies conducted looked at various cleaning and drying methods, penetrant type and application, part geometry factors, emulsification application variables, developer method application, and many other factors. Keys to the success of the program were: the standardized use of a photometer which allowed the researchers to quantitatively measure and compare the brightness of FPI indications; sets of realistic and well-characterized test specimens consisting of titanium 6-4, aluminum 6061, and Inconel 718 each with a statistically relevant range of crack sizes; and evaluation of process performance by probability of detection analysis.

From these studies, numerous findings regarding the FPI processes have been collected and disseminated into the public domain. The most relevant findings have been incorporated into the revision of Aerospace Materials Specification (AMS), AMS 2647C, entitled *Fluorescent Penetrant Inspection, Aircraft and Engine Component Maintenance*, published by SAE in July 2009. This specification details requirements and procedures for the detection of defects in aircraft and engine components during maintenance and overhaul operations. Additionally, all results from the engineering assessments of the FPI program can be accessed on the web at: www.cnde.iastate.edu/faa-casr/fpi. (Continued Airworthiness)

AVIATION FUEL AND ENGINE TEST FACILITY UNLEADED AVIATION GASOLINE PROGRAM

FAA Aviation Fuel and Engine Test Facility (AFETF) researchers successfully completed the first phase of a cooperative research and development agreement with Swift Enterprises of Indiana. Swift has developed a high-octane, high-heat-content, bio-renewable aviation fuel that has the potential for significant reduction in life-cycle carbon dioxide emissions and production on mass scale. The Swift fuel contains no alcohols or oxygenates and can be made from a variety of sugar-based sources.



Test engine in AFETF

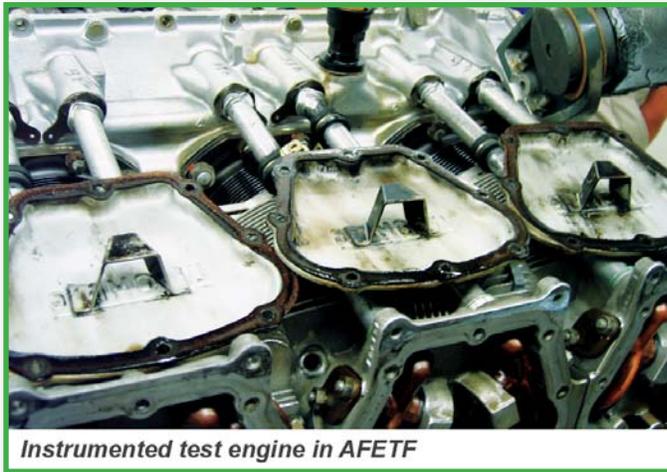
AFETF researchers performed detonation and power performance engine tests on the Swift bio-fuel and compared its performance to that of a locally purchased 100 Low Lead (100LL) in two of the highest octane requirement engines in the GA piston engine fleet. A Lycoming TIO-540-J2BD and a Lycoming IO-540-K were evaluated on both fuels. A power baseline and detonation test was run in the IO-540-K engine comparing the performance of the Swift fuel to that of 100LL and a detonation performance test was run

in a Lycoming TIO-540-J2BD engine. A full laboratory analysis was performed on the Swift fuel to compare its results to the current leaded aviation gasoline specification ASTM D-910. The 100LL was also evaluated for octane and lead content.

The engines produced more than 98 percent of the peak power on the Swift fuel as they did on 100LL. The Swift fuel contained 96.7 percent of the energy content per unit mass of the 100LL but on a volume basis the Swift fuel contained 13 percent more energy than the 100LL. Operation on the Swift fuel resulted in an average decrease in volumetric fuel consumption of approximately nine percent.



AFETF researchers at lab control console



Instrumented test engine in AFETF

The Swift fuel met most of the current leaded aviation gasoline specification and outperformed the 100LL in detonation testing. Average exhaust gas temperatures were 50 degrees Fahrenheit higher for the Swift fuel. The results were published in the FAA report, *Full-Scale Engine Detonation and Power Performance Evaluation of Swift Enterprises 702 Fuel*, DOT/FAA/AR-08/53. Success from the detonation and power performance testing resulted

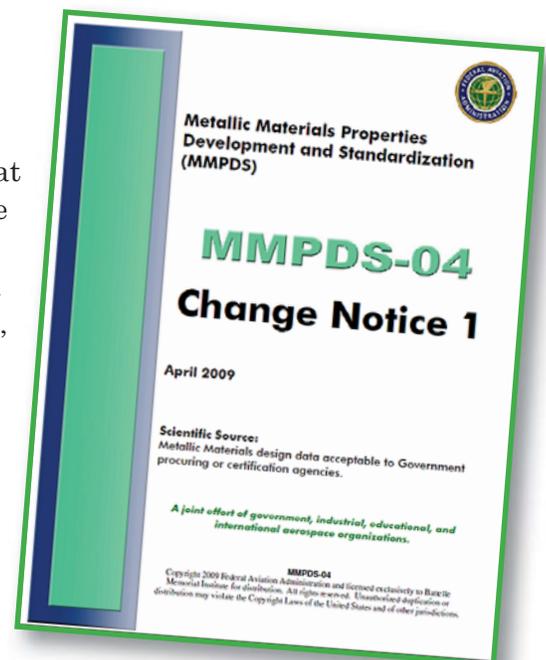
in continued engine endurance tests. The AFETF completed a 150-hour FAR 33.49 endurance type test on the Swift fuel using a Lycoming IO-540-K engine.

The post-test engine measurements have been completed and a FAA report will be published by the end of FY 2010. (Propulsion and Fuels Systems)

METALLIC MATERIALS PROPERTIES DEVELOPMENT AND STANDARDIZATION

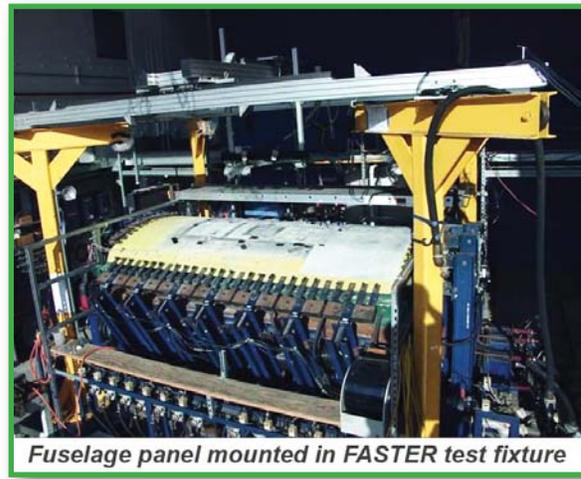
The Metallic Materials Properties Development and Standardization (MMPDS) is an effort led by the FAA to continue the Handbook process entitled *Metallic Materials and Elements for Aerospace Vehicle Structures*, (MIL-HDBK-5). The handbook is recognized worldwide as the most reliable source for verified design allowables needed for metallic materials, fasteners, and joints used in the design and maintenance of aircraft and space vehicles. Consistent and reliable methods are used to collect, analyze, and present statistically based aircraft and aerospace material and fastener properties.

