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FAA's Best Kept Secret

The Civil Aerospace Medical Institute

"The Civil Aerospace Medical Institute (CAMI) is probably one of the FAA's best kept secrets," says CAMI Director, Dr. Melchor Antuñano. As one of the world's premier aviation research facilities, CAMI, located in Oklahoma City, Oklahoma, conducts critical aerospace research that focuses on the safety of pilots, passengers, air traffic controllers, and the entire human support system that embraces civil aviation. Over 280 physicians, researchers, educators, pilots, technicians, and administrative personnel work in CAMI's state-of-the art facilities.

CAMI's mission is to assure civil aerospace safety through excellence in medical certification, education, aerospace medical/human factors research, and occupational health services. To support that mission, the facility has multiple laboratories that allow the researchers to perform real time simulations and/or experiments that are identical to real world aircraft situations.

According to Dr. Antuñano, "CAMI's researchers are global leaders in aerospace medical and human factors research. Our researchers are pioneering new aviation-related technologies, procedures and scientific developments that are leading the way to new global safety standards as we translate research into operations."

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Critical Research for Aviation's Future

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Getting to Know CAMI's Director

Dr. Melchor Antuñano

Dr. Melchor Antuñano assumed leadership of CAMI in January 2001. In this position, he is directly responsible for the administration of the FAA's Office of Aerospace Medicine programs in medical certification, education, aerospace medical research, aerospace human factors research, and occupational health services.

Born in Mexico City, he is a graduate of the National Autonomous University of Mexico School of Medicine and a graduate of the Residency Program in Aerospace Medicine at Wright State University School of Medicine in Dayton, Ohio. The U.S. National Research Council of the National Academy of Sciences awarded him a post-doctoral research fellowship at the U.S. Air Force School of Aerospace Medicine in San Antonio, Texas.

Dr. Antuñano is credited with 307 scientific presentations at national and international conferences in aerospace medicine in the U.S. and in 23 countries worldwide and has written 47 scientific articles covering a variety of aerospace medicine topics. He is Fellow and President-Elect of the Aerospace Medical Association, past President of the Space Medicine Branch, past President of the Iberoamerican Association of Aerospace Medicine, elected member and selector of the International Academy of Aviation and Space Medicine, elected member of the International Academy of Astronautics, Honorary Member of the Greek Aerospace Medical Association, Honorary Member of the Colombian Society of Aviation Medicine, Honorary Member of the Slovanian Aerospace Medical Association, Charter Member of the Aerospace Human Factors Association, Member of the Mexican Society of Aviation Medicine, and a member of other national and international professional societies in aerospace medicine. He is a faculty member at Wright State University School of Medicine, at the University of Oklahoma Health Sciences Center, at the University of Texas Medical Branch in Galveston, at the Universidad Nacional de Colombia School of Medicine in Colombia, and at the Santa Casa de São Paulo School of Medicine in Brazil.

He is also the recipient of 51 awards and recognitions for his academic, administrative, and research achievements, including the DOT Secretary's Award for Meritorious Achievement: Silver Medal; FAA Office of Aviation Medicine's Outstanding Manager Award; the Arthur S. Flemming Award granted by the George Washington University for outstanding accomplishments in the promotion of aviation safety in the U.S. and abroad; the John A. Tamisiea Memorial Award granted by the Aerospace Medical Association and the Civil Aviation Medical Association for unique contributions to aviation medical examiner activities; and the Space Medicine Branch of the Aerospace Medical Association's Young Investigator Award. The House of Representatives of the Republic of Colombia has also presented Dr. Antuñano with the Congressional Certificate of Recognition for Contributions to Improve Aviation Safety in Colombia through Continuing Medical Education. ■

Critical Advancements in Science

Improving Safety Through Genetics Research

"Human genetics is one of the most exciting and fastest-growing fields in the biomedical sciences. The fast pace of discovery and the application of new technologies make this an exciting time to be a part of the human genetics community."

-- Dr. Nicole Vu, FAA's Functional Genomics Laboratory

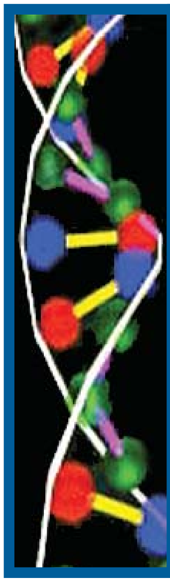
In April 2003, the global scientific community celebrated the Human Genome Project's completion of a high-accuracy sequence of the human genome. Now that the initial sequencing of the human genome is complete, medical researchers are using high-tech laboratory equipment to understand more complex matters like DNA structure and gene expression better.

What is a genome?

Every organism contains DNA. The DNA in each cell is arranged into sections called genes. The entire sequence of DNA in one organism, such as a human being, is called its genome. The human body contains about 100 trillion cells, and each cell contains a copy of the entire human genome.

DNA does nothing on its own, it is simply a recipe for life - the recipe for a cell to make a protein. Proteins carry out the daily work of a cell, and current estimates suggest that in humans there are between 30,000 and 40,000 genes, suggesting a similar number of different proteins. Our genes determine everything about us: our physical appearance; basic personality; predisposition to certain diseases; longevity; talent; ability to learn; etc.

When a cell requires a specific protein, the DNA recipe is read and the protein is made. Gene expression is the switching on and off of genes so that proteins can and cannot be made, according to the needs of the cell. It is one of the fundamental biological processes that enable our cells to grow, survive, and function.



One important tool in modern genetic research and in medical diagnostics is micro-array technology, in which a robot puts thousands of DNA fragments or short DNA sequences corresponding to each gene onto a special glass slide -- sometimes referred to as a gene chip. Researchers can then expose the gene chip to DNA probes produced from a particular body tissue such as skin cells, which have been tagged with fluorescent dye to see which genes turn on and off.

The mapping of the human genome has made it possible for researchers to begin gauging the effects of stress (biological, environmental, chemical, etc.) at the molecular biochemical level. Hence, the goal of many molecular biologists is to understand the mechanisms that control gene expression and how these mechanisms are integrated with developmental and environmental signals to coordinate growth and development.

To understand these biological processes, it is necessary to understand the cell signaling networks that are influenced by expression of a gene.

Gene Expression and Revolutionary Aviation Research

FAA's medical researchers are taking genetic science to a new level as they unlock the human genetic code to answer questions about how things such as illness, alcohol or drug impairment, and drug interactions affect an individual's ability to pilot an aircraft.

Detection of impairment is critical for preventing accidents and protecting lives. Gene expression research allows FAA's scientists at CAMI to link specific biochemical changes, whether normal or abnormal physiological responses, back to a specific gene. Recent technical developments in micro-array techniques have made it possible to try and answer these questions on a genome-wide level. By combining the gene expressions research with traditional biochemical investigative methods, CAMI's functional genomic researchers, Drs. Nicole Vu, Hua Zhu, and Edward Owuor, are acquiring a more definitive knowledge of how, why, and what happened before and after the impairment.

Today, FAA scientists use DNA micro-array techniques to study gene expression patterns. Using state-of-the art medical equipment, researchers are working to under-

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Since 1961, CAMI researchers, many of whom hold M.D. and/or Ph.D. degrees, have published over 1,000 FAA research technical reports and scientific articles in the open literature, helping the civil aviation community understand the medical and human factors challenges of aviation operations. The results of this work have had immediate impact on civil aviation safety.

At CAMI, researchers specialize in either aerospace human factors or medical research. The human factors researchers focus on the design, operation, and maintenance of components of the National Airspace System (NAS). They investigate and study human performance under various environmental conditions with the goals of improving NAS effectiveness, efficiency, and safety. Their primary emphasis is on enhancing human performance through equipment design, interface design, management practices, and human resource procedures including personnel selection and training.

CAMI's aerospace medical research focuses on the biomedical aspects of flight. In highly specialized and sophisticated medical laboratories, these scientists conduct aviation safety research associated with biomedical, pharmacological, and toxicological issues. They also conduct research into environmental factors that influence human physiology and performance, such as the study of protective breathing equipment for use in emergency situations aboard aircraft.

CAMI is now participating in the National Research Council Research Associateship Program. The objectives of this program are to provide postdoctoral scientists and engineers of unusual promise and ability opportunities for research on problems, largely of their choices, that are compatible with the interests of the sponsoring laboratories, and to contribute to the overall research efforts of Federal laboratories.

