AEROSPACE TECHNOLOGY

innovation

NASA Office of Aerospace Technology | Volume 10, Number 5 | September/October 2002

Aerospace Technology + Innovation = Award

Various Innovations Earn Awards

Software of the Year Selected

SBIR-Developed Software Goes a Long Way

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Contents

About the Cover:
Bruce Banks (left) and Walter Hussey examine a Glenn Research Center technology that received a Space Act Award in 2002.

Online Edition: Go to *http://nctn.hq.nasa.gov* on the World Wide Web for current and past issues.

Aerospace Technology Innovation *is published bimonthly by the NASA Office of Aerospace Technology. Your feedback provides an important contribution to this publication.* ***To provide comments or input, or to be added to our regular distribution, please write to the Editor's Internet address listed above or the following postal address: Aerospace Technology Innovation, NASA, Code RC, 300 E Street SW, Washington, DC 20546.*** *Please provide your address, phone number and your industry classification. Material from this publication* ***MAY*** *be reproduced without the permission of the publisher.*

Commercial Development Mission Update

Flight	Payload	Sponsor/Coordinator
11A (STS-113)	SPD is flying one payload.	Zeolite Crystal Growth Samples (ZCG-S) are being flown by The Center for Advanced Microgravity Materials Processing (CAMMP)
ULF-1 (STS-114)	SPD is flying three payloads.	Advanced Astroculture™ (ADVASC) is being flown by the Wisconsin Center for Space Automation and Robotics (WCSAR). Commercial Protein Crystal Growth (CPCG) is being flown by the Center for Biophysical Sciences and Engineering (CBSE). Space Dynamically Responding Ultrasonic Matrix System (Space-DRUMS™) is being flown by the Center for Commercial Applications of Combustion in Space (CCACS).

Innovation… As Only NASA Can

By Walter Hussey
Director, Inventions and Contributions Board Staff

Innovation, the cornerstone of NASA's existence, was recognized by the Space Act of 1958 as a key to the success of the United States civilian space efforts. As they crafted the original charter for NASA, both our executive and legislative leaders wanted the space scientists and engineers—then all working on military rocketry—to contribute to civilian space programs. Also, the nation's leaders wanted the best and brightest of the US scientific and technical community—not just the rocket scientists—to work on catching up with the technical achievements represented by Sputnik.

In their wisdom, they gave NASA a unique tool to meet this challenge with the creation of the Inventions and Contributions Board (ICB), along with its authority to reward scientific and technical contributions to NASA aeronautical and space activities. With our resource environment and the challenges that NASA currently faces, this tool is every bit as important today as it was when first initiated more than 44 years ago, and it will provide welcome assistance to our ability for doing things "… as only NASA can." Through the efforts of the ICB, NASA is recognizing some truly valuable scientific and technical contributions to our mission from our partners in industry, academia and other government agencies, as well as NASA's own scientists and engineers (see the articles that follow for examples).

However, the challenges for NASA are not all in the past. NASA will need even more innovation to move forward to meet the goals set out in new programs such as the Space Launch Initiative (SLI), the Nuclear Systems Initiative (NSI) and the Human Exploration and Development of Space (HEDS) Technology and Commercialization Initiative (HCTI). The ICB is interested in using the Space Act Awards authority to increase incentives to satisfy the greater-than-ever need for innovations in NASA programs. In accordance with the President's Management Agenda, we are expanding the use of electronic government to enable user-friendly Web access for our innovators and awards personnel to input their award information, and we will automate much of the existing process that reviews and evaluates awards. These efforts will make the awards more timely, and thus more of an incentive to performance, as required by another of the President's Management Agenda initiatives—Strategic Management of Human Capital.

We are increasing awareness of Space Act Awards to further inspire contributions of science and technology to NASA's aeronautical and space activities. We will be providing more publicity for the awardees and for their science and technology innovations, as the widest dissemination of the technologies ensures the widest use of these technologies for the benefit of NASA programs and the nation.

The Space Act Awards program will provide a valuable contribution to NASA's mission of "… inspiring the next generation of explorers." Recently, during the Take Our Daughters to Work Day here at Headquarters, the ICB staff sponsored a workshop entitled "NASA Innovators." We were able, through video teleconferencing, to put the children in touch with two of our more prolific inventors, Dr. Ruth Pater and Dianne Stoakley of the Langley Research Center in Hampton, VA. The children were so energized and inspired by these inventors that at the end of each session, we had to almost literally kick the group out so another group could come in. As a result, each of the more than 175 children who participated had the opportunity to begin to think of themselves as future innovators working on space programs. These children will become our next generation of explorers by providing the innovations needed for all of us "to understand and protect our home planet, to explore the universe and search for life."

The Space Act Awards provide a tool that we will use to achieve even greater innovation in the future. If we expect "to improve life here, to extend life to there [and] to find life beyond," then we will need to continue and improve upon NASA's innovative history. Space Act Awards can be a part of the incentives to do that. It is the job of the ICB and the Space Act Awards program to recognize the benefit of these future innovations to NASA. I invite each of you, as you read the following articles, to think of your contribution or one that you might make, and initiate the process to apply for an award, either now or as a result of your future endeavors. ❑

Cover Story

Aerospace Technology + Innovation = Award

Ever had a good idea that you turned into a unique innovation that furthered NASA's space or aeronautical missions? Are you currently working on a project that will, in the future, make a scientific or technical contribution to NASA's civilian aerospace mission? If so, then you may be eligible for a Space Act Award. Also, according to Walter Hussey, director of the Inventions and Contributions Board (ICB) staff, "Past Space Act Awards recipients represent a tremendous inventory of innovation available to NASA researchers for use in current and future space and aeronautical programs." Dr. Robert Norwood, NASA's director of Commercial Technology, notes "many of these technologies are available to our industry partners for use by agreement with NASA." You can visit *http://icb.nasa.gov* to view recent exceptional-level technologies that have been recognized by Space Act Awards.

Applications for Space Act Awards are open to all, including NASA employees, NASA contractors, other government agency employees or contractors, as well as members of the public. Space Act Awards were established by Congress as part of the original National Aeronautics and Space Act of 1958 that created NASA. At that time, Congress wanted to encourage scientists and engineers, many of which were working on the military's programs, to contribute to the nation's new civilian space program. Congress knew that quick growth was needed in the technical talent available to catch up with the advanced technology achievements represented by the launch of the Soviet's Sputnik. According to Hussey, "As valuable as the Space Act Awards were in 1958, they are even more so now. NASA is being called on to meet a multitude of challenges with scarce resources. Only by increasing our innovation can we achieve what is expected of us, and we hope these Space Act Awards can make a major contribution toward inspiring this innovation." Having an inventory and publicizing available technologies and innovators is another goal of the ICB and the Space Act Awards program to assure the fullest possible value from the efforts of NASA's innovators.

Just what do you get when you get a Space Act Award? A Space Act Award is an individual personal monetary award, along with a certificate signed by either the Chair of the ICB, NASA's Chief Engineer Theron Bradley or by the Administrator,

From left, Ralph Jensen, Walter Hussey and Ray Beach discuss flywheel technology during Hussey's visit to Glenn Research Center. Photo courtesy of NASA Glenn Research Center.

Sean O'Keefe. The award recognizes a specific scientific or technical innovation that is of significant value to the aeronautical or space activities of NASA. One key requirement is that the government must have the right to use the innovation without additional charges or fees. For most of the NASA-funded efforts, this automatically conveys it with the funding for contracts, grants or partnerships. For others, this is one purpose of the award incentive, i.e., to recognize and award the contribution of the rights to the government.

Once they have verified that basic eligibility criteria have been met, the Board determines the amount of the award using Space Act criteria such as "… value to the United States." Congress gave NASA the authority to grant awards up to $100,000 for each innovation. Recent awards have ranged form $350 to more than $50,000 for some truly valuable contributions, such as the recent winners of the NASA Invention of the Year (see the May/June 2002 issue of *Innovation* magazine) and Software of the Year (see the March/April 2002 issue of *Innovation* magazine). Space Act awardees represent a large pool of valuable NASA technologies and, as such, are key sources of articles for each issue of this magazine. Dr. Paul Curto, senior technologist on the ICB staff, provides us with three other recent cases that have had significant value. "Dr. Ruth Pater of Langley has patented a new high-temperature, tough polyimide called RP-46. A number of NASA and commercial applications, such as airliner gearboxes and wingboxes, have adopted this lightweight material which could have many more uses in the future. In another case, engineers at Kennedy have found a novel way to extend the accurate detection range of some gas sensors by using a novel calibration technique. The result is that commercial off-the-shelf sensors can detect the presence of some gases down to the finer 10-ppm (parts per million) range, as opposed to the original coarser 1,000-ppm range. Scientists at the Jet Propulsion Laboratory, one of NASA's 10 Field Centers, have developed a two-photon microscope that combines imaging spectroscopy and fluorescent microscopy to create a revolutionary biology research tool for monitoring cellular metabolism, structures and protein expression."