The MMPDS maintains and improves the standardized process for establishing statistically based allowables that comply with the regulations, which is consistent with the MIL-HDBK-5 heritage, by obtaining more equitable and sustainable funding sources. This includes support from government agencies in the Government Steering Group, from industry stakeholders in the Industry Steering Group and from profits selling the Handbook and derivative products. Toward this goal, the commercial version of the MMPDS-04 Handbook, Change Notice 1 was released April 2009. There has been a substantial upgrade with approvals from the 13th through the 15th MMPDS General Coordination Meetings. This includes 8 new alloys and over 225 pages edited or added. (Continued Airworthiness)

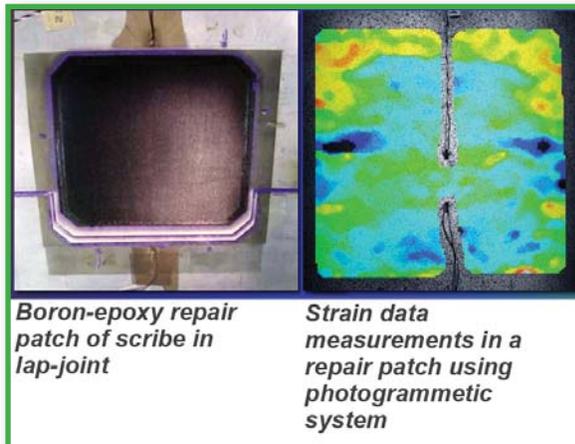


DURABILITY AND DAMAGE TOLERANCE OF BONDED REPAIRS

Adhesive bonding technology offers an efficient and cost-effective approach to airplane structural repairs. Compared to conventional mechanically fastened metallic repairs, bonded repairs are more aerodynamically and structurally efficient. The application of bonded repairs has been studied primarily in the military sector where the durability and damage tolerance aspects have been demonstrated. However, several technical challenges need to be addressed before bonded repair technology will be generally accepted and implemented in primary structural applications in the commercial sector. Currently, credit is typically not provided in certification programs of bonded repairs for slowing crack growth or restoring residual strength. The ability to predict the fatigue behavior and ensure the durability of bonded patches is of primary concern.



The FAA and the Boeing Company have partnered in an effort to gain a better understanding of the durability and damage tolerance aspects of bonded repair technology. This is a cost-share arrangement to obtain verification data to design, analyze, and apply bonded repairs to fuselage structure. In FY 2009 a test and analysis of bonded repairs to scribe-line damage on a Boeing 727 fuselage structure was completed at the Full-Scale Aircraft Structural Test Evaluation and Research facility at the William J. Hughes Technical Center.



The objectives were to characterize the long-term durability of scribe-line bonded repairs under simulated flight load conditions up to one typical design service goal (60,000 cycles) and then determine if the repair patches meet damage tolerance requirements in a residual strength test. This initial study demonstrated that properly designed bonded repairs could

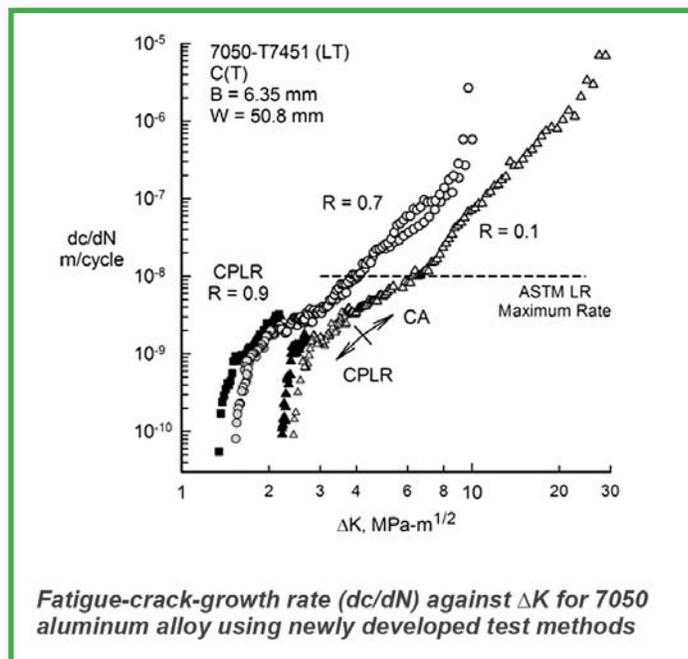
effectively contain damage. Several nondestructive inspection (NDI) methods were field tested and used to detect damage. Analytical models were calibrated to assess bonded repair patch durability and residual strength. Future efforts will focus on methods to assess bond integrity using advanced NDI and structural health monitoring. (Continued Airworthiness)

FATIGUE-CRACK-GROWTH-RATE TESTING IN THE THRESHOLD REGIME

Mississippi State University has developed new test methods to account for limitations in the current ASTM standard for fatigue-crack-growth-rate testing in metallic materials. These methods include compression precracking (CP) methods that generate steady-state constant amplitude (CA) data in a program sponsored by the FAA. Methods currently provided in ASTM E-647 propose the load-reduction (LR) test method to generate constant R-data in the threshold and near-threshold regimes. However, the ASTM LR test has been shown to produce higher thresholds and lower rates in the near-threshold regime than CA data on a wide variety of materials. Therefore, the ASTM LR test method does not generally produce CA data.

One of the methods developed to generate steady-state CA data is called compression precracking constant-amplitude threshold testing. This method requires that after CP loading, the crack must be grown away from the crack-starter notch by a length of at least two compressive plastic-zone sizes to have no influence on the tensile residual stresses caused by compressive yielding on crack-growth-rate behavior and to stabilize the crack-opening loads under the desired CA loading. Another method is the compression precracking load-reduction threshold test method. This method requires that the crack is grown at a low ΔK value after CP loading, and then the standard LR test method is used

once the crack-extension criterion has been met. CP allows the initial ΔK value or rate, before LR, to be much lower than would be needed or allowed (1.0E-8 m/cycle) in the ASTM standard LR test method.



Fatigue crack growth tests were conducted on compact C(T) specimens made of a 7050-T7451 aluminum alloy to study the behavior over a wide range in stress ratios ($0.1 \leq R \leq 0.9$) from threshold to near fracture conditions. Based on these results, efforts are underway in ASTM Committee E-08 to update E-647, the standard on fatigue-crack-growth-rate testing in metallic materials. (Continued Airworthiness)

SURVEY OF REPAIRS, ALTERATIONS, AND MODIFICATIONS, FOR WIDESPREAD FATIGUE DAMAGE

Fatigue of aircraft structure has long been recognized as a significant threat to the continued airworthiness of airplanes. Even small fatigue cracks can significantly reduce the strength of airplane structure. A phenomenon referred to as widespread fatigue damage (WFD) is identified as a severely degraded condition that threatens continued airworthiness of airplanes. A major concern of WFD is that fatigue cracks are initially so small that they cannot be reliably detected with existing inspection methods and can lead to sudden catastrophic structural failure.



Example of repairs to the exterior surface of an in-service airplane

To address this safety concern, the FAA issued a Notice of Proposed Rulemaking (NPRM) on WFD in April 2006. The WFD NPRM proposed a period of time be established for certain transport category airplanes, for which it can be demonstrated that the maintenance program is sufficient to preclude WFD in baseline airplane structure as well as in certain repairs, alterations, and modifications (RAMs). Comments to the NPRM suggested that inclusion of RAMs in WFD assessments should be deferred until additional information is gathered. The FAA concurred that WFD assessments be focused on baseline structure only. However, the FAA continues to take a proactive role and is assessing the need for addressing RAMs for WFD through an effort with the Airworthiness Assurance NDI Validation Center.