Although the majority of the CAMI activities are geared to improving aviation safety now, researchers are also identifying future issues as they look towards the next giant step from civil aviation into civil aerospace operations. And, again, CAMI is leading the way by examining the medical and human factors issues associated with aerospace travel. ■

CAMI's Vision:

The Civil Aerospace Medical Institute, through sustained excellence, is a world leader in all aspects of civil aerospace medicine and research, constantly enhancing global aerospace safety.

Protecting Passengers and Crew

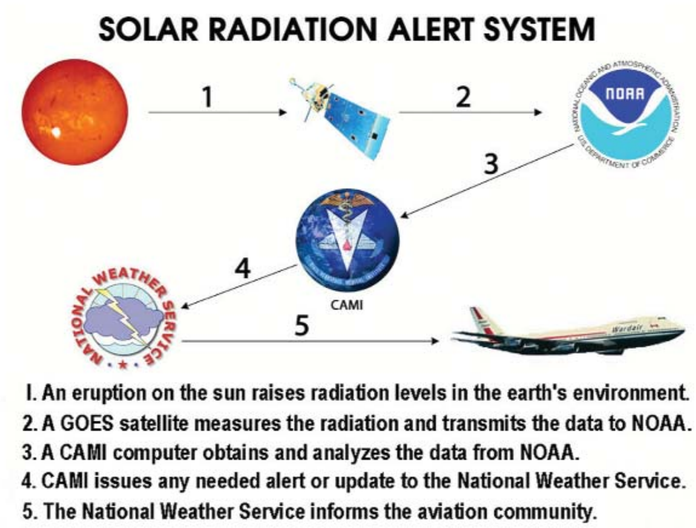
Radiobiology Research

We are all exposed to radiation. Radiation comes from natural sources - the air we breathe, the ground we walk on, and the food we eat - and from man-made sources - radars, x-ray machines and many other devices. Everything in our world contains small amounts of radioactive atoms.

Atoms consist of very small subatomic particles (protons and neutrons) sitting in a central nucleus, orbited by smaller particles (electrons): a miniature solar system. Normally, the number of protons in the center of the atom equals the number of electrons in orbit. An ion is any atom or molecule that does not have the normal number of electrons. Ionizing radiation is any form of radiation that has enough energy to knock electrons out of atoms or molecules, creating ions.

Ionizing radiation can cause changes in the chemical balance of cells, which can cause cell damage or cell death. In some cases there may be no effect. In other cases, the cell may survive but become abnormal, either temporarily or permanently. An abnormal cell may become malignant.

According to Dr. Wallace Friedberg, team coordinator of the FAA's Radiobiology Research Team, "The probability of a radiation-caused cancer or genetic effect is related to the total amount of radiation accumulated by an individual. Based on current scientific evidence, any exposure to radiation can be harmful and increase the risk of cancer; however, at very low exposures, the estimated increases in risk are very small."



Cosmic Radiation

Cosmic radiation consists of energetic charged particles moving through space. The particles originate from sources beyond our solar system and from the sun. When these particles enter the earth's atmosphere they collide with and disrupt atoms in the atmosphere, producing secondary, less energetic, particles. By the time cosmic radiation reaches the ground, its ability to cause biological harm is considerably reduced.

On the ground, cosmic radiation makes up on average about 9 percent of the natural radiation to which we are all exposed. The rest consists of radon gas (68 percent), radiation from minerals in the soil (9 percent), and radiation in our bodies from food and water (14 percent). These proportions and the total exposure vary depending on geographic location because of differences in soil composition and altitude.

The amount of cosmic radiation that we are exposed to depends on altitude and latitude, as well as the stage of the solar cycle. The earth's magnetic field deflects some of the cosmic radiation away from the earth. The shielding ability of the magnetic field is most effective over the equator and least effective over the poles. The charged particles emanating from the sun, the so-called solar wind, can also deflect cosmic radiation away from the earth. The effectiveness of the solar wind in deflecting cosmic radiation particles varies with the stage of the solar cycle, the approximate 11-year cycle of rise and decline in solar activity. When solar activity is low (solar minimum), the solar wind is less effective in deflecting cosmic radiation, and cosmic radiation reaching the earth is more intense.

CAMI's researchers have developed a Solar Radiation Alert system. The system, a collaborative effort by CAMI, the Space Environment Services Center of the National Oceanic and Atmospheric Administration (NOAA), and Northern Arizona University, provides early warning of solar activity

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Radiobiology- *continued from previous page*

that could result in air travelers being exposed to excessive amounts of ionizing radiation.

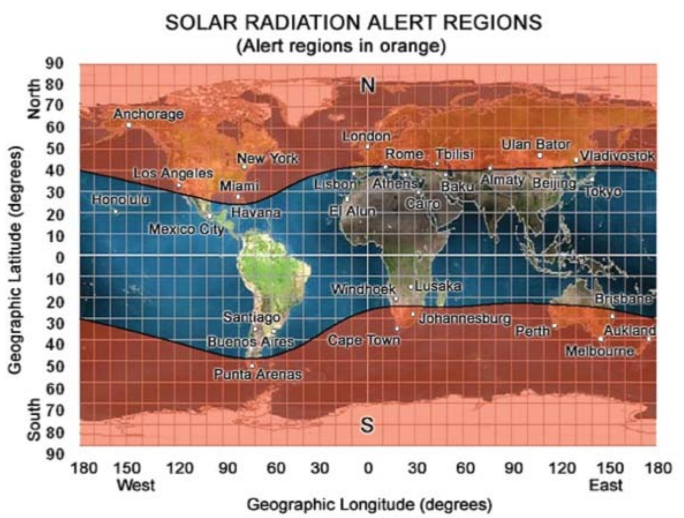
NOAA continuously measures radiation from the sun using geostationary satellites and transmits the measurements to a computer at CAMI. The computer analyzes the measurements and estimates radiation levels at 20,000 to 80,000 feet (in 10,000 foot increments) at high latitudes. If the dose rate equals or exceeds 20 microsieverts per hour at any of the selected altitudes for three consecutive 5-minute periods, a Solar Radiation Alert is transmitted to subscribers of the NOAA Weather Wire Service. Included with the alert are estimates of radiation levels at the selected altitudes along with a recommended maximum flight altitude for air-carrier aircraft. The entire process takes a few minutes.

Air Travel and Radiation Exposure

The amount of exposure to cosmic radiation while flying depends on the amount of time in the air, in addition to altitude, latitude, and solar activity. The intensity of cosmic radiation at aircraft altitudes near the poles, for example, is about twice that at the equator.

Cosmic radiation increases with altitude. At commercial aircraft altitudes, the protective layer of the earth's atmosphere is much thinner than it is on the ground, and the intensity of cosmic radiation is therefore greater.

The cosmic radiation dose rate at flight altitudes can be more than 100 times the dose rate at sea level. Nevertheless, the radiation dose to air travelers is normally relatively small. For example, it would take about 100 one-way flights between New York and Chicago to obtain the same exposure as we get in 1 year



from other sources of natural background radiation.

Because radiation exposure in any amount is considered potentially harmful, the FAA recommends occupational radiation exposure limits for commercial aircraft crewmembers. The limits include a 5-year average effective dose of 20 millisieverts per year, with no more than 50 millisieverts in a single year. For a pregnant crewmember, starting when she reports her pregnancy to management, the recommended limit for the conceptus is an equivalent dose of 1 millisievert, with no more than 0.5 millisievert in any month.

To help frequent flyers determine their exposures, CAMI's Radiobiology Research Team developed computer programs to estimate radiation dosage on flights. These user-friendly programs are available free at http://www.cami.jccbi.gov/radiation.html. The programs calculate the effective dose of galactic cosmic radiation received on an aircraft flying a great circle route (CARI-6) or on a user-defined route (CARI-6M). The programs account for changes in the earth's magnetic field and solar activity. There is an interactive version of CARI-6 that runs on the Internet. It can be reached by a link from the web site. In addition, educational materials, such as *What Aircrews Should Know About Their Occupational Exposure to Ionizing Radiation*, can also be found on-line at the same web site.

FAA's Radiobiology Research Team is working hard to understand the effects of radiation on air travelers and to provide timely information to the public on radiation exposure levels. "It is important to remember, however, that the average traveler is unlikely to fly enough to experience significant effects from cosmic radiation," says Dr. Friedberg.

For additional information on FAA's radiobiology research, please contact Dr. Wallace Friedberg at wallace.friedberg@faa.gov. ■

New Approaches to Accident/Incident Investigation

The Human Factors Analysis and Classification System

The United States air transportation system is one of the safest and most advanced in the world. The U.S. aviation safety record is a tribute to the professionalism of the pilots and crew on board the plane, and to the thousands of people who support them on the ground -- mechanics, dispatchers, passenger screeners, air traffic controllers, safety inspectors, and airport operators. This record is also a result of 5 decades of technological advances and cooperative efforts between government and industry. Despite the many remarkable safety achievements over the past decade, however, more is being done to reduce the already low accident rate.