Members of the ICB are prominent scientists and engineers from NASA who are recognized scientific and technical experts in their particular fields, and who represent a cross-section of the disciplines needed to evaluate the cases that come before the Board. Board members are selected by the Chair and are appointed by the Administrator for an initial three-year term. The Board meets approximately once every two months to review the cases.

In addition to cases that come before the Board for determination of value, the Board has previously determined a specific value for each of three discrete events. Awards for these events, known as initial awards, are available for disclosed innovations that are scientific and technical in nature, when NASA has filed a patent application or a NASA Center official has released software or approved an article for publication in *Tech Briefs* magazine.

Gail Sawyer, the ICB staff program specialist, notes, "This awards program differs from others, also, in that these awards originate at the Centers, where Award Liaison Officers (ALOs) certify and forward the award application to the ICB. There is no call for award nominations; we continuously receive the requests from the Center ALOs." There are no runners-up or losers in these awards either, as each case that qualifies is separately judged and awarded.

With more than 40 years of awards, there is a lot of innovation represented in the files of the ICB. According to Tracie Robinson, ICB staff secretary, "We have records on microfilm, in hard paper copy and in many forms of digitization as systems have evolved over the recent years. We will be making a major effort soon to convert these records to a current database that will be easily accessible to all researchers."

Future innovation of a greater magnitude and increasing the sharing and maximizing the usage of these innovations are absolutely essential to achieving NASA's vision of the future. As Hussey notes, "The Board believes that Space Act Awards are key incentive tools available to NASA that will enable us to meet our mission. The staff will use the awards process to seek to proactively add value to the efforts of NASA through increasing incentives to future innovation, as well as increasing awareness of technology already available to NASA programs."

Please visit the ICB Web site at *http://icb.nasa.gov* or contact an Awards Liaison Officer (contact information can be found at *http://icb.nasa.gov/alos.html*) at one of the NASA Centers to obtain more information on the Space Act Awards program, to see what innovations are available or to apply for an award.

Throughout this issue are several articles about innovations that are previous recipients of Space Act Awards.

Good luck in your future innovating for NASA and use of the technology you find available through these awards. ❑

Various Innovations Earn Awards

The innovations that earn Space Act Awards are varied. Awards have been received for innovations ranging from software to medical devices. Below are a few of the award winners for 2002.

Ames Research Center:

Comprehensive Toolset for Model-Based Health Monitoring and Diagnostics—Rick Alena, Jim Cockrell, Bill Hindson, Ann Patterson-Hine, Dwight Sanderfer and Julie Schonfeld of NASA Ames Research Center with Kevin Cavanaugh, Somnath Deb, Charles Domagala, Sudipto Ghoshal, Venkata Malepati, Venkatesulu Malepati, Krishna Pattipati and Roshan Shrestha of Qualtech Systems, Inc. developed software for designing and developing diagnostic applications such as those required in Integrated Vehicle Health Management systems. Three software tools that support systems engineering, systems design and testability, automated diagnostics and troubleshooting, and system autonomy have been developed during a seven-year collaboration between researchers at Ames and Qualtech. The three tools are: TEAMSTM 5.0, the Testability Engineering And Maintenance System, a tool used in static design/analysis phases of complex systems; TEAMS-RTTM, a real-time diagnostic engine that provides diagnostic functionality for integrated vehicle health systems onboard a flight vehicle or embedded into a run-time architecture; and RDSTM, the Remote Diagnosis Server, an application that can support multiple simultaneous diagnostic sessions from a variety of remote systems. Programs that will benefit from this technology include commercial and military aviation, advanced transportation systems, space shuttles, the International Space Station and robotic and autonomous explorers.

Method and System for an Automated Tool for En-Route Traffic Controllers (Direct-To)—This tool is based on the trajectory analysis methodology and software resident in the Center/TRACON Automation System (CTAS). In today's air traffic control system, aircraft fly on fixed airways, and air traffic controllers maintain aircraft separation by visual monitoring of radar position, heading and altitude information. The fixed airway structure and the lack of automation for radar controllers result in inefficient routings and air traffic control operations. The Direct-To tool continuously and automatically analyzes all aircraft routings to identify those aircraft that can save time by flying directly to a downstream fix on their route of flight. Direct-To displays route advisories, critical aircraft separation information and other information that helps controllers determine when direct routes are possible given current traffic conditions, allowing controllers to quickly assess route and altitude options without being distracted from their primary responsibility for safe aircraft separation. Those honored with this award include Danny Chiu, Heinz Erzberger, David McNally and Philippe Stassart of Ames.

Glenn Research Center:

Hydroformed Ion Optics and Spall-Resistant Woven Screen Surfaces for Ion Thrusters—Bruce Banks developed this contribution that consists of the conception and development of two technologies which solved problems that had been inhibiting the functional application of ion thrusters on spacecraft. The technologies addressed performance and durability issues critical to the successful use of ion thrusters. The technologies consist of a process for the fabrication of hydroformed ion thruster optics and spall-resistant surfaces for the prevention of the formation of large, sputtered flake particles. Both technologies were conceived, developed, patented and successfully demonstrated on the ion thruster in the Deep Space I mission, as well as being functionally used on 18 commercial communication spacecraft.

Microgravity Analysis Software System (MASS)—MASS primarily supports the NASA Biological and Physical Research Enterprise in the mission to "use the space environment as a laboratory to test the fundamental principles of physics, chemistry and biology." MASS adds value to all space experiments by documenting the conditions of the laboratory. MASS results allow the PIMS (Principal Investigator Microgravity Services) project to provide expertise to experimenters in the areas of microgravity experiment requirements, vibration isolation and the implementation of requirements for different spacecraft. MASS also supports the NASA Human Exploration and Development of Space Enterprise mission of "enabling humans to live and work permanently in space."

Boeing and NASA Johnson Space Center engineers use MASS results to analyze ISS structural modes of vibration, improving the ISS.

MASS is a runner-up for the Software of the Year award for 2002. It was developed by Kevin McPherson and Ted Wright of Glenn and Ken Hrovat, Eric Kelly, Gene Liberman, Nissim Lugasy and Tim Reckart of ZIN Technologies.

MASS supports research with NASA-specific goals, including projects in the science disciplines of biotechnology, combustion, fluid physics, fundamental physics and material science; the study of ISS vehicle dynamics and spacecraft fire safety; and the microgravity measurement programs: SAMS, SAMS-II, SAMS-FF, MAMS, OARE, MEL ISS active rack isolation system (ARIS).

The NASA Government Invention of the Year—Michael Patterson, Tim Verhey and George Soulas invented a hollow cathode assembly that is the primary component of the International Space Station's plasma contactor system. This mission-critical system protects the station and its crew from the dangers associated with electrical charges.

As the ISS floats through space in low-Earth orbit, the surface of the structure builds up a static high-voltage charge. The plasma contactor system safely grounds the station from this high voltage, protecting it from arcing that could severely damage its surface. This device is unique in that it reduces the static charge in a self-regulating manner to levels safe enough for astronaut space walks.

The technology was developed from a laboratory device to flight-qualified hardware at Glenn. The innovators then manufactured the space flight hardware for the orbiting research platform. Their efforts increased hollow cathodes lifetimes with inert gases from 500 to 28,000 hours, which enables their use on ion thrusters, a key propulsion tech-nology for NASA spacecraft missions such as Deep Space 1.

Continued on page 10

"Space Vision" goggles developed by Dr. Rafat Ansari could someday be used to remotely monitor eye health. Photo courtesy of NASA Glenn Research Center.

Software of the Year Selected

NASA has selected two software innovations that save significant money and time over more traditional methods as co-winners of its 2002 Software of the Year Award. Each team of developers will receive an award of $50,100 from the NASA Administrator. Other government agencies, private industry and academia have adopted both software design tools.

The DSMC Analysis Code (DAC) software package, developed at NASA Johnson Space Center in Houston, models the flow of low-density gases over flight surfaces. DSMC stands for Direct Simulation Monte-Carlo and is a simulation method. The software provides insight into the interaction of spacecraft and rarified environments, such as those encountered during a spacecraft entry into an atmosphere at high altitudes.

DAC was used to provide information to help optimize and verify maneuvers of spacecraft that orbited Mars after they were slowed by repeatedly skimming through that planet's atmosphere (also called aerobraking), instead of relying on thrusters for deceleration. The technique allowed the spacecraft to be lighter, reducing launch costs.

Another application is analysis of plume impingement—the effects of firing thrusters by one spacecraft on another spacecraft nearby. An early use of the software was analyzing the effect of space shuttle thruster firings as the vehicle approached the Russian space station Mir during the Shuttle-Mir program. This has led to significant changes in docking procedures and venting operations aboard the International Space Station.

DAC is in use at most NASA Centers and within the US military, and is beginning to be employed by the aerospace industry for advanced applications involving high-altitude vehicles. In addition, the unique flow-solvers adapted to DAC allow the software's use in applications in which the object within the flow field is very small, such as MEMS (micro-electromechanical systems) and nanotechnology devices.