Example of repairs to the interior surface of an in-service airplane

The goal of this effort is to provide data to better understand the risks that RAMs may pose for developing WFD. Surveys were conducted on retired airplanes at aircraft salvage locations and on in-service airplanes at the operator's heavy maintenance locations to determine the quality and condition of RAMs. An airplane sample plan was developed to target the number and models of airplanes that would represent the in-service U.S. registered transport category fleet. A total of 134 airplanes are to be surveyed to provide a representative sampling of the population of

approximately 4600 airplanes in the U.S. fleet as shown in the table. At the end of FY 2009, 107 airplanes had been surveyed. The remaining airplanes should be surveyed by the end of the calendar year 2009. Additionally, specimens from retired airplanes were acquired and in-depth teardown inspections were performed to look for the presence of damage indicative of WFD. A database was developed to analyze the data for WFD risk assessments. Once completely populated, recorded data will be examined for trends to quantify the risks that RAMs may pose for developing WFD. (Continued Airworthiness)

Table 1 - Sample plan for RAMs survey

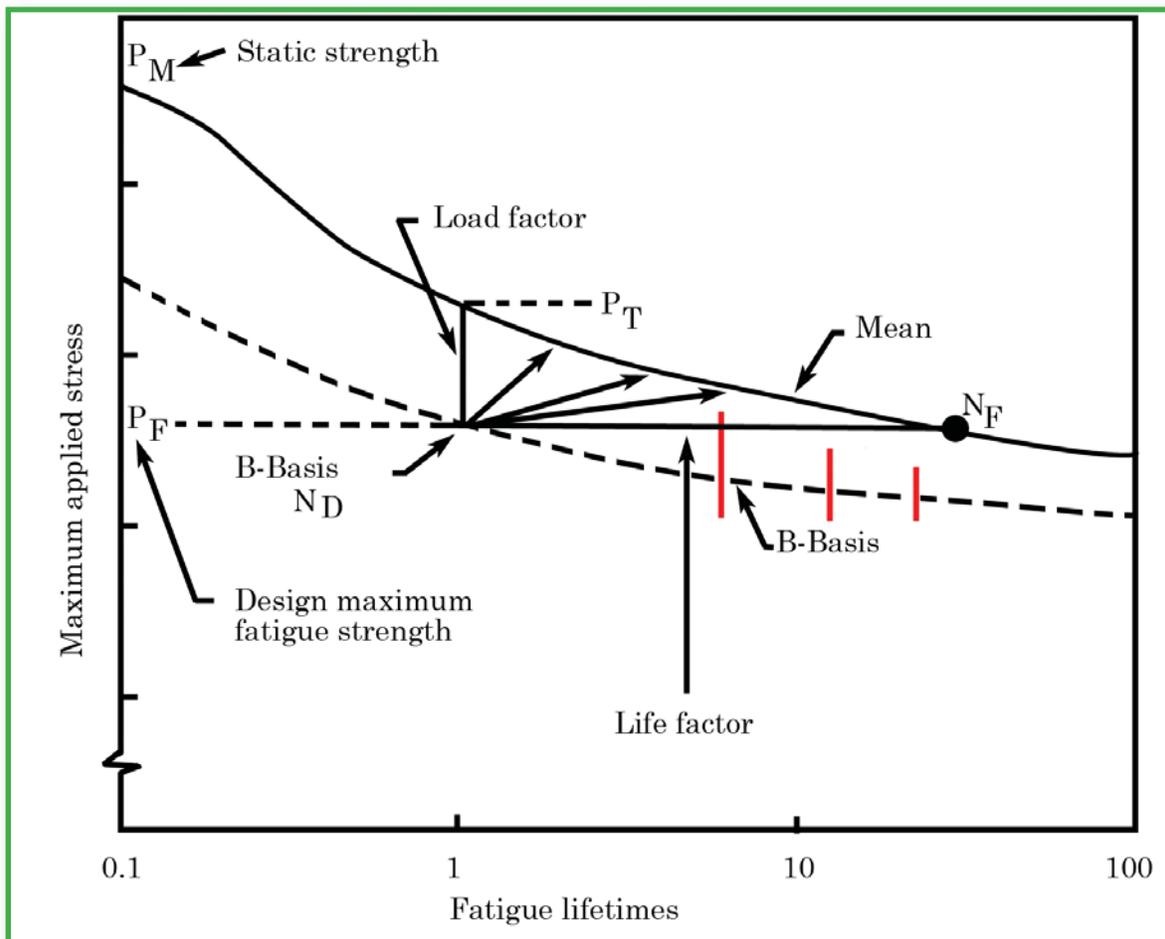
Airplane Model	Number Surveyed	To be Surveyed	Goal
A300, A310	2	4	6
A318, A319, A320, A321	8	9	17
A330	0	2	2
B727	11	0	4
B737 Classic	17	0	15
B737 NG	15	3	18
B747	2	3	5
B757	17	0	13
B767	12	0	9
B777	4	0	4
DC-8F	0	3	3
MD-10, MD-11, DC-10	2	4	6
MD-80, MD-90, DC-9	17	1	18
Total	107	29	120

CERTIFICATION DATA AND PROTOCOLS FOR CERTIFICATION GUIDANCE

The FAA worked with all stakeholders involved in the certification of composite structures to issue a new AC update in 2009. This revision, AC 20-107b, was supported by a number of research programs to establish proper guidance, data, and protocols. In addition, the research organization developed workshops to gather additional comments from the aviation industry on establishing rational procedures for certification efforts using composite materials.

The revised advisory material assessed the certification strategies used in civil aircraft developed since the last revision and identified the areas where conservatisms or assumptions existed in the current knowledge of certification and safety. This study supported the FAA Office of Aviation Safety to issue the first revision to AC 20-107 since the 1980's with a vast amount of additional guidance and information on certification requirements.