As aircraft become more reliable and technological failures become rare, researchers are now focusing on how to understand and improve human performance. Research indicates that 70-80 percent of aviation accidents may be the result of human error. Although, the majority of aviation accidents point to human error, most investigation and prevention programs are not designed around any theoretical framework of human error. Hence, understanding the human role in accidents/incidents has been extremely difficult.

To fill this knowledge gap, CAMI researcher Scott A. Shappell, Ph.D., and the University of Illinois' Douglas Wiegmann, Ph.D., designed the Human Factors Analysis and Classification System (HFACS) to assist accident investigators and other safety professionals in understanding how and why human errors occur. Recognizing the need for a systematic method of classifying human factors in accident investigation, Drs. Shappell and Wiegmann applied Dr. James Reason's model of active and latent failures in complex systems to aviation accident assessment.

"While accident reporting systems in the past have been efficient at identifying mechanical and structural failures, they have lacked efficiency in identifying human errors," explains Dr. Shappell, manager of human factors research at CAMI. "HFACS allows investigators to uncover specific types of human causes contributing to the accident, helping them determine whether the problem is skill-based, perceptual, or attributable to organizational factors."

HFACS is a data-driven investigation and safety analysis program designed to examine system interaction and causes of system failures. It provides accident investigators with a valuable, comprehensive, user-friendly tool for identifying and classifying aviation accident information with regard to human causes. Originally developed for the U.S. Navy and Marine Corps, HFACS examines human error at all levels from the cockpit to personnel communications.

HFACS employs four levels of analysis to understand the underlying causes of incidents/accident: human error or the willful violation of rules and regulations; the preconditions for the unsafe act e.g., substandard states of operators (mental, physical, physiological) and substandard practices; unsafe or inadequate supervision; and organizational factors. HFACS also provides objective subcategories for detailed analysis, such as subdividing unsafe acts into errors and violations and subdividing errors into skill-based errors, decision-related errors, and perceptual errors.

To test their new system, Shappell and Weigman have applied HFACS to analyze human error data associated with aircrew-related commercial aviation accidents using database records maintained by the National Transportation Safety Board and the FAA and general aviation accidents involving controlled flight into terrain. They found that investigators could reliably accommodate all the human causal factors associated with these accidents using the HFACS system. In addition, the classification of data using HFACS highlighted several critical safety issues in need of intervention research. These and other studies have proved the Human Factors Analysis and Classification System as a reliable taxonomy for investigating human factors

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Understanding Human Error

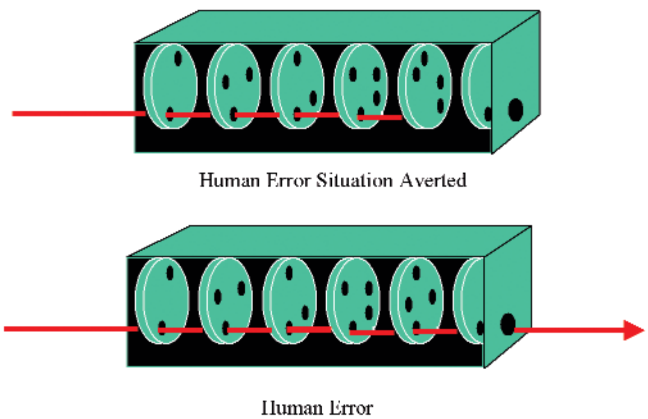
The JANUS Technique

"We're only human" is a familiar phrase to most. However, being human can sometimes make us vulnerable to occasional poor judgment or decision-making, with unfortunate and sometimes potentially disastrous results. In fact, an estimated 70 to 80 percent of all aviation accidents are the result of human error. It is far easier for investigators to determine and report a technical failure that led to a crash or incident, such as a failed engine or faulty wire, than to ascertain what could sometimes be the subtle human actions or errors that may also precipitate an aviation accident or other types of aviation incidents.

Ultimately, to reduce aviation incidents we must find ways to reduce the occurrences of human error by implementing methods to mitigate them. It is a goal of the FAA and the aviation community to reduce the number and severity of human errors, thereby maintaining our safe flying environment. But first, we must determine, among other things, what those errors are, how often they occur, under what conditions they occur, and how these errors can be best classified.

Human errors have been under investigation for some time, and to date, there have been a number of different taxonomies developed to collect information about their causal factors. Two general points of view have emerged. One is that we can eliminate human error altogether by identifying the appropriate training, equipment, procedure, etc. The other is that the chance of human error will always be present, and so we must try to identify where vulnerabilities in the human and in the system exist so that we can strengthen them. Vulnerabilities of many types may be present and interact to culminate in human error. These can include characteristics of the organization (in which the human is but one element), actions by other people with whom the human interacts, the equipment available to do the work, environmental factors over which one has no control (such as the weather), and one's own personal characteristics and attitudes.

Human Error Might Result From a Series of Vulnerabilities or Just One



The Human Factors Analysis and Classification System (HFACS) is a classification system that enables users to classify the human factors that lead to aviation accidents according to factors ranging from pilots' unsafe acts to organizational factors. In this manner, trends in causal factors data across a number of accidents can be seen. The FAA, the military, and commercial and general aviation sectors currently use the HFACS framework to classify causal factors. While HFACS was being used in the U.S., the European aviation community leader, EUROCONTROL, developed and used a different technique through its Human Error in ATM (HERA) program. HERA was developed to identify error points in air traffic control systems. This technique, similar to HFACS, analyzed information contained in reports of past incidents to generate a database of causal factors.

As a collaborative effort, the FAA and EUROCONTROL developed a joint approach to the analysis of human error in air traffic management. The harmonizing of the HFACS and HERA techniques is JANUS. JANUS combines the best of both systems. Working with our European counterparts we have harmonized the core taxonomy for defining human error. Variations of JANUS are being adopted as part of the official investigation in some European countries. To classify human errors, the JANUS technique systematically leads the user through a logical sequence of questions so that the breadth of the event is captured, potential bias is avoided, and the pertinent causal f actors are diagnosed. Because an aviation incident, such as an air traffic operational error, can be a result of a series of critical decisions or a chain of events, the technique permits this type of unfolding analysis. The technique permits users to also identify and describe the human error in its context, to better understand how the error occurred. The context includesfactors that influence performance, such as what tasks were being performed, the quality of the performance, and environmental and organizational influences.

Initial validation of the FAA version of JANUS was completed in May 2003 through coordination with Mr. Anthony Ferrante (AAT-200) as the ATC management sponsor.. EUROCONTROL member states conducted parallel validation activities. During the 2003 fiscal year, FAA researchers trained in the use of the JANUS technique collected data on 79 operational errors. A total of 29 air traffic facilities volunteered to participate, including air route traffic control centers, terminal radar approach controls facilities, and towers.

In Milan, Italy, on October 8, 2001 an MD-87 had just lifted its front wheels for takeoff as a Cessna Citation 525 entered the runway without permission. The aircraft collided and the MD-87 careened into Linate Airport's baggage hangar and exploded in flames. The Cessna burned on the runway. Weather at the time of the accident was reported as "heavy fog". Both aircraft were destroyed and 118 people died.

In addition, human factors researchers also reviewed the runway incursion at Linate Airport in Milan, Italy, using the JANUS technique to identify and classify potential human and contributing factors. CAMI researchers have completed a draft version of JANUS for ground operations in runway safety. This was developed in collaboration with the Airport Operations Manager and other subject matter experts from Will Rogers World Airport in Oklahoma City.

Further work is being undertaken in exploring use of this approach for the real-time investigation of incidents and how to better link the identification of causal factors to error mitigation strategies, such as the design of more effective training techniques.

The JANUS approach offers promise to a variety of other disciplines as well, such as for exploring the possibilities of predicting sources of error before they occur. For example, potential users might include: decision makers and managers responsible for safe operations; psychologists and human factors practitioners; incident investigators and analysts; reliability engineers; and software developers.

For additional information, please contact Dr. Julia Pounds at julia.pounds@faa.gov. ■

Meeting Future Air Traffic Needs

POWER

As new and more complex technologies are introduced into the national airspace system, it is important to understand the interaction between the air traffic controller and the technology. Through research in areas such as selection, training, automation, workload, and communication, the FAA is identifying the most effective procedures to be used in combination with new technology applications and a more capable workforce to make the global air transportation system of the future safer and more efficient.