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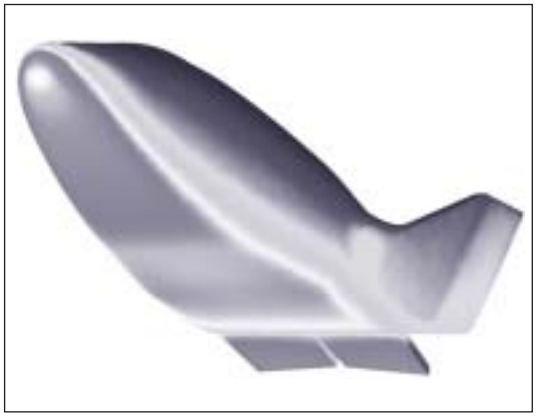

The DAC software has been used to predict the aerodynamic characteristics of the X-38 in the transitional regime and the significant increments associated with interaction of its ACS thrusters and the oncoming freestream. Artwork courtesy of Johnson Space Center.

The DAC team is led by Gerald J. LeBeau and includes Forrest E. Lumpkin, Katie A. Jacikas and Phil C. Stuart of Johnson, and Richard G. Wilmoth and Christopher E. Glass of NASA Langley Research Center in Hampton, VA.

The NASA Software of the Year co-winner, Cart3D, is an aerodynamic simulation tool on which work began in 1992 at NASA Ames Research Center in Moffett Field, CA. This software package provides designers and engineers with an automated, highly accurate computer-simulation suite that streamlines the conceptual and preliminary analysis of new and existing aerospace vehicles.

Cart3D provides a revolutionary approach to computational fluid dynamics—the computer simulation of how fluids and gases flow around an object. Before the advent of this software, the basic computational tool, the grid layout used in analyzing designs of airplanes and spacecraft, had to be hand-generated and required months or even years to produce for complex models. Cart3D automates grid generation to a remarkable degree, enabling even the most complex geometries to be modeled 100 times faster than before.

Simulations generated by Cart3D help identify and fix problems in military transport aircraft and

helicopters. Cart3D's novel approaches allow simulation of complex geometries in fields other than aerospace, ranging from astrophysics to computer science, to electromagnetics. The software is in wide use by universities and corporations, as well as most NASA Centers and other government agencies, for a plethora of applications.

Cart3D was developed jointly by Michael Aftosmis and John Melton of Ames, and Professor Marsha Berger of the Courant Institute, New York University.

Each year, the NASA Chief Engineer sponsors the NASA Software of the Year competition, an international competition for the largest award for software excellence, with technical support from the agency's Inventions and Contributions Board. The Software of the Year Award is one of the Space Act Awards.

More information about the winners may be found at *http://icb.nasa.gov/swoy2002/* ❑

For more information, contact John Ira Petty at Johnson Space Center, ✆ 281/483-5111 or Victoria Steiner at Ames Research Center, ✆ 650/604-9000. Please mention you read about it in Innovation.

Glenn Innovations Win Award

Art restoration and computer simulation may not be the first things that come to mind when aerospace research is mentioned, but work conducted at NASA Glenn Research Center, Cleveland, is changing these perceptions. This year, Glenn is the recipient of two prestigious R&D 100 Awards, presented annually by *R&D Magazine* to the year's 100 most technologically significant new products.

Numerical Propulsion System Simulation (NPSS), a propulsion system simulation software program, and an art restoration technique using atomic oxygen are Glenn's winners for 2002.

NPSS is a world-class propulsion system simulation tool that provides users with unprecedented capability and ease of use. NPSS is an emerging US standard for aerospace simulations and is built and maintained with the full interaction of every major aircraft engine manufacturer in the US. The program was a Software of the Year Award winner in 2001.

NPSS provides NASA and the US aerospace industry with a revolutionary engineering capability that will reduce the cost and risk associated with advanced propulsion system development. The reduced risk translates into increased safety for aeronautics and the human exploration of space.

Cynthia Gutierrez Naiman, Glenn's NPSS team lead, worked with a team of 39 engineers from Glenn and other organizations including Analex, Cleveland, OH; Arnold Engineering Development Center, Arnold AFB, TN; The Boeing Company, Seattle, WA; General Electric Aircraft Engines, Cincinnati, OH; Honeywell, Phoenix, AZ; Integral Systems Inc., Cleveland, OH; Modern Technologies Corp., Middleburg Hts., OH; Pratt & Whitney, East Hartford, CT; Rolls Royce Co., Indianapolis, IN; RS Information Systems Inc., Cleveland, OH; Teledyne Continental Motors—Turbine Engines, Toledo, OH; Williams International, Walled Lake, MI; Wright Patterson Air Force Base, Dayton, OH; and ZIN Technologies, Cleveland, OH.

The second award-winning technology involves removal of organic and carbon contaminants from the surfaces of paintings and other art objects by means of low-energy atomic oxygen. Atomic oxygen, which can be produced in a vacuum or at atmospheric pressure, is highly reactive and capable of removing smoke, char and other contaminants from the surfaces of paintings without damaging the underlying paint pigment. The process has successfully restored fire-damaged and defaced paintings that were previously considered beyond repair by conventional techniques.

This technology, developed to simulate the low-Earth orbital space environment, has made it possible to etch as well as alter the surface chemistry and texture of many materials through atomic oxygen interaction processes. Commercial applications of this technology include medical, industrial and art restoration and cleaning.

Bruce Banks, chief of the Electro-Physics Branch, says, "We haven't even begun to realize all the potential applications for this technology." Sharon Miller, a researcher in the same branch, was the co-developer of the technique.

NASA Glenn has won a number of these prestigious awards over the years. Of 118 awards received by NASA since the award's inception in 1966, 83 have been for Glenn-developed products and technologies. ❑

For more information, contact Laurel Stauber at Glenn Research Center, ✆ 216/433-2028, ✉ *laurel.j.stauber@mail.grc.nasa.gov*. Please mention you read about it in Innovation.

Variety

Continued from page 7

Noninvasive Fiber-Optic Probe for Early Detection of Eye and Bodily Diseases—From the weightlessness of space to Glenn Research Center's National Center for Microgravity Research on Fluids and Combustion, Dr. Rafat Ansari has devoted himself to researching down-to-Earth applications of his dynamic light-scattering (DLS) technique. His research has advanced the development of ophthalmic instruments used to detect early signs of eye diseases such as uveitis, cataracts, diabetic retinopathy and age-related macular degeneration (AMD). There is also a possibility that the instruments could be used to detect Alzheimer's disease. Since the eye is easily accessed by light, the optical technologies created by Ansari also can be used for the evaluation of structure and physiology in health, aging and disease.

"Surgeries in a space environment or on distant planets during an expedition phase may not be a viable option," Ansari explained. "With space-vision goggles, doctors will not only be able to remotely monitor the astronauts and cosmonauts for the possibilities of radiation-induced cataracts but also observe EEG (electroencephalograph) and heart monitors, and record body temperatures. Blood sugar and cholesterol levels could also be monitored without taking a blood sample."

Ansari's laboratory is in the process of designing and constructing space-vision goggles. The goggles include a compact device based on his technique of DLS and other optical techniques and sensors supported by an Internet web system to monitor an astronaut's health during long-term space travel.

Until recently, Ansari's efforts have focused largely on four areas of research—cataracts, diabetes, AMD and Alzheimer's disease.

Cataracts, AMD and Alzheimer's disease primarily target people throughout the world over the age of 60. Cataracts are the gradual formation of protein clumps that eventually cloud the lens of the eye. Protein deposits called amyloids are present in the brains of people with Alzheimer's disease. With the adoption of DLS techniques, physicians will be able to look into the lens, cornea, aqueous, retina and vitreous of an eye for amyloid protein. Detecting the disease in its earlier stages may lead to treatment with anti-inflammatories, antioxidants or hormone-replacement therapies.

Although there remains no cure for cataracts, ongoing clinical research conducted between NASA and the National Eye Institute/National Institutes of Health using Ansari's DLS Probe has led to successful clinical testing of this new optical technology. It has enhanced ophthalmologist's ability to trace the beginning stages of eye disease painlessly, noninvasively and quantitatively in humans.

Kennedy Space Center:

The Hazardous Gas Detection System (HGDS) 2000 Software—The Space Shuttle Program requirements mandate "hazardous gas detection in all purged cavities." KSC personnel designed and wrote the HGDS 2000 Software to control a mass spectrometer system that samples Orbiter Aft Fuselage (main engines), Mid-Body (fuel cells), Payload Bay and External Tank (ET) inter-tank (hydrogen and oxygen tanks) systems. The mass spectrometer also samples the Hydrogen Tail Service Mast for hydrogen, oxygen, argon and helium in concentrations from low parts per million (ppm) to percent levels. The HGDS is operated from a console in the Launch Control Center Firing Room and is used during propellant loading in the hours just prior to launch, as well as during fuel-cell servicing a few days before launch to ensure that the space shuttle does not launch with a potentially dangerous leak that could ignite or detonate during ascent. Therefore, an operational HGDS is mandatory for loading operations and launch. The improved technologies incorporated into the design of this software would have prevented the abort of STS-93 at T-8 seconds.