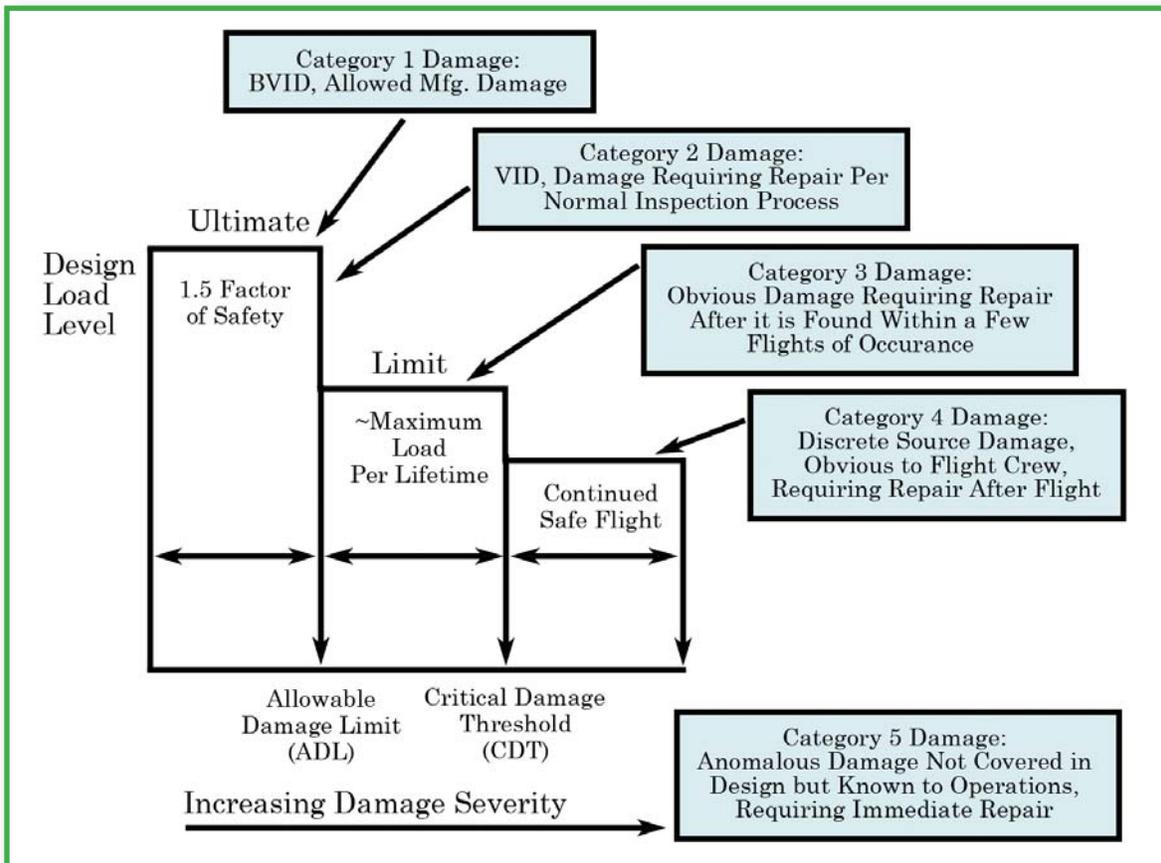
The AC update involved coordination of observations from investigations of standard practices by aviation manufacturers; standard operating conditions supplied by airlines; and focused research to resolve conflicts in approaches to certification. At issue were all areas of certification of composite structures for civil aviation standards and resulted in an addition



of 25 pages of guidance to the 11-page AC 20-107A. Extensive additions were made to the material and fabrication; static proof of structure; fatigue and damage tolerance proof of structure; general guidance considerations, and a new section on continued airworthiness. In the fatigue and damage tolerance area, the definition of levels of damage was amplified and additional detail added. The continued airworthiness section focused on design for maintenance, maintenance practices, substantiation of repairs, damage detection, and established expectations for demonstrating competency in these areas.

Specific research inputs to the process included work on fatigue-life-testing protocol which was originally developed in the mid-1980's from available data. This was analyzed to determine if the current generations of materials required the same restrictions on fatigue substantiation testing or if a generalized approach could be developed to take advantage of new material capabilities. The initial work being performed on impact damage formation also influenced the revision. Assessment of requirements for material procurement and fabrication control were included in this revision. In addition, the outputs from extensive maintenance practices research formed the basis for the new information on continued airworthiness.

This work provides the foundation for a comprehensive acceptable means of compliance with the structural requirements to substantiate the safety of modern composite structures. This revision documents the standard practices developed through cooperation between the FAA and industry. (Advanced Materials/Structural Safety)



SEPARATION ASSURANCE

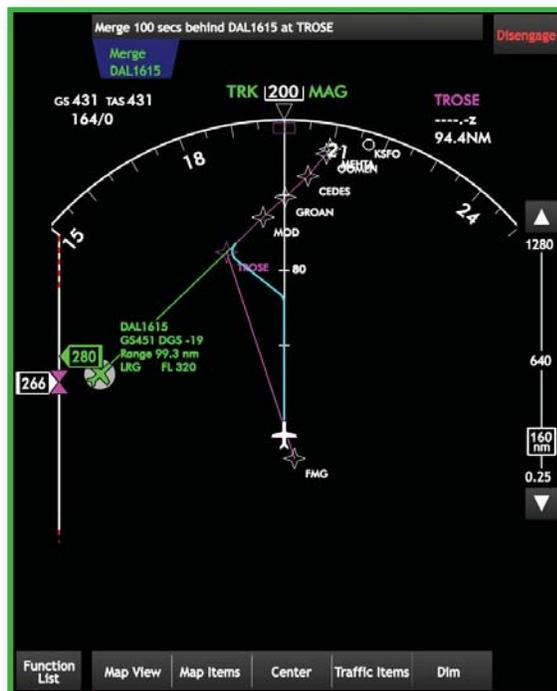
A reduction in accidents and incidents due to aerospace vehicle operations in the air and on the ground

MULTI-PURPOSE COCKPIT DISPLAY OF TRAFFIC INFORMATION

NextGen will use CDTI, ADS-B and other new technologies and procedures to enable delegation of some traditional ATC tasks to the cockpit. But to take advantage of these advances aircraft must first be appropriately equipped and no single design supports the broad array of envisioned delegations. In 2009, CAASD researchers completed development of a prototype multi-purpose CDTI.

The prototype development process included both the necessary algorithmic processing and the user interface and has allowed CAASD researchers to conclude that multi-purpose CDTI is feasible. Algorithm work focused on the four basic dimensions needed to support the notion of a multi-purpose CDTI: constituent capabilities or functions; a rule base governing the simultaneous activation of multiple constituent capabilities or functions; an automated, context-sensitive selection of sub-algorithms supporting each constituent capability or function; and an arbitrator capable of selecting the most appropriate output(s) from each of the activated capabilities or functions to be shown to the flight crew.

In addition, CAASD focused significant attention on the user interface. This aspect of the work aimed to prove that the activation, monitoring, and use of the constituent capabilities or functions could be arranged to preclude confusion for the user. CAASD developed a user interface that allowed the format of the input to closely mirror the expected phraseology a controller would use in issuing clearances and/or instructions that would motivate the use of the CDTI. Outputs from the constituent capabilities or functions were also standardized to the extent possible.



CAASD conducted an experimental evaluation of the user interface. Pilots were asked to use the CDTI in a number of scenarios that involved air-to-air ADS-B applications in most operating domains. Pilots received minimal training on the features of the display and, yet, were able to operate it effectively.