"To better understand the human-machine interface, FAA researchers are helping to determine how the design of advanced automation and decision support tools may affect controller workload," explains Elaine Pfleiderer, CAMI Human Factors Research Laboratory. "In the past, we measured workload by having air traffic controllers provide subjective ratings. Because these measures are subject to rater bias, we are now conducting research to develop a set of objective task load measures."

As part of this effort, CAMI's human factors researchers developed the Performance and Objective Workload Evaluation Research (POWER) software. POWER is designed to quantify air traffic controller activity and taskload. Researchers identified a list of more than 20 POWER measures describing different aspects of air traffic controller activity that are objective, routinely recorded, and therefore, relatively easy to obtain. The measures encompass controller and aircraft information, such as traffic volume, the average heading, speed, and altitude changes, the number of handoffs, data entries, route displays, point-outs, data block offsets, conflict alerts, etc.

POWER collects actual data from several air traffic control databases and then uses the information to calculate controller task load in a variety of situations. If FAA's researchers find these measures accurately correspond to controller workload and performance, the Agency can use them to identify the potential negative effects on controllers of using new procedures and automation technologies.

According to Pfleiderer, "Once we verify the validity of the POWER software, we will use POWER to develop baseline measures of controller activity and task load for en route air traffic controllers. These baselines will be extremely useful for evaluating the effects of changes in equipment and procedures used by controllers."

Future POWER research will continue to examine varying combinations of measures to improve the ability to calculate taskload and performance for air traffic controllers. As well, researchers will compare and contrast measures obtained from different air traffic facilities to identify patterns and ensure POWER consistently provides precise measurement that truly reflects controller activity.

Preliminary research results for POWER can be found on-line at: www.hf.faa.gov/docs/508/docs/cami/0110.pdf - *Investigating the Validity of Performance and Objective Workload Evaluation Research* and www.cami.jccbi.gov/aam-400A/Abstracts/2002/FULL%20TEXT/0202.pdf - *POWER: Objective Activity and Taskload Assessment in En Route Air Traffic Control.*

For further information, please contact Elaine Pfleiderer at elaine.pfleiderer@faa.gov. ■

FAA Software Identifies the Cream of the Crop

Air Traffic Control and Airways Facilities Personnel Selection

The FAA projects the number of flights to rise from over 40 million in the year 2000 to approximately 55.6 million by 2014. Couple this 40 percent increase in air traffic with the projected retirements of approximately 300 air traffic controllers and air facilities systems specialists per year and the addition of new and more complex technology and you have a real hiring need.

In anticipation of the future need for new controllers and systems specialists, personnel research psychologists at CAMI are responsible for the development and validation of personnel selection tests and processes for critical FAA occupations. The fundamental scientific question investigated by the CAMI scientists is the relationship of human abilities to aviation job performance. The practical application of the science takes the form of computerized tests, automated application forms, and job-task simulations used to identify the "cream of the crop" among the hundreds, and sometimes, thousands of applicants for jobs in mission-critical occupations in the FAA.

While much of the research is performed "in house," the CAMI researchers also collaborate with FAA line organizations, human resources staff, contractors and experts from universities across the nation to deliver fair, reliable, valid, and useful employee selection procedures for the agency. For example, the Air Traffic Selection and Training (AT-SAT) is the product of a long-term collaboration between CAMI, the FAA Academy Air Traffic Division, the Air Traffic Resource Management Program, two Washington-area contractors, and several well-known experts from several universities.

AT-SAT is a computer-administered aptitude test battery that assesses if job applicants have the abilities needed to perform effectively as air traffic controllers in the terminal or en route environments. Examples of the abilities assessed by AT-SAT include prioritization, tolerance for high-intensity work situations, planning, reasoning, decisiveness, and problem solving. AT-SAT takes about eight hours to complete and replaces the old written OPM aptitude test and FAA Academy nine-week resident non-radar screening program. After the research team reported the completion of a concurrent validation study in 2001, CAMI researchers continued validating the accuracy of AT-SAT by tracking individuals hired using this personnel selection tool. These new hires are being followed through training at the FAA Academy and into field on-the-job training. Researchers will monitor the relationship of the scores achieved by the applicant hired using the AT-SAT to training outcomes at the FAA Academy and in the field.

AT-SAT was recognized in 2001 by the Society for Industrial and Organizational Psychology for outstanding applied research. AT-SAT was implemented in 2002, even as enhancements are being developed under the direction of CAMI researchers in anticipation of the hiring wave to come in the next several years as the result of controller retirements. Another example of an employee selection tool is the highly successful Airway Facilities Computerized Application Processing System (AFCAPS) for screening applicants for the Airways Transportation Systems Specialist occupation. AFCAPS resulted from collaboration between the CAMI Selection and Validation Research Team, the Airway Facilities Resource Management Program, FAA Human Resources Management, and the Aviation Careers Examining Division, and has served as the paradigm for other automated applicant screening processes in the agency. For example, the automated screening process used for the Federal Air Marshal program expansion in late 2001 and early 2002 was modeled on AFCAPS.

These employee selection tools are based on the current National Airspace System (NAS) configuration, technology, operations, and maintenance needs. However, CAMI researchers are constantly considering the impact of new technologies, procedures, and operating concepts on the profile of abilities required to succeed in mission-critical FAA occupations. "The FAA selected the current controller, technician, and systems specialist workforce on the basis of the knowledge, skills, and abilities required to operate, maintain, and manage today's air traffic control system. However, tomorrow's national airspace system may require additional knowledge, skills, and abilities as new, more sophisticated

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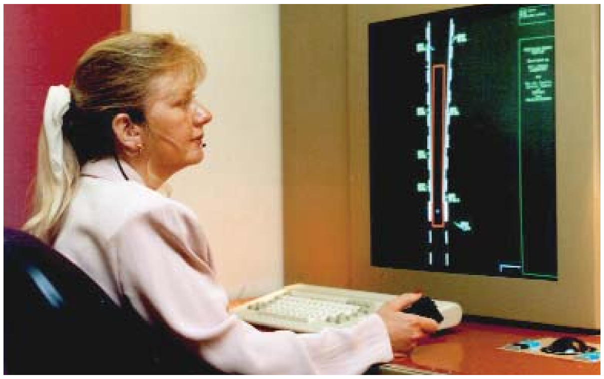
How Tired Are We?

Understanding Fatigue

The work environment in an air traffic control tower can be a dark, lonesome place for air traffic controllers who work the late and very early shifts. And, it can be very tiring. However, because controlling air traffic is a 24-hour, 7-day a week operation, shift work is often required and unavoidable.

Studies show that optimal performance is impossible without adequate sleep. Not getting enough sleep affects memory and the ability to perform complex tasks like the planning and problem-solving necessary to predict and resolve conflicts between aircraft. Working on a schedule that changes constantly can pose challenges to getting enough rest. In fact, studies show that while only 15 to 20 percent of day workers report suffering sleep disturbances, a greater percentage of shift workers who work night rotations report this problem.



Air traffic controllers in the U.S. use a variety of shift scheduling practices. Approximately 25 percent of controllers are on a 2-2-1 schedule, which requires working 2 afternoons, 2 early mornings, and 1 midnight shift. Controllers have used this type of schedule for more than 3 decades. It allows the controllers to work 4 shifts during "normal" waking hours and only one midnight shift. After the midnight shift, it allows approximately 3 days off - time enough to recover from any sleep deprivation. This schedule provides the controller both daytime and evening time off.

Most shiftwork schedules, particularly those that require working at night, pose problems to the worker. CAMI researchers have identified some of the problems with the 2-2-1 rotation. This schedule can result in sleep loss and fatigue as a result of 1) shortened time off between shifts, 2) working consecutive early morning shifts that start before 8 a.m., and 3) working at night. In addition, the 2-2-1 can prove stressful for controllers with families because of the frequent shift changes. Also, the compressed schedule does not allow much flexibility for controllers to cope with unexpected/unscheduled events.

Another common schedule is the 2-1-2, a rotating schedule that does not include a midnight shift. Instead, it allows controllers to work 2 afternoon, 1 mid-day, and 2 early morning shifts. The first 3 shifts enable controllers to sleep 7.5 to 8.5 hours before each shift. Sleep duration prior to the 2 early morning shifts still tends to be reduced because of the early start times. However, this schedule does not provide the facility with staffing on the midnight shift. In some cases, controllers may alternate between the 2-2-1 and 2-1-2 workweeks.