The HGDS 2000 Software provides the system with the ability to utilize custom algorithms to improve the detection capability of the instrument vendor's software from 50–100 ppm to better than 1 ppm. These algorithms also improve the ppm accuracy of the instrument to 1 ppm, compared with the vendor's software capability of 100–1,000 ppm. The software can be utilized to support residual gas analyzers (RGAs) and medical gas analyzers used in anesthesiology, quantitative analysis in chemical research or industrial processes like the manufacture of semiconductors, where gas concentration analysis to the ppm level is required.

In FY2002, NASA awarded more than 1,800 innovators who contributed almost 800 technologies to NASA's aeronautical and space activities. ❑

For more information, contact Betsy Robinson at Ames Research Center, M/S 202A-3, Moffett Field, CA, ✉ *brobinson@mail.arc.nasa.gov*, ✆ 650/604-3360; Laurel Stauber at Glenn Research Center, ✆ 216/433-2028, ✉ *laurel.j.stauber@mail.grc.nasa.gov*; or Pam Bookman at Kennedy Space Center, ✆ 321/867-6381, ✉ *Pamela.Bookman-1@ksc.nasa.gov*. Please mention you read about it in Innovation.

Making Software More Reliable

Research is currently being conducted at NASA Ames in Moffett Field, CA on the ability of software to find its own errors.

The validation and verification (V&V) of software is being studied throughout the software industry, but the goal of this particular project is to demonstrate scalable, or size-adaptable, analytic verification technology (making sure the coding is right) on a major subsystem for aerospace. The approach is to advance the capabilities of model-checking technology to support verification of software and to evaluate the technology on realistic examples obtained from collaborations with aerospace companies. Researchers have presented the results of several case studies in applying model checking to software that was used to guide the research—notably the application of model checking to a real-time embedded aerospace operating system (DEOS) to discover a subtle error not uncovered during testing. From several years of research, the results have been a set of synergistic verification algorithms, or mini programs, that enable the analysis of large verification problems.

The cost of software aspects of flight certification for avionics systems has grown significantly in recent years because of the increased complexity of software in avionics systems. This software provides advanced control, communication and safety features at a reduced cost and weight. However, verification and certification of software for high levels of assurance is extremely expensive due to the manual effort needed to support the extensive testing required by the Federal Aviation Administration (FAA).

The difficulty of verification and certification will continue to increase due to an industry trend toward Integrated Modular Avionics (IMA), which aims to further reduce costs. IMA allows multiple applications of varying criticality levels to execute on a shared computing resource. Part of the cost-savings strategy of IMA is that software applications will be individually certified, allowing them to be mixed-and-matched with avionics platforms. Currently, this is not supported by the FAA certification process, which takes the approach of certifying each platform configuration separately. This new approach researched by NASA Ames is promising because it is well known that individual testing of an IMA is inadequate to assure that arbitrary combinations of applications will operate together safely, as they are not generally tested together.

Reducing the manual effort required to support certification and, at the same time, increasing the levels of assurance, will require significant advances in software verification and certification technology. There is a class of technologies called analytical verification tools that has the potential to address these issues. These techniques involve the analysis of mathematical models of software systems, which are based on the execution semantics of the software. The analytical verification tools include model checking, static analysis and abstract interpretation. To enable these tools to support verification of real avionics systems, the applicability and scalability of these techniques must be improved. In addition, methods for applying the tools and quantifying benefits of using them to support verification must be developed to integrate the new technology into the certification process. The tools and techniques also must be integrated with standard engineering methods and processes to be cost-effective.

The general technical thrust of research develops technology that allows the use of model checking to support the analysis of critical avionics software systems. Specifically, the focus develops advanced model-checking algorithms to support object-oriented programming languages. This approach addresses the applicability and scalability of model checking, while providing a tighter integration with engineering by directly supporting programming language models. To provide further scalability, extending automated program abstraction technology to allow model checking of complex software systems has worked well. Automated techniques have also been developed for verification test driver generation, which addresses one of the major costs of applying the tools in practice.

This research approach has developed prototype tools to evaluate technology on real systems and provide potential near-term benefits. The main tool that has been developed is the Java PathFinder model checker. As part of the evaluation process, Honeywell Technology Center has been given the ability to analyze several versions of their DEOS real-time operating system, which has increased confidence in the implementation of critical aspects of this system.

Due to the size of real-world software systems, the majority of work to date has focused on defect detec-

Continued on page 13

Inventor Recognized 25 Years Later

Retired Kennedy Space Center engineer Adam Kissiah's design is proof that technology developed today can benefit humankind years after its creation.

As a result of his hearing problem and three failed corrective surgeries, Kissiah began researching other rehabilitative possibilities. In 1977, with no medical background, he developed today's widely used cochlear implant.

That personal quest, which lasted three years, benefited not only him but many more people. Popular radio talk show host Rush Limbaugh has credited the "medical marvel" for his ability to hear after a disease left him totally deaf in his left ear and 80-percent deaf in his right.

Unlike a hearing aid, which just makes sounds louder, this invention selects information in the speech signal and then produces a pattern of electrical pulses in the patient's ear. It is impossible to make sounds completely natural, because a mere 22 electrodes are replacing the function of tens of thousands of hair cells in a normally hearing ear.

"It replaces the function of the hair cells that have been damaged, lost or destroyed by disease, drugs, trauma or simply by inheritance," said Kissiah.

Kissiah uses an analogy to simplify the process. "It would be like all the inter-coastal waterway bridges in Florida being gone. If you were to suddenly remove all those bridges, there could be no communication from the mainland. The hair cells are the bridge—the mechanical part of the ear," he said.

Now, 25 years after the implant was patented, Kissiah is getting the recognition he deserves by receiving an exceptional category NASA Space Act Award, which includes an appropriate monetary award and a certificate signed by the NASA Administrator.

Adam Kissiah (right), a retired NASA-KSC engineer, shows a photo of Allan Dianic's daughter, who has benefited from a cochlear implant that Kissiah developed while at NASA. Dianic (left) is a software engineer with ENSCO. Photo courtesy of Kennedy Space Center.

According to Pam Bookman, KSC's Awards Liaison Officer, this points out that we can always go back and capture awards. Bookman frequently encourages KSC employees to report their significant contributions because some may believe innovative thinking is just part of their job.

According to Pam Bookman, KSC's Awards Liaison Officer, this points out that we can always go back and capture awards. Bookman frequently encourages KSC employees to report their significant contributions because some may believe innovative thinking is just part of their job.

"Recognition for this important invention is long overdue," said Bookman. "This is the largest award ever received by a KSC inventor."

The Space Act Awards program was authorized under the Space Act of 1958 to provide official recognition and to grant equitable monetary awards for those inventions and other scientific and technical contributions that have helped to achieve NASA's aeronautical and space goals. The awards are also designed to stimulate and encourage the creation and reporting of similar contributions in the future.

Kissiah, though humbled about the recent attention, is also excited about the honor. "This is being done almost every day in medical centers in the country. Regardless of what level of participation I had, it is nice to know I contributed to making many lives better," he said. "That is indeed special. It allows me to think I did something that helps." ❑

For more information, contact Robin Flynn of the Kennedy Space Center Technology Commercialization Office, ✆ 321/861-7154, ✉ *Robin.Flynn-1@ksc.nasa.gov*. Please mention you read about it in Innovation.

Creating

Continued from page 11

tion rather than producing guarantees that behavioral properties of the software are satisfied. Exhaustive model checking of all system behavior is not possible due to memory limitations. It is, however, possible to give guarantees of the absence of certain errors if a partial analysis of the system is done. More precisely, by analyzing a system with an environment that cannot perform all possible legal actions at any time, then it still may well be possible to show the system behaves correctly. Therefore, by guaranteeing that during execution the environment only executes actions that have been analyzed, then the system will behave correctly. It is easy to use runtime monitoring to check that the system execution stays within the analyzed bounds. It is even possible to go a step further by initiating a recovery unit whenever the bounds are exceeded. Of course, the bounds need not just be on environment behavior, but might be predicated on the behaviors analyzed during model checking, which may include restrictions of system behavior not influenced by the environment.

In the next phase of the project, techniques will be developed to capture restrictions on system behavior under which absence of errors can be guaranteed in such a way that one can use runtime monitoring and recovery to maintain correct system behavior. In preliminary work, it has been shown that one can use certain filters on environmental behavior to show absence of certain errors. These filters can then be used within a runtime monitor that can check such properties during system execution.

A long-term goal for this research is to develop techniques by which the model checker can "learn" the structure of the system, and therefore the shape of the graph of reachable states, which will ultimately optimize the analysis of the system. ❑

For more information, contact David Lackner at the NASA Ames Research Center Commercial Technology Office, Mail Stop 202A-3, Moffett Field, CA 94035-1000, ✆ 650/604-5761, 🖷 650/604-1592, ✉ *dlackner@mail.arc.nasa.gov*, Web site: *http://technology.arc.nasa.gov*. Please mention you read about it in Innovation.

Beyond Remote Control

The Computing, Information and Communications Technology (CICT) program is one with many highly technical areas, including high-level autonomy. High-level autonomy is where a system is programmed to perform without interaction. Researchers at NASA Ames in Moffett Field, CA developed a conceptual, high-level autonomy architecture for rovers to conduct research on Mars, in collaboration primarily with NASA Jet Propulsion Lab (JPL) and Carnegie Mellon University (CMU).