In 2010, CAASD plans to conduct further research on the multi-purpose CDTI information to incorporate an effective alerting and messaging scheme into the display and to complete design revisions motivated by the evaluation in 2009. In addition, CAASD plans to conduct an evaluation of an enhanced prototype and continue coordination activities with government and industry stakeholders. (CAASD)

SITUATIONAL AWARENESS

Common, accurate, and
real-time information of
aerospace operations,
events, crises, obstacles,
and weather

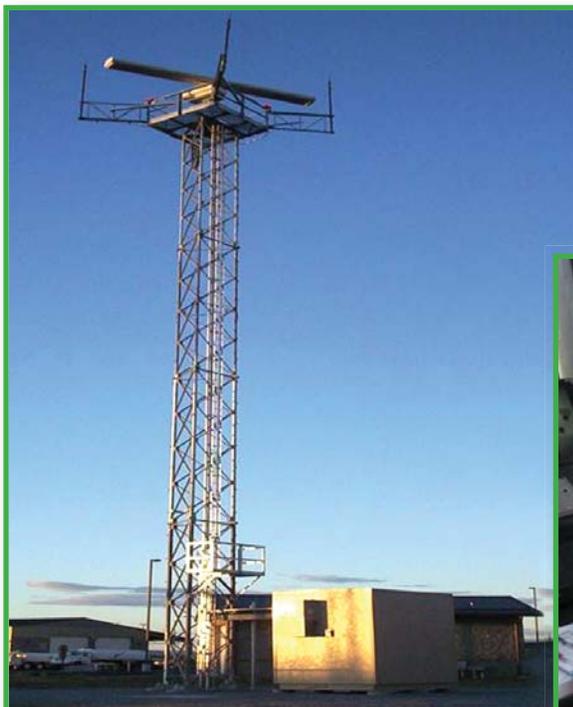
FAROS

Final Approach Runway Occupancy Signal (FAROS) provides a direct pilot warning capability by flashing the Precision Approach Path Indicator (PAPI) lights when a potential hazard is detected on a runway that is being approached by an arriving aircraft. Flashing of the PAPI lights is the annunciator for FAROS. The first FAROS test system was installed at Long Beach, CA. Three indication loop segments along runway 12/30 constitute the detection system. The PAPI flashes whenever an aircraft or vehicle occupies one of the elements. An enhanced version of FAROS (E-FAROS) was installed and tested at Dallas/Fort Worth International Airport (DFW). This version of FAROS will cause the PAPI to flash only when an aircraft or vehicle is on a runway and an aircraft on approach to it is within 1.5 nautical miles of the runway threshold. The surveillance source for E-FAROS at DFW is the Airport Surface Detection Equipment-3-Model X and the Airport Surveillance Radar-9. The system is also capable of using Airport Surface Detection Equipment-3 inputs. Operational testing of E-FAROS was completed at DFW in April 2009. The final report for E-FAROS operational evaluation at Dallas Fort Worth International Airport was completed in August 2009. (CAASD)

LOW COST GROUND SURVEILLANCE

In 2009, the FAA's Advanced Technology Development and Prototyping group continued test and evaluation of two Low Cost Ground Surveillance systems at Spokane International Airport. After extensive evaluations the team determined that one of these, the Critical Area Management System (CAMS) millimeter-wave sensor was not technically feasible for airport safety applications. The CAMS testing was discontinued, and the team has

begun removal of this system and restoration of the airport site. The other system tested at Spokane is the NOVA 9000 ATC system by ParkAir. This technology was deemed promising enough to pursue as a potential runway safety application. (CAASD)



Radar Site at GEG



NOVA 9000 Surface Management System

CECIL FIELD STUDY—A CASE STUDY ON ROUTINE SPACE VEHICLE OPERATIONS IN THE NAS FOR NEXTGEN

Futron Corporation was directed by the FAA to develop a short study to identify NAS integration requirements associated with proposed twice-weekly commercial space transportation operations. The operations included in this report are limited to those based on the Scaled Composites WhiteKnightOne/SpaceShipOne operations out of Mojave, California. Currently, this combination is the only one that has actually flown and was used as a model for the newer, Virgin Galactic, commercial WhiteKnightTwo (WK II)/SpaceShipTwo (SS II) vehicles. There are several other mission concepts under development including vertical launch/parachute recovery, horizontal air-breathing launch with rocket-powered Kármán Line penetration (328,000 feet), and air-breathing powered return and landing. In addition, for the purpose of the study, all operations are assumed to be from the former Cecil Field Naval Air Station southwest of Jacksonville, Florida.

The case study was developed to depict typical operations in the 2025 timeframe and an assumed flight rate of two flights a week. The goal of the study was to uncover any unique requirements that must be considered in the development of NextGen to allow for this type of commercial space tourism with minimal impact on the NAS as it develops.

The study found that several issues previously believed to be critical had minimal impact to the NAS. The first of these was the impact of high altitude flight through commercial airways. After careful study of the flight paths for this type of operation it was found the actual flight footprint was fairly small and very little airspace was needed. Once the spacecraft is released, it climbs from above 40,000 feet to over 350,000 feet returning to the same small area over the ground. On return to between 40,000 and 70,000 feet altitude, the spacecraft converts to a glider that proceeds on an almost straight line to approximately 8,500 feet directly over Cecil Field for landing. Because of the inability of the space craft to hold or perform a missed approach, the most critical issue for airspace controllers is the requirement to have a window for the spacecraft to land after release from the carrier aircraft. The window for this clearance appears to open about 20 minutes after release from the carrier aircraft. Actual release of the spacecraft can also be significantly delayed to provide spacing for other aircraft approaching Cecil Field giving Jacksonville TRACON controllers significant operational flexibility. The window for landing would normally be a period less than five minutes in duration. After landing, the spacecraft is normally clear of the runway within 30 minutes and the parallel runway is able to support normal operations throughout the removal of the spacecraft.



Artist's concept of WhiteKnightTwo Virgin MotherShip Eve and SpaceShipTwo together on ascent

Carrier aircraft (WK II) operation will have almost no impact on controllers as it is able to fly under a normal flight plan and its operation is relatively predictable and does not normally present any issues to NAS controllers. The carrier aircraft with SS II departs from and returns to Cecil Field like any other aircraft.

All other support aircraft operations are conducted in visual flight rule conditions under normal local flight plans and operations are virtually transparent when compared to other normal aircraft operations in the area.

It was the top-level conclusion of this study that the flights described in this report will not have a significant impact on NAS operations. Furthermore, use of this type of operation in other geographic areas could be easily integrated into the NAS, especially those with lower traffic density than the area used in the study. Because of the unique nature of these types of flights, individual proposed site evaluations would be necessary, but there were no systematic issues that would prevent the use of this operation in other locations. (Commercial Space Transportation Safety)

HIGH ALTITUDE WIND PREDICTION AND MEASUREMENT TECHNOLOGY ASSESSMENT

Within the Commercial Space Launch Amendments Act of 2004, Congress authorized the FAA to publicize regulations in the areas of experimental permits and human spaceflight (crew and passenger) requirements. Legislation was written to allow humans to travel into space for the first time on commercial launch vehicles and to ensure that the passengers and crew involved in commercial space are informed of all risks inherent to space travel, including those associated with the launch vehicle. Commercial launch sites have limited equipment and real-time data to support real-time launch decision making. In particular, there is a lack of wind data from 50,000 ft (the altitude reliably attained by high-resolution balloon measurements) to 100,000 ft (the altitude attained by low-resolution systems and high performance radars). Significantly higher altitudes would require some development. The altitude limitations are mitigated by the fact that at 100,000 ft (~ 30 km), air density is reduced from sea values by a factor of ~ 100. The aerodynamic drag on vehicles and debris is similarly reduced.

A study was done to review and evaluate technology to detect winds at these altitudes, including possible remote-sensing technologies and the sensitivity of proposed systems to high-altitude wind conditions. Accurate wind data at these altitudes is very important for suborbital reusable launch vehicles because of the lack of time to adjust the trajectory once the main engine cut-off has occurred. In addition, it is important to characterize the tendency of winds to move debris laterally as it falls. The dispersion of debris by the winds increases the risk on the ground and in the air, when risk to aircraft is considered. This study also assessed possible upgrades to extend the vertical coverage for Doppler Radar Wind Profilers (DRWPs).