The 2-2-1 and 2-1-2 schedules are both defined as rapidly rotating, counter-clockwise shift schedules. They are rapidly rotating because shifts change every 1 or 2 days. And, they rotate counter-clockwise because at each shift change, the next shift starts earlier rather than later. A much less common air traffic control schedule is the straight shift, during which individuals work 5 early morning shifts. Although this schedule is stable, researchers still found them problematic because these workers were found to only get 5-6 hours of sleep per night as a result of early wake-up times.

CAMI's human factors research team works to understand better the relationship between shift work and fatigue through laboratory and field research. The team's goal is to provide information to the FAA's Air Traffic Service management and to the technical workforce about potential problems and to recommend various countermeasures to reduce fatigue.

It is clear that schedules involving shift work pose certain challenges and provide certain benefits to the employee. Researchers have found, however, that individuals generally do not fully adapt to working at night. They have also compared clockwise and counter-clockwise rotations to determine if direction of rotation proved a significant factor in problems associated with rapidly rotating schedules. The results indicated that direction of rotation is not a significant factor with regard to sleep, performance, or physiological responses and that, once again, the primary problem areas in both rotations involved the early morning and midnight shifts.

Because researchers determined that there really is no single "best" shift work schedule when working at night is a requirement, they are investigating a number of countermeasures to cope with fatigue. For example, controllers are advised to take breaks, consume small amounts of caffeine, and get enough sleep. But these measures alone are not enough to prevent fatigue.

Human Factors for Air Traffic Control Specialists: A User's Manual for Your Brain, also provides the results of human factors research to air traffic controllers in a format that is straightforward and easy to read. The 46-page booklet is divided into 5 easy-to-read and well-illustrated chapters that provide quick tips on how to enhance the factors that contribute to or influence controller performance. Chapter 4, "Fatigue Busters: Tips for Sleeping Better and Maintaining Alertness on the Job," contains clear explanations and tips on fighting the effects of fatigue. The booklet can be found on-line at _http://www.hf.faa.gov/docs/volpe/hfatcs.pdf._

CAMI's countermeasures research has focused primarily on maintaining performance on the midnight shift. To date, researchers have completed 2 napping studies, analyzing data from 20-minute, 45-minute, and 2-hour naps. These studies show that napping provides some benefits. But, immediately after waking up from a nap, some individuals experience sleep inertia. Sleep inertia is the period of grogginess that sometimes occurs following a nap. Researchers are now examining how long an individual should wait after waking up to go back to work.

Mild exercise was also recently examined as a potential countermeasure. In this study, exercise did not benefit performance on the night shift. It may be that the level of exercise was too mild or that exercising at night is not an effective fatigue countermeasure. However, CAMI's scientists continue to seek beneficial countermeasures as part of their ongoing shift work and fatigue research.

CAMI's scientists also provide air traffic controllers educational materials designed to help combat fatigue and to promote improved adaptation to a rotating shift schedule. Recently, air traffic controllers received feedback from a national survey on shiftwork and fatigue and a CD-ROM explaining the problems associated with shift work and suggested coping strategies.

For additional information on the FAA's shift work and fatigue research, please contact Thomas Nesthus, Ph.D., Albert Boquet, Ph.D. or Crystal Cruz, M.S., of the Behavioral Stressors Research Team in CAMI's Human Factors Research Laboratory (405) 954-6826. ■

A New Look at a Crucial Sense

Pilot Vision

The visual needs of a pilot sitting in the cockpit are quite different from those required to sit in an office or read the newspaper at home. Since nearly 80 percent of all flight information comes from visual cues, optimum vision is essential for pilots. Pilots must have good distance vision to detect and identify airborne traffic, as well as hazards that may be on runways and taxiways. And, they must be able to see clearly at near and intermediate distances to read printed materials correctly, such as flight manifests, charts, maps, and check cockpit instruments to ensure that proper flight procedures are safely followed. In addition, pilots are also exposed to physical and physiological forces that affect visual function in the cockpit environment.

According to Dr. Van B. Nakagawara, the FAA's vision research team lead, "Pilots must make quick decisions based on visual cues. The seriousness of these decisions underscores the importance of the work done by CAMI's Vision Research Team. Our work helps the FAA and the aviation community not only understand how current and emerging vision procedures, technologies, and devices affect the ability of a pilot to fly safely, but also helps to educate pilots on the importance of maintaining optimum visual performance in the aviation environment."

Currently, more than 50 percent of civil pilots use some form of visual correction to meet aeromedical certification standards. However, a single correcting device may not be practical for all aviation activities. The types of ophthalmic devices needed are often determined by the flight activities being performed. For example:

- Aerobatic pilots may be advised to wear soft contact lenses, since they are not as easily dislodged as rigid lenses.
- Monocular aviators should wear eye protection devices, since they can receive ocular trauma from flying objects in the cockpit during turbulence or aerobatic maneuvers.
- Pilots should not wear monovision contact lenses, since they reduce stereopsis (binocular depth perception) and distant visual acuity.
- Presbyopic airmen who wear contact lenses should be fitted with lenses for distant vision and prescribed eye glasses to correct for near vision.
- Airmen should not wear opaque or translucent colored contact lenses, because they may affect peripheral vision of the pilot, especially at dusk and at night.
- Since color vision is important, pilots should avoid using lenses with dark tints and tints that distort color vision.

Sometimes, the corrective devices themselves can cause problems for aviation personnel. In fact, NTSB and FAA databases identified 15 mishaps in which factors such as lost/broken eyeglasses, problems with sunglasses, eyeglass incompatibility with personal protective breathing equipment, adaptation difficulties, inappropriate ophthalmic prescriptions and contact lenses were contributing factors in aviation accidents or incidents. The review and reporting of these mishaps and self-reported operational problems provide important information that the FAA uses to educate flight crewmembers, aviation medical examiners, and eye care practitioners and to make recommendations that can assist pilots in avoiding similar hazardous situations and enhance aviation safety.

In some cases, new devices and procedures may improve visual acuity in a clinical setting but can reduce visual performance when exposed to aviation environmental stressors. For example, the vision research team undertook a study of laser eye surgery and its potential impact on pilots. In an educational brochure published upon completion of that research, the FAA cautioned that "aviators considering laser surgery should know that clinical trials claiming success rates of 90 percent or higher are based on criteria of 20/40 or better, not 20/20 or better, uncorrected visual acuity."

Researchers also identified complications of the surgery that could affect civilian pilots such as: a long healing period; pain; glare/halos/starburst aberrations; under/over-correction; recurrence of myopia; increased intraocular pressure; corneal haze; scarring; cataracts; reduced best corrected visual acuity; and reduced acuity in low light. As a result of this study, the FAA decided to consider applicants who have had laser eye surgery only after they are fully healed and stabilized, provided there are no complications and all other visual standards are met. The Agency advised pilots, however, that potential employers, such as commercial airlines and private companies, might have policies that consider refractive surgery a disqualifying condition. Also, civilian pilots who wish to fly military aircraft (Army, Air Force, or Naval Reserves) should know that, in most cases, the military does not allow its pilots to have refractive surgery. For more detailed information about these and other possible concerns about refractive surgery, please see *Laser Eye Surgery: Will It Fly?* (online at: http://www.cami.jccbi.gov/aam-400A/Brochures/Laser_eye.htm.)

In another recent study, the vision team examined the effects of glare. Glare is a temporary visual sensation produced by brightness within the visual field that is significantly greater than that to which eyes are adapted. Intense glare from natural and artificial light sources may result in temporary impairment, greatly increasing the risk of an accident. The team identified 130 accidents between 1988 and 1998 in which natural glare was a contributing factor. The majority of these accidents occurred during clear weather and atmospheric conditions and were associated with approach/landing and takeoff/departure phases of flight. The researchers also discovered that many of these accidents happened during flight maneuvers at low altitude in airspace congested with other aircraft or obstacles, such as trees, power lines, utility poles, and terrain.