A recent rover test at Ames was the first step in showing the integrated functionality of a number of autonomous software components being developed within the Automated Reasoning project. The components involved in the test included the visual interface (VIZ) for displaying a model of the rover and its environment; a rover executive that can execute contingent, concurrent plans; a ground-based planner; high-quality stereo imaging; target assessment algorithms for segmenting the rock from the ground and identifying flat patches on the rock; motion planning algorithms for arm placement; and hand-eye calibration, i.e., coding to allow the rover camera frames and arm coordinate frames to calibrate at the same time.

Although only a minimal functionality of each of these components was tested, and although the environment in which the system was tested was completely benign, the lab test fulfilled the objective of demonstrating single-cycle rover ground commanding for target instrument placement.

Bob Morris, NASA's project manager for Intelligent Systems within CICT explains, "The goal is to develop a suite of software systems that will collectively allow for more automatic surface exploration by rovers on Mars. This lab test was the first stage in solving the difficult problem of integrating these software systems so that they work together to give a rover the ability to automatically navigate to a target of interest and place a science instrument on the target to collect data without control from elsewhere." ❑

For more information, contact David Lackner at the NASA Ames Research Center Commercial Technology Office, Mail Stop 202A-3, Moffett Field, CA 94035-1000, ✆ 650/604-5761, 🖷 650/604-1592, ✉ *dlackner@mail.arc.nasa.gov*, Web site: *http://technology.arc.nasa.gov*. Please mention you read about it in Innovation.

Partnership Improves Actuator, Saves Money

A Dual-Use Cooperative Agreement between the Office of Technology Transfer at Stennis Space Center (SSC) and BAFCO Inc. of Warminister, PA has produced an improved linear actuator for use on the rocket engine test stands at Stennis Space Center.

A linear actuator is the servomechanism that supplies or transmits a measured amount of energy for the operation of another mechanical system; accuracy, reliability and speed of the actuator are critical to proper performance of the entire system. The BAFCO Model 773 is a next-generation, high-thrust, high-response electro-hydraulic actuator designed to meet identified performance standards in aerospace, industrial and petro-chemical applications.

"This actuator is the result of a focused partnership between NASA and our company to resolve production problems, as well as high unit costs," said Jim Hamtil, president of BAFCO Inc. "The Model 773 meets National Fluid Power Association (NFPA) standards for cylinder performance, along with US and European standards for electrical component functions. It is a unique piece of equipment that meets or exceeds established performance standards at mid-range pricing levels."

Stennis provides testing of space shuttle main engines, rocket propulsion systems and related rocket components. Stennis maintains several test facilities with a number of cells, or positions, to perform propulsion testing. As the testing facilities continue to age, maintenance costs have increased. In an attempt to control component replacement costs, NASA partnered with BAFCO to resolve questions regarding manufacturing processes, delivery lead-time and high unit costs.

A Dual-Use Cooperative Agreement between Stennis Space Center and BAFCO, Inc. has produced an improved linear actuator for use at Stennis. Artwork courtesy of Stennis Space Center.

BAFCO identified four suppliers that manufactured components meeting the performance standards required by NASA. "We no longer have to individually engineer each component," said Hamtil. "Our company has been able to purchase commercial off-the-shelf (COTS) components and modify them using BAFCO technology and expertise. Subsequently, production and delivery lead-time have been reduced. Production to delivery, the entire process has been reduced from 14 weeks to between four and eight weeks. Correspondingly, the unit price has been lowered."

To date, all 30 of the actuators Stennis purchased from BAFCO have been installed in the E-Complex at Stennis, with performance levels having met or exceeded those of all previously used actuators.

"This agreement allowed our company to not only address a government need, but also to enhance our commercial product at the same time. As a result, the Model 773 is receiving increased interest from companies outside the traditional applications areas," says Hamtil.

"This dual-use project is an excellent example of how NASA and industry can partner to develop a NASA-needed technology while at the same time help fulfill a commercial market place need," said John Bailey, NASA Office of Technology Transfer dual-use manager. The dual-use concept of product development is based on the sharing of costs, risks and successes between the government and a commercial partner. In these projects, NASA can contribute technology development, unique facilities and know-how, engineering resources and funding. In turn, the commercial partner contributes unique expertise, facilities, manufacturing, marketing capabilities and potential cash resources. The result is an approach that provides flexibility and draws upon the capabilities of both parties. ❑

For more information, contact the Office of Technology Transfer at John C. Stennis Space, ✆ 228/688-1929. Please mention you read about it in Innovation.

Airfield Wind Advisory System Reduces Flight Risks

An Airfield Wind Advisory System (AWAS) can reduce the risks associated with unknown winds during airplane takeoffs and landings. It was developed by one Kennedy Space Center (KSC) and two NASA Headquarters innovators, and patented by Dryden Flight Research Center.

An AWAS includes a self-contained weather station, located at an airfield, that measures speed and direction of the wind, the temperature, the barometric pressure and the humidity. This ground station digitizes these measurements and transmits the measurement data in real time via radio to portable units in aircraft cockpits. The portable units automatically detect the data and display the information to pilots. In 1999, a prototype of the AWAS system was demonstrated to function successfully in tests at KSC's Space Shuttle Landing Facility.

An AWAS ground station is designed for automatic operation with minimal maintenance, using either alternating current from a power line or power from a solar photovoltaic array with battery backup. AWAS ground stations can include solid-state transducers with no sliding parts such as sonic anemometers and/or strain-gauge wind sensors for high reliability but could also be designed to take advantage of previously installed anemometers, weather vanes and other weather-measurement devices. AWAS ground stations also can contain Web server computers, which transmit the information to wide-area networks over Intranet or Internet links upon demand. The transmitted information can include not only the data from the AWAS weather measurements, but also Global Positioning System (GPS) data and/or other geophysical data from measurement devices to support scientific observations.

An AWAS airborne unit includes an antenna, receiver, microprocessor, data-storage elements, a power supply and a backlit liquid-crystal display device. The simplest version provides a no-clutter display that can be read by the pilot in a one-second glance, showing the following data: the identity of the airfield, represented by a three- or four-character label assigned by the Federal Aviation Administration (FAA) to every airfield or helipad; the direction of the wind in degrees measured from magnetic north; the steady-state and peak gust wind speeds in knots; and the most favorable runway for takeoff and landing.

To select the most favorable runway, the microprocessor in the airborne unit compares the wind vector with the runway heading, which are stored in an internal database, and calculates the headwind and crosswind values. The runway that is indicated on the display device is the one with the highest headwind and lowest crosswind components. A switch enables the pilot to command the display of the headwind and crosswind data for the selected runway.

A standby switch shuts off the display device but allows the remainder of the airborne unit to operate in a listening mode to conserve energy when not in range of an airfield. Advanced versions may include keypads to enable pilots to select specific airfields or runways, or to enter special data or queries.

Specialized AWAS software, which may also be incorporated into wireless personal data assistants (PDAs) and handheld GPS devices, could provide graphical depictions of airfield diagrams and winds. The Internet version of the AWAS is intended for use with wireless PDAs and cellular telephones that provide access to the Internet.

The receiver in an AWAS airborne unit automatically detects the signal from an AWAS ground unit at an airfield and activates the display device when in range of the airfield. The display helps the pilot to select the optimum approach to the airfield while 8 to 10 miles (about 13 to 16 km) out, thus saving 3 to 5 minutes per landing. Under visual flight rules (VFR), when approaching an uncontrolled field, the pilot is required to make contact with the UNICOM of the airfield to request wind and runway information (UNICOMs are nongovernment communication facilities that provide airport information at some airports).

If there is no answer, as is often the case, the pilot must fly over the airfield to view the windsock while visually avoiding other traffic, estimating the wind speed and entering the traffic pattern to land. Meanwhile, the pilot also must trust that other pilots are making the same assumptions about the winds and the landing runway. This procedure typically involves extra maneuvering and backtracking. With the AWAS, the pilot knows the wind at the airfield and knows which runway is most favorable, and therefore is able to fly a more direct approach to the landing pattern, without guesswork or extra maneuvering. More importantly, the pilot knows the headwind and crosswind for each runway without question, and therefore will be able to plan ahead for the appropriate aircraft alignment and control inputs.

According to the Aircraft Owners and Pilots

Continued on page 16

Airfield

Continued from page 15

Association annual aviation safety report for the US (the Nall Report), takeoff and landing accidents are "seldom fatal," but the numbers of such accidents are still considerable. During one year, there were 743 takeoff and landing accidents in the United States, which resulted in 46 fatalities. The AWAS can contribute significantly to a reduction in the numbers of such mishaps and fatalities. As shown in the Nall Report for general aviation, the greatest number of accidents by far occurs during the takeoff and landing phases of flight. These two phases require the greatest skill and most intense concentration from the pilot, and occur when the aircraft is closest to the ground, at its most vulnerable maneuvering speed and with the least amount of maneuvering airspace. Wind conditions are extremely critical during these phases of flight. By having the current wind and gust conditions immediately available, the pilot can mentally prepare the approach or takeoff in advance, and reduce the need for surprise reactions. The AWAS can also reduce the risks associated with practicing crosswind landings by making the wind information always readily available to the student pilot and instructor.