Table 2 summarizes the vertical range of the systems considered in the study in both metric and English units.

Three measurement systems (balloon, radar, and Light Detection and Ranging, or LIDAR) were examined and characterized. In addition, numerical weather-prediction models have been reviewed. Each system has its advantages and disadvantages. The principles and the operational characteristics of balloon and radar-based techniques for measuring upper-air winds in support of launches and recoveries were examined. Each technique has advantages and disadvantages. The most effective approach to meeting upper-air-wind requirements may involve a mixed set of instruments, each with different strengths.

Balloon-based systems tend to have finer spatial (vertical) resolution than radar-based, whereas the radar-based systems have finer temporal resolution. The two kinds of systems appear to have approximately equal accuracy and reliability. As implemented at the Eastern Range, the quality-control latencies for balloon- and radar-based systems are each about five minutes. The radar profilers scan a fixed vertical volume whereas balloons drift with the wind. The volume of the latter sample is neither constant from profile to profile, nor is the volume overhead.

The best mix for generating high-quality wind profiles may consist of a DRWP in combination with balloons. The former gives more timely observations in a fixed volume, while the latter provide higher resolution. (Commercial Space Transportation Safety)

Table 2 - Summary of Approximate Vertical Coverage for Various Systems

Method	Peak Altitude Capability (km)	Peak Altitude Capability (ft)
Doppler radar	20	65,000
Doppler LIDAR	25	82,000
Jimsphere	17	56,000
AMPS (High res)	17	56,000
AMPS (Low res)	33	108,000
WRF model	32*	105,000*
*Configurable: The basic limitation is the altitude coverage of the data used to initialize the models, up to ~ 32 km (105,000 ft) in practice.		

TEMPORAL WINDS DATABASE CONSIDERATIONS FOR SAFETY EVALUATION OF UNGUIDED SUBORBITAL LAUNCH VEHICLES

The rise of new inland launch sites in the continental U.S. has raised awareness of the need to ensure suitable environment databases exist to assess the impact of winds on planned launch operations of unguided suborbital rockets from these launch sites. Quite often launch operators will measure the wind environment at the launch site of their planned launches and determine a planned impact point for their single or multistage vehicle given this measured wind and the implementation of a wind weighting system. In most instances, the launch operator needs to account for the temporal effect of winds on their planned impact points. These temporal effects, in combination with dispersions, influence the clear out zone for the launch of these rockets.

In cooperation with the FAA, the Aerospace Corporation will perform a study to evaluate the impact of temporal winds on unguided suborbital rockets. This study will have two objectives:

First, to determine if a suitable temporal wind database exists at three inland launch sites of interest and

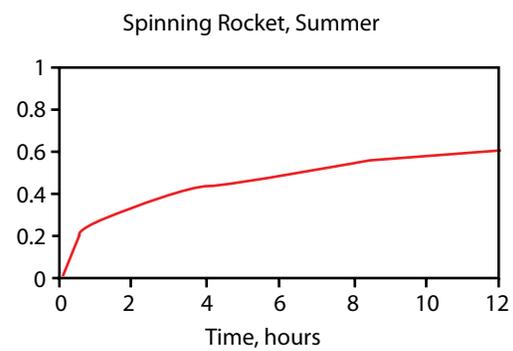
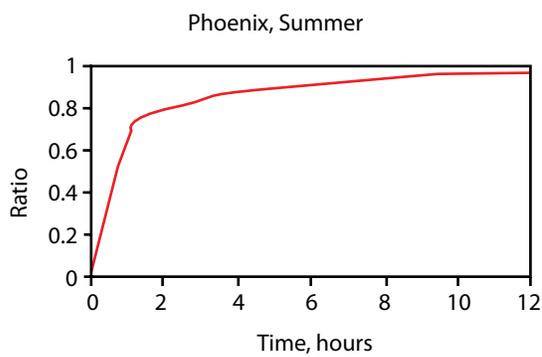
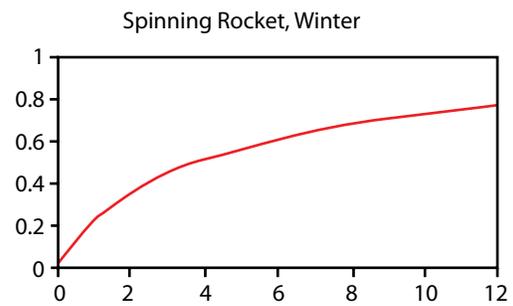
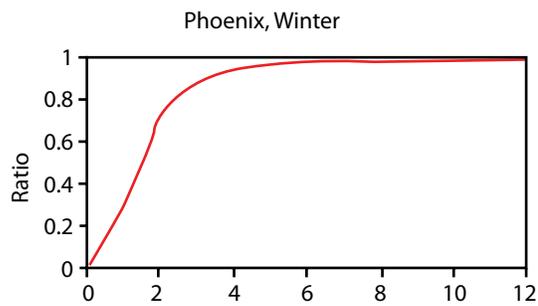
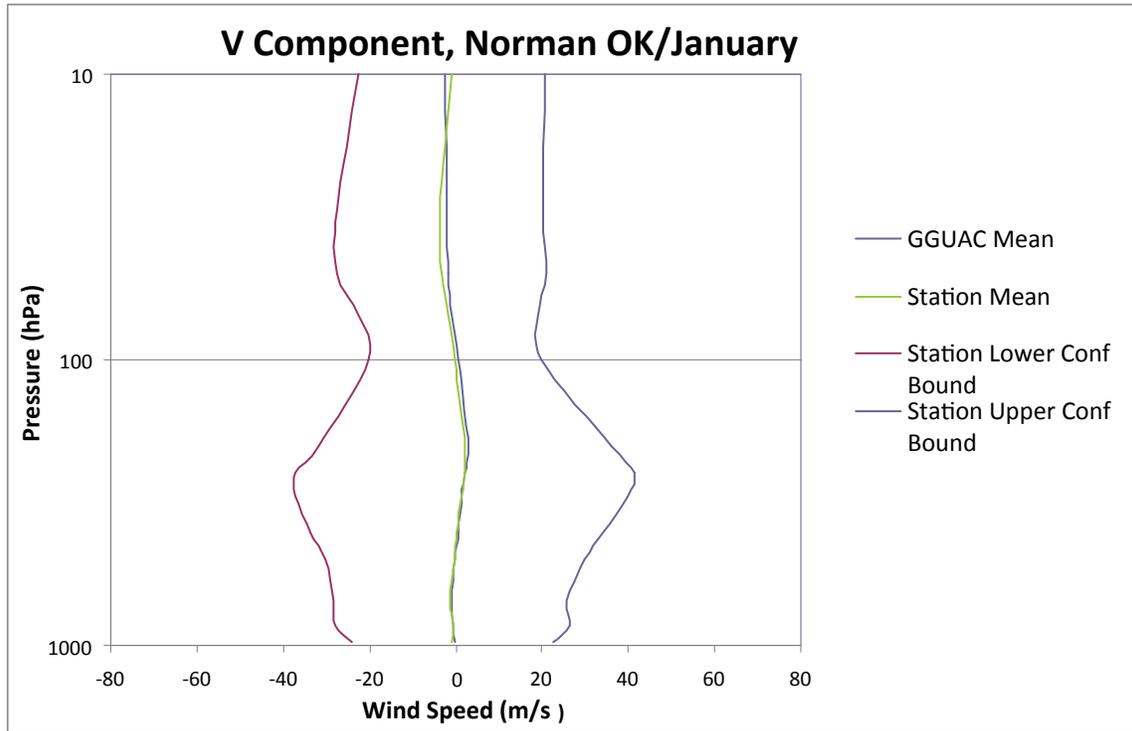
Second, to determine how much temporal winds can change the planned impact point of an unguided suborbital rocket, whether it is a suborbital to 30,000 feet or 360,000 feet.