According to Dr. Nakagawara, "the team also identifies new vision-related concerns and assesses their potential

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Classification System- *continued from page 7*

data in aviation accidents and incidents and for revealing previously unknown human-error trends. (See: *A Human Error Analysis of General Aviation Controlled Flight into Terrain Accidents Occurring Between 1990-1998* on-line at www.hf.faa.gov/docs/508/docs/cami/0304.pdf; *A Human Error Analysis of Commercial Aviation Accidents Using the Human Factors Analysis and Classification System (HFACS)* on-line at www.hf.faa.gov/docs/cami/0103.pdf; and *The Human Factors Analysis and Classification - HFACS* on-line at www.hf.faa.gov/docs/508/docs/cami/00_07.pdf

The U.S. military and international military and civil aviation organizations are now employing HFACS to investigate and/or analyze data from hundreds of aviation accidents. In addition, HFACS is being tested by a commercial airline under a 3-year grant funded by the FAA. Investigators are using this tool to look beyond the actions of individuals and consider critical preconditions, such as the role of supervisors and the role of organizations in the error process. As a result, safety risks in diverse activities, such as flight operations, air traffic control, and aircraft maintenance, are being addressed.

Drs. Shappell and Wiegmann have been recognized internationally for their ground-breaking work. In July 2003, the Aerospace Medical Association honored them with the Harry G. Moseley Award for outstanding contributions to flight safety. In November 2002, they received the Admiral Luís de Florez Flight Safety Award from the Flight Safety Foundation for their work on HFACS.

For additional information on HFACS, please contact Dr. Scott Shappell via email at scott.shappell@faa.gov. ■

Forensic Toxicology

Improving Accident Investigations

CAMI's medical researchers play a unique and critical role in accident investigations. Working closely with Aviation Accident Investigation and the NTSB, the FAA's forensic toxicologists are involved in the investigation of every aviation accident, as well as major highway, railroad, and boating accidents. As the aviation community's only Forensic Toxicology team, they work with the accident investigation team to detect and identify the presence of drugs and poisons in bodily fluids and tissues.

In 1990, CAMI received approximately 73 percent of the accident samples; however, by the year 2000, this percentage was up to 92 percent. This increase in the number of forensic toxicology cases is the result of the development of a successful and professional relationship between CAMI researchers, NTSB, and FAA Regional Flight Surgeons.

Forensic toxicology is a discipline of forensic science concerned with the study of toxic substances or poisons that are harmful to human beings, of which there are many thousands. "FAA's toxicologists are concerned with identifying toxins, determining how toxins act within the body and when their harmful effects occur, what are the symptoms of various toxins, and how those toxins and symptoms affect the ability of pilots to fly their aircraft," explains Dr. Dennis Canfield, Manager, Bioaeronautical Sciences Research Laboratory. "Aviation forensic toxicology is a unique medical field, encompassing theoretical considerations, methods and procedures from many disciplines including analytical chemistry, biochemistry, molecular biology, epidemiology, pharmacodynamics, pathology, and physiology."

In aviation accident investigations, researchers analyze post-mortem specimens from the pilots for legal and illegal drugs. Since 1990, the FAA's forensic toxicologists have received biological samples from all pilots involved in fatal commercial accidents and the majority of all general aviation accidents. Failure to receive samples from the remaining accidents is generally attributed to (1) unrecoverable pilot remains from accident sites, (2) the religious belief of the deceased pilot's family against autopsy and postmortem analysis, and/or (3) a decision not to seek forensic toxicology results.

Typically, when a fatal aviation accident occurs, NTSB investigators, who make the final decision on the submittal of specimens for analysis, send biological samples from the pilot and/or copilot to CAMI for toxicological analysis. The specimens, coordinated through the FAA's Office of Accident Investigation and the local coroner/medical examiner offices, are shipped in TOX-BOX evidence containers. Normally, only those specimens from the crewmembers are examined for the presence of drugs and alcohol. However, in some cases when there is a fire, researchers examine specimens from passengers (if available) for carboxyhemoglobin and cyanide to determine if they were exposed to fire or combustion gases.

Specimens are carefully inventoried to account for every piece of evidence received from an aviation accident. Detailed reports ensure that scientists account for every drop of sample used from a case. All batches submitted for analysis contain a blind positive control and a blind negative control to monitor test results. Further security measures prohibit analysts from accessing the receiving area. And to maintain legal chain of custody requirements for evidence in the case of litigation, three levels of security are in place to ensure the integrity of the test results.

Upon receiving the biological specimens, FAA's forensic toxicology researchers detect and measure drugs, alcohol, toxic gases, and toxic industrial chemicals to determine if and how these may have contributed to the accident. They also study the conditions that affect the accuracy and validity of these measurements and adapt or develop improved methods for making such measurements. Clinical chemical

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Cabin Evacuations

Egress Study Identifies Need for Improved Emergency Procedure

While FAA researchers located at the William J. Hughes Technical Center are making huge strides in designing a Fireproof Cabin of the Future (see Summer 2003 issue), their counterparts at CAMI are also enhancing aircraft safety by improving cabin evacuation procedures and requirements. In the event of an aviation accident where a crash occurs, time is a crucial element. "Evacuations take precious time - when seconds can mean the difference between life and death," explains Dr. Garnet A. "Mac" McLean, Team Leader, CAMI Cabin Safety Research Team. "Thus, understanding the factors that slow emergency evacuation is vital to passenger safety and survival."

Evacuation research provides valuable information about the problems and difficulties of removing passengers and crew from a particular aircraft in an emergency. "The performance of crew under the stress of evacuating and the effects of physical and behavioral constraints on passengers can only be measured and evaluated in a real-life setting," states Dr. McLean. "Factors, such as door size, aisle width, exit sill height, seating configuration, exit location and operation, exit marking, and galley location can all contribute to delays in evacuating passengers. Such factors may not be captured by a computer model."

In August 2002, the FAA released a report containing the results of the research team's latest and largest evacuation study. This study took over 3 months of intense effort and involved 2,544 inexperienced participants who met various health and human protection requirements.

The team used a narrow-body transport airplane simulator equipped with a Type-III overwing exit for the test, which focused on evacuation efficiency related to passageways configured at 6, 10, 13, or 20 inches in width. The test also gauged evacuation times relative to removal and placement of the exit door, i.e., whether it was placed in the adjacent seat or thrown

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Personnel Selection - *continued from page 11*

technologies are introduced," explains Dr. Dana Broach, of CAMI's Selection and Validation Research Team. "For example, historically the FAA trained air traffic controllers to use distance-based traffic management techniques, but Free Flight Phase I is introducing time-based traffic management, which may involve different skill sets for controllers. This may be a challenging time for personnel selection as new technologies are being introduced, but older technologies are still in place, some not to be phased out for at least another 8 to 10 years."

CAMI's human factors researchers are prepared to meet this challenge head on. Current research is focusing on: the validation and enhancement of existing, near-term selection procedures for mission-critical occupations; the continued development, refinement, and validation of a methodology for identifying gaps between current and future knowledge, skill, and ability requirements; and the research and development requirements for the next-generation selection tools needed to support long-term hiring requirements. As a result, CAMI researchers have committed themselves to a number of research projects designed to aid human capital planning.

For example, researchers developed a prototype statistical tool to estimate the average number of employees that are likely to be lost annually through retirement or attrition, based on historical separations data. This tool, the Statistical Retirements and Attritions Model (SCRAM), will be integrated into an Office 97® compatible desktop application and will utilize historical data concerning retirements, separations, and promotions out of key workforces to build a forecast of future retirements and attrition.

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Forensic Toxicology- *continued from page 16*

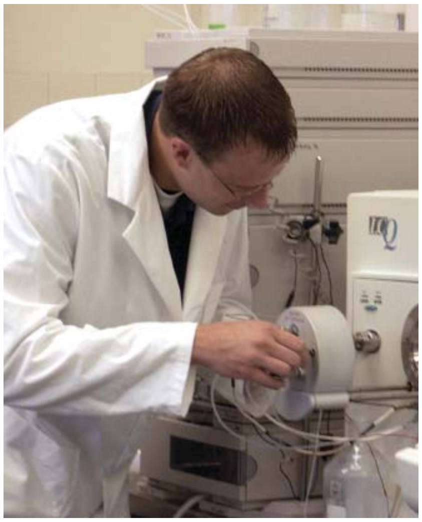
measurements are made and analyzed to determine significant health trends in aviation personnel, and additional analytical services support other CAMI research tasks.

After carefully reviewing analytical findings, toxicology reports are sent to the NTSB, FAA's Office of Accident Investigation, and other authorized agencies, such as coroners, medical examiners, and law enforcement agencies. However, CAMI maintains the case-related records and analytical data. Unless there is pending litigation, specimens of negative and positive cases are properly destroyed after 2 and 5 years, respectively, from the date of their receipt at CAMI.

Each aviation accident is different, and so is the postmortem toxicology of the accident-associated fatalities. Accurate sample analysis depends greatly on the availability and amount, as well as the number and concentration of analytes. Analytes are chemical, bacterial and biological substances, such as caffeine, e. coli, and glucose respectively, that researchers can analytically measure and test.