The AWAS also can be used to disseminate weather information in real time for applications other than aviation. Examples of potential users include the National Weather Service, the military, commercial weather services, marine and agricultural concerns, the Federal Emergency Management Agency and emergency services, including firefighters during forest fires. ❑

For more information, contact Jerry Brown at NASA Langley Research Center, ✆ 757/864-1073. Please mention you read about it in Innovation.

NASA Works to Found Innovative Research Institute

NASA's oldest research laboratory is working to ensure America's future dominance in aerospace innovation and education. The Langley Research Center in Hampton, VA is teaming with the National Institute of Aerospace Associates (NIAA) of Reston, VA, a newly formed nonprofit corporation, to create a world-class institute called the National Institute of Aerospace (NIA). The new institute will perform cutting-edge aerospace and atmospheric research, develop new technologies for the nation and help inspire the next generation of scientists and engineers.

Locating the NIA at the Langley Research Center will facilitate the Institute's involvement in agency-sponsored research programs and foster collaboration with NASA, including access to its world-class research facilities.

This innovative government-academic partnership is comprised of a cost-reimbursable, indefinite delivery/indefinite quantity contract and a cooperative agreement. The maximum value of the contract for a five-year base period is $49 million. The value of the basic five-year cooperative agreement is $69 million. If the three five-year options are exercised under the cooperative agreement, the combined potential total value would be $379 million.

The NIAA is made up of seven nonprofit organizations or universities, including: American Institute of Aeronautics and Astronautics Foundation, Reston, VA; Virginia Polytechnic Institute and State University, Blacksburg, VA; University of Virginia, Charlottesville, VA; University of Maryland, College Park, MD; North Carolina State University, Raleigh, NC; North Carolina Agricultural and Technical State University, Greensboro, NC; and Georgia Institute of Technology, Atlanta, GA.

The Institute is a long-term commitment on the part of NASA to expand collaboration with universities, industry, other government agencies and the broader scientific community to fully leverage expertise inside and outside of government. Once fully operational, the Institute will become a strategic partner, working with NASA to enhance its world-class aerospace and atmospheric research capability. The Institute will complement Langley's research creativity and expand research and technology development opportunities. In addition, the NIA will be a significant new research and education asset for the nation.

The Institute, through its partner universities, will offer master's and doctoral degrees in science and engineering using both a local campus and the latest innovations in distance learning. The Institute will also be a catalyst for economic development by stimulating the commercialization of new intellectual property and facilitating the growth of new business opportunities. The Institute will be a prominent new voice promoting the benefits of aerospace research. ❑

For more information, contact Dr. Charles E. Harris, NASA Langley Research Center, Mail Stop 110, Hampton, VA 23681, ✆ 757/864-3447, 757/864-8980. Please mention you read about it in Innovation.

Ground Tests Complete on Active Aeroelastic Wing

Engineers and technicians at NASA Dryden Flight Research Center have wrapped up the last major ground tests before beginning the first research flights in a project to demonstrate that twisting or warping flexible wings can enhance aircraft performance.

The ground vibration and structural mode interaction tests on the Active Aeroelastic Wing (AAW) F/A-18A test aircraft were completed in mid-September, according to Dryden's AAW project manager Denis Bessette.

A joint program of the US Air Force Research Laboratory (AFRL), Boeing's Phantom Works and NASA Dryden, Active Aeroelastic Wing is researching the use of lighter-weight flexible wings for improved maneuverability of future high-performance military aircraft. The program intends to demonstrate improved aircraft roll control through aerodynamically induced wing twist on a full-scale manned supersonic aircraft.

"The project reflects a return to aviation's beginnings, when the Wright brothers devised a primitive wing-warping method to control the Wright Flyer, and a gateway to the future, a future where aircraft will sense their environment, morph and adapt their shape to the existing flight conditions," said Bessette. "These future aircraft will take advantage of years of evolutionary lessons exhibited in bird-like flight."

AAW research could also enable thinner, higher aspect-ratio wings on future aircraft, which could result in reduced aerodynamic drag, allowing greater range or payload, and improved fuel efficiency.

"Active Aeroelastic Wing technology is important to the Air Force because it represents a new approach to designing wings and is applicable to a wide variety of future air vehicle concepts that are under study," said Pete Flick, AAW program manager for the AFRL Air Vehicles Directorate. "The AAW design approach removes some constraints that limit conventional wing design, opening up the envelope for future designers."

During the most recent tests, the F-18 rested on three large airbags, while electro-mechanical shakers induced vibrations into the wings at varying amplitudes and frequencies. Test instrumentation measured how the structure reacted as these vibrations propagated through the aircraft to determine potentially adverse effects.

The upper wing surfaces of the Active Aeroelastic Wing F/A-18 test aircraft are covered with accelerometers and other sensors during ground vibration tests at NASA Dryden Flight Research Center.

In the ground vibration tests, the F-18's hydraulics were powered up, but the control surfaces were inactive. The structural mode interaction tests take the process one step further, with the flight controls operating and the interaction of the flight control surfaces with the aircraft structure observed. This test assures that vibrations caused by the actions of the flight controls are damped or suppressed, rather than reinforcing each other to cause large, uncontrolled vibrations or "flutters" that could lead to catastrophic failure of the aircraft structure.

The testbed F/A-18A, provided by the US Navy, was modified with additional actuators, a split leading-edge flap actuation system and thinner wing skins that allowed the outer wing panels to twist up to five degrees. The traditional wing control surfaces—trailing edge ailerons and the leading and trailing edge flaps—were used to provide the aerodynamic force needed to twist or "warp" the wing. Project engineers hoped to obtain almost equivalent roll performance of production F/A-18s at transonic and supersonic speeds without using the horizontal stabilators and with smaller control surface deflections.

A six-month long structural loads testing program on the F/A-18's modified wings, one of the most extensive tests ever performed in Dryden's Flight Loads Laboratory, was conducted in 2001. As part of those tests, the wings were subjected to loads up to 70 percent of the design limit load of the airplane, with load distribution over the wings a particularly critical item. ❑

For more information, contact Denis Bessette at NASA Dryden Flight Research Center, ✆ 661/276-3110. Please mention you read about it in Innovation.

Virtual Propulsion System Meets Real-Time Diagnostic System

NASA researchers recently demonstrated successful real-time fault detection and isolation of a virtual main propulsion system. Using a detailed simulation of a vehicle propulsion system to produce synthesized sensor readings, the NASA team demonstrated that advanced diagnostic algorithms, running on actual flight-class computers, could successfully diagnose the presence and cause of faults in real time. This demonstration was conducted as part of the NASA Propulsion IVHM Technology Experiment (PITEX), an effort led by Glenn Research Center at Lewis Field in Cleveland, OH, with Ames Research Center at Moffett Field, CA and Kennedy Space Center in Florida as the other participating Centers. Ames Research Center manages the Integrated Vehicle Health Management (IVHM) project for NASA's 2nd-Generation Reusable Launch Vehicle Program.

The goal of this research is to mature and demonstrate key Integrated Vehicle Health Management (IVHM) technologies—one of several technologies that are involved in NASA's Space Launch Initiative (SLI), an Agency-wide effort to significantly increase crew safety while reducing payload launch costs. PITEX operates as a key element of a Risk-Reduction Task being performed for NASA by the Northrop Grumman Corporation in El Segundo, CA. "NASA is committed to changing the way we operate and maintain launch systems. Information technology can lead the way, and demonstrations like this are part of making sure we are on the right path," said William Kahle, IVHM project manager at NASA Ames.

Glenn researchers developed a detailed simulation of a main propulsion feed system, which they ran under both nominal and fault conditions to generate time histories of propulsion system parameters. Noise was superimposed on the simulation output to provide realistic sensor signals. Typical propulsion system failures, such as valves sticking open or closed, regulator problems and sensor and microswitch failures, were injected at various points in a simulated mission.

The simulated data were fed, in real time, to IVHM software running on a computer, designed and assembled by Kennedy Space Center, that is a commercial-grade version of actual flight hardware. "In all cases, the PITEX diagnostic software detected and isolated the injected fault correctly," said Claudia Meyer of GRC, PITEX team lead. In addition, resource utilization tests were performed to measure the real-time performance of the diagnostic software on the flight-like hardware. Data revealed that resources were largely underutilized, indicating that the diagnostic system could be expanded to cover additional components.

The PITEX diagnostic solution features monitor software that processes the raw sensor data and Ames-developed model-based diagnostic software—Livingstone—that detects and isolates anomalies. Livingstone uses a qualitative model of the system to predict the expected state; system-level reasoning is performed to resolve differences between the observed and expected states.

In continuing work, the PITEX diagnostic solution is being migrated to Northrop Grumman's IVHM Virtual Test Bed (IVTB). In the IVTB, a broad range of vehicle subsystem health managers, in addition to propulsion, will be considered, and the benefits of coordinating the subsystem health managers through area and system-level health managers will be demonstrated. "The PITEX team is really blazing a trail that IVTB, and eventually the whole SLI program, will follow to create and validate future health-management systems," said Dr. Stephen Brown, Northrop Grumman Corporation chief scientist for the IVHM task. "Real-time health management, such as demonstrated by PITEX, will lead to revolutionary improvements in the safety and cost of future reusable launch vehicles."