The change in planned trajectories will be related to the monthly wind variation.

Aerospace Corporation conducted a survey to determine if the Global Gridded Upper Air Station (GGUAS) database, a database the FAA regulation calls out, provides suitable environments at the launch sites of interest by comparing the GGUAS monthly winds with stations winds collected at these three launch sites (or stations). Aerospace Corporation collected existing temporal wind data from these stations and from stations located at the Eastern Test Range and assessed a low-altitude and high-altitude unguided suborbital launch vehicle to determine the relationship between the temporal winds and the monthly winds. The figures below represent the launch of the Up Aerospace unguided suborbital launch vehicle and preliminary data showing that station monthly winds are in good agreement with the GGUAS monthly winds. In addition, the figures below summarize the results of the analysis. They show

- the ratio of the temporal winds impact ranges relative to the monthly variation and
- low-performing rockets are much more sensitive to the temporal winds pointing out the need to have wind measurements closer to the actual launch time of these rockets.

(Commercial Space Transportation Safety)



WEATHER IN THE COCKPIT BASELINING AND ASSESSMENT

Adverse weather is both a challenge for safe flight operations and a significant limiting factor for airspace capacity. Approximately 70 percent of NAS delays are attributed to weather (Leader, 2007). In air transport operations, numerous takeoff and landing accidents have followed encounters with convective weather and winter precipitation. Predicting and avoiding weather and determining when conditions have deteriorated sufficiently to increase risk requires a great deal of attention from air transport pilots and airline operations centers. NextGen expects a greater degree of collaboration between pilots and controllers in weather-related decision making and presumes a degree of shared situation awareness beyond current systems. Pilots and controllers will need consistent understandings of the weather situation to collaboratively resolve challenging flight conditions. As cockpit and air traffic weather information systems and products enter the NAS, they should facilitate both near-term and future operations and provide, at a minimum, the same access to information that participants now have with the expectation that a wider breadth of information should become available to all users in the future.



To support this transition, CAMI assembled information on present, near-term and envisioned weather information requirements for the air transport flight decks, GA cockpits, and airline operations centers (AOC). Personnel evaluated the procedures, products, priorities, and communication methods used in AOCs.

Dispatchers from the airlines gave very similar ratings of priorities across most of the weather factors. The only differences of note were that dispatchers from the larger, long-haul airlines gave somewhat higher priorities to some of the wind factors. This may result from the greater flexibility in route planning and route changing associated with longer flights; greater distances allow for more significant diversions to cope with the safety, efficiency, and comfort issues associated with motion of the air. While there were small differences between the airlines, they all consulted several information sources to develop a picture of weather relevant to their flights. The larger operations developed products of their own, often based on data delivered from a commercial source of weather information. (Flightdeck/Maintenance/System Integration Human Factors)

ATM IMPLICATIONS OF UAS OPERATIONS IN CONTROLLED AIRSPACE

Demand for access to the NAS by unmanned aircraft systems (UAS) is increasing. However, UASs have several unique operational characteristics that could have an impact on ATM. In 2009, CAASD researchers conducted a HITL simulation of multiple UAS traffic scenarios in a sector at Oakland's Air Route Traffic Control Center. The simulation goal was to begin to quantify ATC-related human factors issues associated with UASs in Class A airspace. The evaluation compared controller performance and workload/acceptance ratings while varying the ratio of UASs to manned aircraft within the participant's sector. In addition, when the participants issued control instructions to the UASs, a variable maneuver delay was applied of up to 30 seconds before the UAS would execute the control instruction.

The simulation results showed that controller workload increased as the ratio of UASs to manned aircraft increased. The controllers indicated that the increased workload was primarily due to the UASs not being Reduced Vertical Separation Minima (RVSM) compliant as well as the UASs performance differences. The lack of RVSM meant that controllers had to maintain two different separation standards depending on aircraft type. Upon completion of the study, participants commented that they would be comfortable with up to two to three UASs in the simulated sector, but six UASs (the maximum tested in the simulation) in the sector at one time were too many. The participants also indicated that they preferred to give control instructions to the manned aircraft, but the results showed that on average participants issued more commands to the UASs than manned aircraft, which may have contributed to their increased workload ratings.

The controllers indicated that 5- and 15-second maneuver delays would be acceptable in most operational conditions, but 30-second maneuver delays would be unacceptable. Although the participants experienced maneuver delays during the simulation, several commented during the debriefing that they had not noticed any delays. Also, during the simulation, none of the controllers commented about any of the particular UASs when their maneuvers were delayed by 30 seconds. (CAASD)

SYSTEM KNOWLEDGE

A thorough understanding of how the aerospace system operates, the impact of change on system performance and risk, and how the system impacts the nation

NEXTGEN TOWERS

Air traffic in the U.S. is expected to increase significantly over the next several decades. Some high-end estimates indicate that by 2025 the total passenger enplanements may more than double and total aircraft operations may triple in comparison to today's traffic. In the next 10-15 years, most U.S. tower facilities will reach the end of their useful life and the cost of new tower construction is escalating. To respond to these concerns, the FAA developed the NextGen Towers (NT) operational concept to increase capacity and address the predicted growth in airport tower operations, while still addressing the cost prohibitive nature of replacing ATC towers with new towers. The NT concept reduces the need for physical infrastructure associated with ATC towers and will provide a means to control airport traffic from a ground level location. As part of the research plan, the FAA conducted a HITL Talk Aloud analysis in 2009. This HITL examined the out-the-window information requirements controllers have in the existing tower environment so that these requirements may be functionally allocated in a NT. The HITL Talk Aloud Analysis was conducted in a training simulation environment at the Ronald Reagan Washington National Airport. The results obtained from the HITL Talk Aloud will drive functional and physical architectures for NT in future HITL simulations and field demonstrations. (NextGen - Operations Concept Validation - Validation Modeling)

NEXTGEN IMPLEMENTATION MODELING AND PERFORMANCE

As the FAA continues NextGen implementation, it is essential that modeling, simulation, and performance assessment tools and methodologies continue to provide insight into the evolution of the complex NAS. In 2009, CAASD researchers evolved that capability through the development of a process to characterize the benefit mechanisms associated with NextGen Operational Improvements (OIs), improving the methodology to create current and future demand scenarios, and using existing tools to gain insight into the NAS-wide effect of changes to key parameters associated with planned NextGen OIs.