Depending upon the distribution characteristics of certain drugs, appreciable amounts may be present in some body parts, but not in others. Urine, for example, is generally an appropriate matrix for finding drug metabolites. Metabolites are breakdown substances from an original substance that occur through the process of metabolism. Often, it is the metabolites of a drug that researchers test for in the forensic examination rather than the original drug. Because the original drug does not completely come through the body unchanged, the rate of absorption is influenced by a variety of factors, including height, weight and frequency of use.

During all forensic toxicological evaluations, researchers test for alcohol consumption. Until recently, however, toxicologists had difficulty determining if the ethanol present in the body was the result of alcoholic beverages (ethanol is the main component of all alcoholic drinks), or the result of normal postmortem ethanol formation in the body as a natural fermentation process. There is no difference between consumed ethanol and postmortem ethanol. Therefore, toxicologists use known distribution of ethanol in the body to determine the origin of the ethanol present in forensic samples. CAMI's Forensic Toxicology Research Team, however, recently discovered a key to more accurately determining the origin of ethanol and can now predict pre-death alcohol consumption.



CAMI's forensic toxicologists are setting the standards for their profession. In May of this year, CAMI's Bioaeronautical Sciences Research Laboratory, under the Aerospace Medical Research Division, completed its College of American Pathologists Inspection. The inspection process included a complete in-depth review of the processes, procedures, and capabilities of the Forensic Toxicology Research and Biochemistry Research/Bioinformatics Research Support functions within the Laboratory. The inspectors, impressed with the program and its scientists, reported, "This is an excellent forensic laboratory." For the second year in a row, the inspectors gave the laboratory an "Outstanding Rating with Distinction."

Through the FAA's role in toxicology and other biomedical research, the aviation community is broadening its understanding of biomedical, toxicological, and human performance factors in accidents. The FAA, in conjunction with the NTSB, uses this

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research to: reduce accidents and major incidents caused by drugs and alcohol by understanding their impact on human performance; identify medical conditions present in fatal aviation accidents and determine the effectiveness of present medical certification standards; notify the FAA and NTSB of possibly incapacitating medical conditions not reported in the pilots medical that may have caused an accident; and provide regulatory authorities and the public with up-to-date information on the effects of drugs on pilot performance and the effectiveness of present and proposed medical certification standards.

For additional information on Forensic Toxicology, please contact Dr.. Dennis V. Canfield at dennis.canfield@faa.gov. ■

Personnel Selection - *continued from page 17*

Other research in support of agency human capital planning focuses on building baseline descriptions of mission-critical occupations and then analyzing the impact of specific technology programs and operations concepts on knowledge, skill, and ability requirements in those occupations. For example, CAMI researchers directed a formal, comprehensive baseline job/task analysis for the Airway Facilities systems specialist occupation. At the same time, CAMI collaborated with a contractor to evaluate changes in the baseline skill and knowledge requirements arising from broad changes in electronics such as the increasing density and modularization of components, embedded software, and remote monitoring, diagnosis, and configuration. The CAMI research team began work in 2003 at the request of Air Traffic Services to establish a baseline description of work performed by computer specialists, an increasingly important workforce both in NAS operations and administration of the FAA.

CAMI researchers actively collaborate with scientists at leading universities throughout the nation. For example, CAMI provided archival data on air traffic controllers to personnel selection researchers and students at the University of Oklahoma and Louisiana State University under a cooperative agreement. The university researchers and students analyzed the data with cutting-edge statistical techniques, resulting in an innovative state-of-the-art approach to evaluating an air traffic control applicant's background and experience that balances fairness with predictive validity. The work was recognized as outstanding in an award from the International Personnel Management Association Assessment Council to the lead researcher. CAMI research tools such as the single-sector and multi-sector versions of the Controller Teamwork Evaluation and Assessment Microworld (CTEAM), a low-fidelity simulation of radar-based air traffic control tasks, are being used by researchers and graduate students at several universities in investigations of topics such as individual differences and expertise.

CAMI research psychologists also collaborate with aviation psychologists around the world as well. For example, Dr. Broach co-edited the first book ever devoted solely to the topic of air traffic controller selection with Dr. Michael Heil, a former CAMI scientist, and Mr. Hinnerk Eissfeldt of the German Aerospace Research Establishment (DLR). Researchers and practitioners from Italy, the Netherlands, Germany, Eurocontrol, and the USA contributed chapters on topics such as ability requirements, cognitive selection tests, personality measures, and workforce planning.

Through the development of new selection tools, the FAA will be able to accurately, fairly, and reliably assess job applicants for success potential and streamline the hiring process. The ability to aptly pinpoint desirable traits in applicants will also enable the FAA to hire the most competent and capable air traffic controllers and airway facilities systems specialists in an ever-changing NAS.

Additional information on past and current research tasks and accomplishments is available from the CAMI website (http://www.cami.jccbi.gov/aam-500/selection.html). For further details, please contact Dr. Dana Broach at dana.broach@faa.gov or Dr. Raymond King at raymond.king@faa.gov. ■

Cabin Evacuation - *continued from page 17*

outside the exit. Researchers placed participants in groups of 30, 50, or 70 to identify group size effects on egress. To understand better how motivation affects speed of egress, they also monetarily rewarded participants whose average egress times were in the top 25 percent of all subjects.

The results of the first evacuation for each group revealed that hatch disposal location slowed egress in some access aisle width configurations but not in others. These findings are consistent with prior research showing that passageway configuration has only minimal effects on emergency egress as long as ergonomic minimums involving passageway configuration are respected.

In contrast, differences in the physical characteristics of the participants produced large differences in egress performance. For example, subject waist size proved to be the most significant predictor of individual egress time, with gender, age, and height, respectively, as the next most significant predictors of subject evacuation times. Group size did not create significant differences in individual evacuation times.

Differences in group motivation levels also did not produce much effect on egress times, as the more highly motivated groups did not exhibit extreme behavioral intensity. This appeared to result from verbal cues given by flight attendants that helped adjust participant behavior at the exit to produce less pushing and jamming. In contrast to prior studies, where the monetary reward resulted in more chaotic behavior that ultimately slowed evacuation times, subject egress times appeared to decrease with the possibility of a monetary reward.

Of great interest was the extent to which passenger preparedness greatly affects egress. In fact, 35 to 40 percent of the total time variances in the study occurred as a result of subject procedural and behavioral inconsistencies due to a lack of experience and egress skill. This underscores the need to improve and develop more effective education and training materials for aircraft passengers. Passengers that are better educated in emergency preparedness will evacuate more efficiently - and that means increased survivability.

This and other egress studies are helping the FAA to validate aircraft evacuation procedures and, when necessary, to establish new egress requirements. For additional information, please contact Dr. McLean via email at mac.mclean@faa.gov. ■

Study results can be found in *Access-To-Egress I: Interactive Effects of Factors That Control the Emergency Evacuation of Naïve Passengers Through the Transport Airplane Type-III Overwing Exit.* This report is available online at www.cami.jccbi.gov/AAM-400a/Abstracts/2002TechRep.htm.

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Pilot Vision - *continued from page 15*

impact on the aviation community. For example, low-powered lasers, often used by instructors as pointers during presentations, may adversely impact a pilot's vision when used improperly." There are a number of reported cases in which lasers pointed directly into the path of aircraft caused ocular effects such as flash-blindness, afterimage, and glare. Individuals exposed to the beams from pointers can be subject to such effects which could lead to temporary vision dysfunction and cause possible physical dangers if the exposed person is engaged in a vision-critical activity such as driving, flying or operating machinery.

Often pilots ask vision-related questions that cannot be adequately addressed with the available knowledge base. When such questions arise, the vision researchers develop and conduct an appropriate research project, using state-of-the-art ophthalmic equipment and research subjects to answer difficult questions and make recommendations that may impact certification and regulatory decisions. To leverage limited resources, they also work collaboratively with other government agencies, universities, and industry.

The Agency's vision research team also continually monitors the fields of optometry and ophthalmology to stay abreast of the latest advances in corrective devices and procedures. This includes reviewing current research, reports and journals, as well as attending vision science meetings. With knowledge of current developments, the team advises FAA regulatory officials, air traffic control personnel, pilots, and aviation medical examiners when questions concerning vision and the aviation environment arise.

In addition to scientific research, periodically the researchers update demographic and vision-related statistics to better understand and anticipate the vision-related needs of aviators and air traffic control specialists. Many airmen use optometric devices or have had procedures performed to correct their vision and fly with medical restrictions or waivers.