The Space Launch Initiative is NASA's technology research and development program aimed at dramatically increasing safety and reliability, and reducing the cost of a 2nd-generation reusable launch vehicle. All NASA's Field Centers and the Air Force Research Laboratory are actively participating in the Space Launch Initiative and are vital to its success. NASA's Marshall Space Flight Center in Huntsville, AL leads the Space Launch Initiative for NASA's Office of Aerospace Technology. ❑

Further information on the Space Launch Initiative can be found at the following Web sites: *http://www.slinews.com* and *http://www.spacetransportation.com*

SBIR-Developed Software Goes a Long Way

A 1999 Software of the Year honorable mention and recipient of a 2000 *R&D Magazine* R&D 100 Award, the Ring-Buffered Network Bus (RBNB) is an example of an SBIR that has grown from its original use. Developed by Dryden Flight Research Center, with Creare, Inc. of Hanover, NH, the RBNB is software that is helping to tame the vast amount of information flowing through the Internet. Called the RBNB DataTurbine®, it provides multi-site streaming data access, both real-time and historical, with collaborative or on-the-fly processing capabilities. The software adds memory to network communications and facilitates time correlation of distributed data sources. It also enables and facilitates remote monitoring, data distribution, application integration and interactive data processing between multiple data sources and sinks.

Intended for creating networks of measurements and distributed measurement processing, DataTurbine is a software server that provides a buffered network path between suppliers and consumers of information. This buffering mechanism goes beyond traditional file-based sharing technologies by adding a time dimension to the data. By incorporating DataTurbine-based management into Web and application services, the integration of static and dynamic information is greatly simplified. In addition, the ability to organize DataTurbines into hierarchies and layers facilitates deployment of scalable virtual networks for specific users or uses.

The applications of an Internet-based management tool such as DataTurbine are numerous. It can be used for manufacturing process control, medical and physiological management, business and commercial on-demand multimedia data streaming, distance learning, scientific data processing and enterprise process automation.

The software also shows promise for making air travel safer by offering a solution for meeting the often-conflicting goals of providing high-performance data acquisition and quick access to those data by many users. By effectively storing live data and analysis of that data in the network, the construction of situational awareness and decision support tools for pilots, air traffic management, maintenance personnel and others is made easier. The DataTurbine has been involved in advanced experiments for NASA's Aviation Safety Program and is also involved in developing systems architectures for intelligent vehicle health management on manned or autonomous vehicles.

Using this technology, entire fleets of aircraft may someday be able to communicate with each other and with ground-based facilities through interoperable on-board and open-air data networks. Flight data recorders, known as black boxes, could be augmented with DataTurbine-enabled network services.

Dryden also has initiated a project with Creare to develop a suite of Java-based object-oriented software tools to aid the design, analysis, implementation and use of cost-effective distributed health-management systems, using RBNB. While object-oriented paradigms with graphical interfaces are revolutionizing many fields, distributed health monitoring evolves toward intelligent decision-support systems involving sensors, signal processing and a consequential need to analyze both current and historical data from a number of often-changing data sources and types. Timely access to machinery health information leads to increased operational efficiency.

For the medical industry, RBNB is a useful tool for systems integrators and application developers. Application examples include adapting live telemedicine environments to couple video-on-demand with other sensor-history-on-demand capabilities, implementing temporary source-side measurement storage services for later transmission across intermittent links and building new integration, fusion and data management capabilities into Web-based emergency response infrastructure.

"The DataTurbine is a step toward vastly easier integration and interoperability for decision-making support tools," says Larry Freudinger, Dryden's lead engineer for measurement and telemetry network applications, and co-developer of the DataTurbine software. ❑

For more information, contact Larry Freudinger at Dryden Flight Research Center, ✆ 661/276-3542, ✉ *l.freudinger@dfrc.nasa.gov*. Please mention you read about it in Innovation.

The Ring Buffered Network Bus DataTurbine provides multi-site streaming data access, both real-time and historical, with collaborative processing.

NASA Helps Industry Relieve Pressure Safely

In many industrial applications, pressure relief valves (PRVs) perform the critical function of safely releasing pressure before potentially damaging buildups occur. Conventional relief valves, however, have proven unstable, leading to premature wear and devastating consequences. A high-performance pressure relief valve, the PRV95, now being manufactured by Marotta Scientific Controls, Inc. of Montville, NJ, provides the answer to premature wear and instability. Using an improved valve design developed under a NASA SBIR contract from John C. Stennis Space Center (SSC), Marotta's PRV95 pressure relief valve provides stability over the entire operational range, from fully closed to fully open. The valve employs upstream control for valve positioning, which makes the valve more stable and affords excellent repeatability with minimal lag time.

"It opens and closes softly, and does not oscillate or generate hard impacts; oscillation can result in a hard impact pressure release, which can lead to an explosion in the presence of oxygen," says Bill St. Cyr, chief of the Test Technology Branch at Stennis Space Center.

Marotta's PRV95 design is unique in its ability to maintain a seal near the set point of the relief limit. Typically, relief valves seal tightly up to 90 percent of set point and then reseat when pressure is reduced to 85 percent of set point. The PRV95 technology maintains seal integrity until 98 percent of set point and will reseat a 95 to 97 percent of set point. This allows the operator to protect the system while not exceeding its limits.

A high-performance pressure-relief valve developed under an SBIR contract with Stennis Space Center provides stability over the entire operational range, from fully closed to fully open. Artwork courtesy of Stennis Space Center.

The key to stable, soft-opening/soft-closing operation is upstream control. A conventional "pop" type pressure relief valve is characterized as operating under downstream control. Once the valve has opened, the flow is controlled mainly by an effective cross-sectional area downstream of the valve seat. In the PRV95, the flow-limiting cross-section remains upstream of the valve seat at all times, thereby creating upstream control. The figure below illustrates the basic design and principle of operation of a controlled pressure relief valve.

As in a conventional relief valve, excessive upstream pressure opens the valve by lifting a poppet from a seat in the valve body. However, the poppet in the PRV95 includes a conical portion and a paddle upstream of the conical portion. When the valve is closed and the upstream pressure is below the set point, the conical portion of the poppet engages about half the thickness of a main valve seat, forming a tight seal. In this condition, the paddle engages the wall of a cylindrical passage upstream of the main valve seat. When the upstream pressure rises to approximately the set point, the poppet moves downstream a little, but the valve is not yet open; the conical portion of the poppet remains partly engaged with the main valve seat, while the paddle remains in the cylindrical passage in the retainer. As pressure rises above the set point, the conical portion of the poppet moves out of the main valve seat, and the paddle moves out of the cylindrical passage in the retainer.

Primarily designed to operate in systems that contain gases and liquids in a variety of pneumatic, hydraulic and cryogenic applications, the PRV95 valve offers several advantages over valves with different operating characteristics. These advantages include a smooth transition from fully closed to fully open; noise and wear reduction through elimination of chatter; reduction in the risk of product fire and explosion through elimination of hard impact; and corresponding reductions in the uncontrolled venting of hazardous fluids and products. In summary, the increased stability of the valve operation results in better performance, with wider operating ranges and control. All of these attributes translate into the additional advantage of lower lifecycle costs. ❑

For more information, contact the Office of Technology Transfer at Stennis Space Center, ✆ 228/688-1929. Please mention you read about it in Innovation.

Open Channel Software Leads Commercialization of NASA-Sponsored COMPARE Software

Open Channel Software, in conjunction with the NASA Glenn Research Center and the University of Akron, held a one-day seminar in early October on the COMPARE software program, which has been newly improved for commercial use. The COMPARE (Constitutive Material PARameter Estimator) software was originally developed through a NASA-sponsored collaboration between researchers at the NASA Glenn Research Center and the University of Akron to advance the power and performance of material science modeling in the design of engineering components and structures. The COMPARE seminar was conducted at the Ohio Aerospace Institute and provided industry participants and others with a hands-on opportunity to test the capabilities of the COMPARE software.

The COMPARE software greatly speeds the adaptation of experimental data to material science models. It utilizes advanced math to provide a fast and efficient tool to define the key parameters of a model from experimental data, reducing the time required from weeks or months to minutes and hours. In addition, it takes into consideration multi-axiality with the same ease as in uni-axial modeling, allowing for the modeling of far more complex environments. Further information on the COMPARE software is available at *www.compare-ocs.com*

Open Channel works in partnership with the NASA Glenn Research Center and other NASA Centers as part of the NASA Commercial Technology Program's efforts to foster the market-driven development of NASA software for both NASA and commercial applications. The nonprofit Open Channel Foundation provides easy access to a growing array of NASA software code available for transfer, use and collaborative development through the Web site at *www.openchannelfoundation.org*

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In turn, Open Channel's commercialization arm focuses on transitioning software from NASA and other research institutions into the marketplace. In the case of COMPARE, over the past year Open Channel Software worked with the Commercial Technology Office and key researchers at the NASA Glenn Research Center, NASA's Midwest Regional Technology Transfer Center (GLITeC), the NASA Illinois Commercialization Center and the University of Akron to craft a commercialization pathway and further enhance the COMPARE software. ❑

For further information, go to *www.nctn.hq.nasa.gov* or contact Jonathan Root at NASA Headquarters, ✉ *jonathan.root@hq.nasa.gov*, ✆ 202/358-1845. Please mention you read about it in Innovation.