The future NextGen concept of operations is described by the mid-term OIs developed by the NAS Enterprise Architecture Office and the FAA's Office of NextGen Planning and Operations. CAASD analysts worked closely with FAA system engineers to further decompose the capabilities outlined in the OIs into DoD Architecture Framework (DoDAF) artifacts that led to the creation of ~400 operational requirements that characterize the required capabilities for the nominal mid-term NextGen system. The DoDAF artifacts enabled the benefit and cost analysts to further refine their understanding of the key benefit mechanisms that facilitated operational benefits in the system. The benefit mechanisms and their relationships to one another were captured in Benefit Mechanism Influence Diagrams. The diagrams served as a framework to communicate the details of the benefits to other stakeholders and to facilitate the quantification of each mechanism. The influence diagrams identified over 50 unique benefit mechanisms and have been leveraged to inform the benefits descriptions in the Enterprise Architecture and the *NextGen Mid-term Concept of Operations for the National Airspace System* published in 2009 by the FAA. The benefit mechanisms are also being used as a key input into a comprehensive business case analysis of NextGen in the mid-term.

CAASD researchers also made several improvements to the demand scenario creation process to support NextGen Implementation Modeling and Performance. CAASD performed analyses to determine the appropriate number of days to include in a sample to represent the target year. CAASD looked at daily metrics such as sector traffic levels, center counts, airport weather, and airport delays using different sample sizes, and determined that a sample of about 30-36 days would adequately ensure coverage across the quartiles of these selected metrics. CAASD also developed a capability to build base-year and corresponding future-year demand schedules. A part of this new capability is a new process to trim and link flights simultaneously. This joint trimming and linking process allows for more realistic itineraries with reasonable turnaround times between flights in the future years. Demand is one of the most influential factors in system-wide analysis and the advances in demand scenario generation achieved in 2009 will enable more insightful analysis moving forward.

In addition, CAASD conducted analysis to identify NextGen OI-related factors input into CAASD's system-wide air transportation simulation model that are most influential on key operational benefits-related metrics, and where in the NAS they have the largest effects. In 2009, three operational areas were examined: airport capacity, en route capacity, and time in visual meteorological conditions at airports. The analyses found that changes in key factors such as individual airport capacity or sector capacity of as little as 10 to 20 percent resulted in significant shifts in NAS-wide delay depending upon the location and connectivity of the location where the adjustment was made. In the end, the analysis confirmed a belief that the influence of parameters related to airport capacity and en route sector capacity are strongly related to usage and volume. The data from this analysis can be leveraged to assess the impact of potential NextGen implementation plans based on the usage and demand levels of the NAS resources affected by the potential changes. Further analysis is planned to investigate additional influential factors and to further refine an understanding of the general response of the NAS (as modeled) to particular targeted changes. (CAASD)

ACRONYMS AND ABBREVIATIONS

100LL	100 Low Lead	COTS	Commercial-Off-The-Shelf
4D	Four-Dimensional	CP	Compression Precracking
4DT	Four-Dimensional Trajectories	CSAHWG	CDTI Symbolology Ad Hoc Working Group
AAFEX	Alternative Aviation Fuel Experiment	CSPR	Closely Spaced Parallel Runways
AAWU	Alaska Aviation Weather Unit	Data Comm	Data Communications
AC	Advisory Circular	DFW	Dallas/Fort Worth International Airport
ACES	Airspace Conflict Evaluation Simulator	DoD	U.S. Department of Defense
ACRP	Airport Cooperative Research Program	DoDAF	DoD Architecture Framework
ADAF	Airfield Deicing and Anti-Icing Fluids	DRWP	Doppler Radar Wind Profilers
ADS-B	Automatic Dependent Surveillance - Broadcast	E-FAROS	Enhanced Version of FAROS
AEC	Aviation Emissions Characterization	EA	Environmental Assessment
AEDT	Aviation Environmental Design Tool	EFB	Electronic Flight Bag
AEE	FAA Office of Environment and Energy	EIS	Environmental Impact Statement
AMS	Aerospace Materials Specifications	EPA	U.S. Environmental Protection Agency
AOC	Airline Operations Center	ERDC	En Route Data Communications
APMT	Aviation Environmental Portfolio Management Tool	ETA	Estimated Time of Arrival
APU	Auxiliary Power Unit	FAA	Federal Aviation Administration
ASAP	Aviation Safety Action Program	FAR	Federal Aviation Regulation
ASRS	Aviation Safety Reporting System	FAROS	Final Approach Runway Occupancy Signal
ASTM	ASTM International	FEWS	Future En Route Workstation
ATC	Air Traffic Control	FIP-AK	Forecast Icing Product - Alaska
ATCOV	Air Traffic Control Color Vision Test	FLM	Front Line Manager
ATCS	Air Traffic Control Specialist	FMS	Flight Management Systems
ATD	Anthropomorphic Test Dummy	FPI	Fluorescent Penetrant Inspection
AFETF	Aviation Fuel and Engine Test Facility	FT	Fischer-Tropsch
ATM	Air Traffic Management	FTWS	Future Terminal Workstation
BMP	Best Management Practice	GA	General Aviation
CA	Constant Amplitude	GC/MS	Gas Chromatography/Mass Spectrometry
CAAFI	Commercial Aviation Alternative Fuel Initiative	GGUAS	Global Gridded Upper Air Station
CAASD	Center for Advanced Aviation Systems Development	GHG	Greenhouse Gas
CAD	Color Assessment and Diagnosis	GOES	Geostationary Operational Environmental Satellites
CAMI	Civil Aerospace Medical Institute	GUI	Graphical User Interface
CAMS	Critical Area Management System	HAP	Hazardous Air Pollutant
CDA	Continuous Descent Arrivals	HITL	Human-In-The-Loop
CDTI	Cockpit Display of Traffic Information	IC4D	Interactive Correction in Four Dimensions
COA	Continental Airlines	ICAO	International Civil Aviation Organization
		IFR	Instrument Flight Rule
		ISU	Iowa State University
		JAIaB	Job Analysis Information Database

JPDO	Joint Planning and Development Office	RAMs	Repairs, Alterations, and Modifications
JTA	Job Task Analysis	RNA	Ribonucleic Acid
LIDAR	Light Detection and Ranging	RNAV	Area Navigation
LR	Load-Reduction	RVSM	Reduced Vertical Separation Minima
MMPDS	Metallic Materials Properties Development and Standardization	SAE	Society of Automotive Engineers
NAS	National Airspace System	SAFO	Safety Alert for Operators
NASA	National Aeronautic and Space Administration	SIF	Stress-Intensity Factor
NDI	Nondestructive Inspection	SIMMOD	FAA's Airspace and Airport Simulation Model
NDT	Nondestructive Test	SJA	Strategic Job Analysis
NextGen	Next Generation Air Transportation Systems	SRA	Solar Radiation Alert
NOAA	National Oceanic and Atmospheric Administration	SS II	SpaceShipTwo
NO _x	Nitrogen Oxide	STARS	Standard Terminal Automation Replacement System
NPRM	Notice of Proposed Rulemaking	TA	Tailored Arrivals
NT	NextGen Towers	TBO	Trajectory-Based Operations
NTSB	National Transportation Safety Board	TRACON	Terminal Radar Approach Control
OI	Operational Improvement	UAS	Unmanned Aircraft Systems
PAPI	Precision Approach Path Indicator	WFD	Widespread Fatigue Damage
PM	Particulate Matter	WK II	WhiteKnightTwo
ppm	Parts Per Million	WTMA	Wake Turbulence Mitigation for Arrivals
q-PCR	Quantitative Polymerase Chain Reaction		
R&D	Research and Development		

The NARP, related appendices, and the *R&D Annual Review* may be found online at:

www.faa.gov/go/narp