Epidemiological data is used to determine the incidence and prevalence of specific ophthalmic conditions or type of corrective devices and examine past and future trends in the civil airman population. This information can then be used as a guide for conducting clinical studies to examine the relative risk of aviation accidents or incidents for various subsets of the civil airman population.

The FAA's vision research team, comprised of Van Nakagawara, Kathryn Wood, and Ron Montgomery, ensures optimum safety by studying all aspects of visual performance in the aerospace environment. This includes, but is not limited to, visual acuity, contact lenses in aviation, visual perception, vision standards, eye protection, and other specialized vision enhancement procedures. And, this team serves the Agency as an advisory resource in areas relating to ophthalmic factors affecting aviation safety. Current research includes:

- supporting the airman medical certification process,
- assessing the impact of corrective devices and techniques available on the market,
- evaluating the effects of aging and chronic disease as they relate to airman visual performance, and
- promoting suitable vision screening procedures by evaluating newly emergent techniques for the assessment of visual performance and their applicability to aviation.

FAA's researchers share their research with the aviation community through articles published in the Federal Air Surgeon's Medical Bulletin (www.cami.jccbi.gov/AAM-400A/FASMB.html), Office of Aerospace Medicine Reports (www.cami.jccbi.gov), aviation, scientific and professional journals, and educational brochures. ■

AGARS and BGARS

Top Notch Simulators

National Transportation Board safety statistics show that over 1,700 general aviation accidents occurred in the United States last year. In fact, the accident rate for general aviation aircraft increased slightly from 6.28 per 100,000 flight hours in 2001 to 6.56 in 2002. To help reduce this accident rate, the FAA is taking a multi-faceted approach to enhancing general aviation safety.

As part of this effort, CAMI researchers in the Human Factors Research Laboratory are investigating the factors and conditions that may affect general aviation pilot performance. "Assessing human performance and understanding the performance and safety benefits of advanced aviation systems, displays, and controls for general aviation pilots is critical to reducing the accident rate," explains Dr. Dennis

Beringer, CAMI's Team Leader for flight-crew performance research. "That is why we are studying the potential positive and negative affects of things such as advanced flight controls (performance-controlled and fuzzy-logic systems) and advanced integrated flight displays (highway-in-the-sky primary flight displays, terrain-depicting primary flight displays, head-up displays, head-referenced displays) on pilot performance."

With accident reduction as a primary goal, CAMI's researchers use state-of-the-art simulators to replicate real-time flying situations. These simulators collect empirical data that is used to quantify, analyze, and predict the performance of general aviation pilots. One simulator, the Advanced General Aviation Research Simulator (AGARS), allows researchers to reconfigure cockpit panels and consoles to support human factors studies on current aircraft displays. It also enhances the ability to study various innovative future display and control layouts. Researchers use the data from these and other tests to identify affordable intiatives for enhancing pilot performance, which, ultimately reduces the number and severity of accidents and incidents in the general aviation community.

This high-fidelity, reconfigurable flight deck simulator can also replicate the complex interactions of environment, hardware, communications, crew resource management, situational awareness, and risk variables in simulated general aviation flight protocols. The simulator's design allows it to be reconfigured quickly for multi-engine and multi-crew applications, such as a turboprop or business jet. The classes of aircraft and aircraft systems that may be simulated through reconfiguration include:

- Class I: Non-complex aircraft (Cessna 172 Skyhawk currently available);
- Class II: High performance, complex, single engine aircraft with pressurization (Piper PA-46 Malibu currently available);
- Class III: Twin engine reciprocating or turbo-prop aircraft;
- Class IV: Turbojet aircraft (Learjet 35; Cessna Citation V); and
- Class V: Advanced Aircraft Cockpit Concepts, such as innovative glass cockpit displays, controls, sensors, system integration, software, communications, and navigation.

The AGARS simulator is configured for interfacing with a number of peripheral displays, and the cockpit is equipped with a true pull-down head-up display that has been used to examine the use of perspective-view guidance imagery. A 12-inch liquidcrystal display is also available, on which numerous cockpit displays such as weather/NEXRAD, moving map, and electronic flight bag have been depicted for evaluations. A head-based stereoptic display can also be interfaced with either simulator that is being used to evaluate means of presenting perspective guidance and/or terrain data unconstrained by the limits of panel-mounted or head-up displays.

The simulator out-the-window view is provided by a high-fidelity visual system with a 150 degree-wide field-of-view, capable of both day- and night-time views, with taxiway and full weather and ground environment control. The visual system also permits variations in runway lighting, airport and terrain characteristics, and atmospheric conditions, all of which can influence the pilot's decision making and flight performance while en route and during visual approach and landing maneuvers.

A recent modification to the simulator allows out-the-window presentation of controllable thunderstorm cells that can be correlated with in-cockpit displays of weather data. Traffic visible in the out-the-window scene is controlled by scenario generation software, allowing the viewed aircraft's behaviors to be either preset, triggered by actions of the simulator, modified by the test conductor as conditions warrant, or any combination thereof. Graphical editing allows scripted flight paths to be reviewed and modified easily.

"We must get in front of accidents … anticipate them …and use hard data to detect problems and disturbing trends."

-- FAA Administrator Marion Blakey, August 26, 2003

The visual database currently provides for line-oriented flight from Oklahoma City to Albuquerque, New Mexico, via Amarillo, Texas. All intervening airports are provided within a 30-nautical mile band of U.S. Interstate-40. Highly accurate terrain information is provided for the three major airports, as well as for Oakland International at Oakland, California, which can be used when studying over-water approaches. The simulator provides simulated audio, in addition to the visuals, that gives the simulator a realistic feel, along with force feedback in the flight controls.

Several methods for collecting data are available, including on-line recording of controller and aircraft activities (digital; rates up to 30 samples per second; as many as 200 variables for several hours) and time-indexed pilot-controller (audio/video) communications. Pilots using the AGARS to test new equipment also have the benefit of being able to provide immediate feedback on the usability of a device. Not only is the AGARS equipped to interface with various external display systems and avionics (multi-function displays, GPS units, etc.), but it can also interface with other simulators, either at CAMI or located elsewhere, to permit joint simulation of major FAA research projects.

The Basic General Aviation Research Simulator (BGARS) is a PC-based flight simulator that uses medium-fidelity flight controls (Precision Flight Systems - Dual Professional Flight Console) and high-fidelity out-the-window views (Microsoft Flight Simulator 2002/2004). The simulator contains five out-the-window views spanning

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AGARS and BGARS - *continued from page 23*

a 225-degree field and can be interfaced with actual aircraft flight and navigation displays through a serial connection. Flight performance data can be recorded at up to 5 times per second for several hours and can consist of any of over 200 flight performance and aircraft status variables. Throttle quadrants for both single and multi-engine aircraft can be installed in a few minutes. Aircraft configurations that are supported include any that are available with Microsoft Flight Simulator 2002/2004. The large out-the-window database allows flights anywhere in the world. In addition, experimenters can control weather and artificial traffic within the simulation and can introduce aircraft system failures using an experimenter station interfaced to the simulator. The BGARS system provides CAMI scientists with a stable aero-model medium-fidelity device for conducting rapid-response screening experiments and for examining questions involving the use of PC-based aviation training devices.

For additional information on the general aviation human factors research or on the research simulators, please contact Dr. Beringer at dennis.beringer@faa.gov. ■

Genes - *continued from page 3*

From left to right: Mark Huggins, Dr. Dennis V. Canfield, Dr. Nicole T. Vu, Dr. Hua Zhu, Dr. Edward D. Owuor

stand gene-level changes and the mechanisms that create adverse reactions in the body. Familiarity with such genetic-level reactions may allow scientists to develop biological mitigation techniques to prevent aircraft accidents and incidents.

Researchers are examining how drugs, alcohol, radiation, fatigue, stress, and a broad range of other environmental factors, affect gene expression. Examining the varying gene expression patterns is significant in clarifying how the body reacts to certain stressors. By understanding that reaction, researchers can take the steps necessary to enhance proactively aviation safety and performance in flight crew and air traffic controllers.

For example, among other projects, CAMI's functional genomics researchers are currently identifying target molecules of alcohol intoxication so they can develop strategies for prevention of performance impairment. They are also identifying the molecular networks that signal fatigue so they can identify the biomarkers of fatigue for accident investigation and prevention. This and other genetic groundbreaking research will help the FAA save countless future lives.

For additional information, please contact Dr. Nicole Vu at nicole.vu@faa.gov. ■