Moving Forward

Technology Opportunity Showcase

Technology Opportunity Showcase highlights some unique technologies that NASA has developed and that we believe have strong potential for commercial application. While the descriptions provided here are brief, they should provide enough information to communicate the potential applications of the technology. For more detailed information, contact the person listed. Please mention that you read about it in **Innovation**.

Body Fluids Monitor

NASA is seeking industrial partners to license the Body Fluids Monitor for commercialization. This invention relates to a process and apparatus for determining amounts of body fluids in a subject using bioelectrical response. Based on circuit components, the total volume of body water, the volume of extra-cellular water, the total blood volume and the total plasma volume of a subject may be calculated utilizing a sequence of measurements and processing steps. NASA originally developed this device to measure the loss of fluids from astronauts during space flight.

This invention has several advantages over other methods. Its noninvasive nature allows the assessment to be repeated quickly and safely. Other invasive methods are time-consuming and cannot be repeated until the diluting substance leaves the body. Additionally, the nonradioactive nature of this invention does not put the subject at an increased risk due to the use of radioisotopes. Total blood volume may be assessed. The measurement error and accuracy of this technique is similar to current clinical standards (dilution techniques). The accuracy of the assessment of total body water and extra-cellular fluid volume is greater with this method than with previous bioimpedance methods.

This process may be used in both research and clinical settings to determine an individual's hydration level. It may also provide a convenient, lightweight system and method for use in medical clinics and health and exercise clubs for monitoring an individual's body mass and percentage of body fat. In addition to providing an accurate electrical circuit representation of the human body, this technology may find applications in the assessment of cerebral and other regional blood flows, muscle mass of the upper and lower limbs, cardiac output, bone mineral content and total body protein, and blood pressure.

Potential commercial uses include usage in hospital settings to measure body fluids pre- and post-surgery, as well as during surgery to monitor blood loss and liquids going back into the body; monitoring health and health conditions such as osteoporosis through the measurement of bone mineral content; and usage in field research and field applications because of its unique portable design. ❑

For more information, contact Michael Powell, PhD, Research Scientist, at Johnson Space Center, ✆ 281/483-5413, 281/483-2888. Please mention you read about it in Innovation.

Low-Cost, Long-Lasting Liquid Coating

NASA Kennedy Space Center currently seeks qualified companies to license and commercialize its newest liquid-applied coating technology. Developed to protect embedded steel surfaces from corrosion, this material is made of inexpensive, commercially available ingredients and is easily applied by brush or spray to the outer surface of reinforced concrete.

This highly reliable, low-cost liquid-applied coating offers companies a convenient method of protecting embedded steel rebar surfaces from corrosion. By transferring the corrosion-preventive measures from the interior of the formed concrete to the concrete surface, companies will have an efficient and practical means of slowing or even stopping the internal corrosion process.

The coating may be used to prevent corrosion of steel in concrete in several applications, including highways and bridges, piers and docks, concrete balconies and ceilings, parking garages, cooling towers and pipelines.

The inorganic, galvanic coating contains one or more of the following metallic particles: magnesium, zinc and indium. In addition, the coating may contain moisture-attracting compounds that facilitate the protection process. After the coating is applied to the outer surface of reinforced concrete, an electrical current is established between the metallic particles and the surfaces of the embedded steel rebar. This electrical (ionic) current is responsible for providing the necessary cathodic protection for the embedded rebar surfaces. KSC's Materials Science Laboratory and Beach Corrosion Test Site have characterized the coating's performance. Early tests determined that the coating met National Association of Corrosion Engineers' (NACE's) RP0290-90 100-millivolt (mV) polarization development/decay depolarization criteria for complete protection of steel rebar embedded in concrete. Other tests verified that the embedded rebar became negatively polarized, indicating the presence of a positive current flow with a shift in potential of over 400 mV. Accelerated life tests, tests with chlorides to simulate contamination, and compound optimization tests are currently being performed.

There are many benefits to this technology. Because the coating is applied to the outer surface of the reinforced concrete and not directly to the rebar, corrosion prevention is achieved after construction is complete. Application is performed quickly and can be repeated to provide extended protection. The low cost is achieved through relatively inexpensive labor and materials. Because the coating lasts 10 years or more, maintenance costs are also reduced over the lifetime of the structure. ❑

For more information, contact Lynne Henkiel, KSC Industry Liaison, at ✆ 321/867-8130 or ✉ *Lynne.Henkiel@ksc.nasa.gov* and reference Case Number KSC-12049. Please mention you read about it in Innovation.

NASA Commercial Technology Network Directory

NASA ONLINE

Go to the NASA Commercial Technology Network (NCTN) on the World Wide Web at *http://nctn.hq.nasa.gov* to search NASA technology resources, find commercialization opportunities and learn about NASA's national network of programs, organizations and services dedicated to technology transfer and commercialization.

NASA Field Centers

Ames Research Center
Selected technological strengths are Information Technologies, Aerospace Systems, Autonomous Systems for Space Flight, Computational Fluid Dynamics and Aviation Operations.

Carolina Blake
Ames Research Center
Moffett Field, California 94035-1000
650/604-1754
cblake@mail.arc.nasa.gov

Dryden Flight Research Center
Selected technological strengths are Aerodynamics, Aeronautics Flight Testing, Aeropropulsion, Flight Systems, Thermal Testing and Integrated Systems Test and Validation.

Jenny Baer-Riedhart
Dryden Flight Research Center
Edwards, California 93523-0273
661/276-3689
jenny.baer-riedhart@mail.dfrc.nasa.gov

Glenn Research Center
Selected technological strengths are Aeropropulsion, Communications, Energy Technology and High-Temperature Materials Research, Microgravity Science and Technology, and Instrumentation Control Systems.

Larry Viterna
Glenn Research Center
Cleveland, Ohio 44135
216/433-3484
Larry.A.Viterna@grc.nasa.gov

Goddard Space Flight Center
Selected technological strengths are Earth and Planetary Science Missions, LIDAR, Cryogenic Systems, Tracking, Telemetry, Command, Optics and Sensors/Detectors.

Nona Cheeks
Goddard Space Flight Center
Greenbelt, Maryland 20771
301/286-5810
ncheeks@pop700.gsfc.nasa.gov

Jet Propulsion Laboratory
Selected technological strengths are Deep and Near Space Mission Engineering and Operations, Microspacecraft, Space Communications, Remote and In-Situ Sensing, Microdevices, Robotics and Autonomous Systems.

Art Murphy
Jet Propulsion Laboratory
Pasadena, California 91109
818/354-3480
art.murphy@jpl.nasa.gov

Johnson Space Center
Selected technological strengths are Life Sciences/Biomedical, Spacecraft Systems, Information Systems, Robotic and Human Space Flight Operations.

Charlene Gilbert
Johnson Space Center
Houston, Texas 77058
281/483-0474
charlene.e.gilbert@jsc.nasa.gov

Kennedy Space Center
Selected technological strengths are Emissions and Contamination Monitoring, Sensors, Corrosion Protection and Biosciences.

Jim Aliberti
Kennedy Space Center
Kennedy Space Center,
Florida 32899
321/867-6224
jim.aliberti-1@kmail.ksc.nasa.gov

Langley Research Center
Selected technological strengths are Aerodynamics, Flight Systems, Materials, Structures, Sensors, Measurements and Information Sciences.

Wilson Lundy
Langley Research Center
Hampton, Virginia 23681-0001
757/864-6005
w.t.lundy@larc.nasa.gov

Marshall Space Flight Center
Selected technological strengths are Materials, Manufacturing, Non-Destructive Evaluation, Biotechnology, Space Propulsion, Controls and Dynamics, Structures and Microgravity Processing.

Vernotto McMillan
Marshall Space Flight Center
Huntsville, Alabama 35812
256/544-2615
vernotto.mcmillan@msfc.nasa.gov

Stennis Space Center
Selected technological strengths are Propulsion Systems, Test/Monitoring, Remote Sensing and Non-Intrusive Instrumentation.

Kirk Sharp
Stennis Space Center
Stennis Space Center, Mississippi
39529-6000
228/688-1914
kirk.sharp@ssc.nasa.gov

NASA's Business Facilitators

NASA has established several organizations whose objectives are to establish joint-sponsored research agreements and incubate small start-up companies with significant business promise.

Bill Musgrave
Ames Technology Commercialization Center
San Jose, CA
408/557-6820

Greg Hinkebein
Mississippi Enterprise for Technology
Stennis Space Center, MS
228/688-3144

Wayne P. Zeman
Lewis Incubator for Technology
Cleveland, OH
440/260-3300

David Kershaw
Florida/NASA Business Incubation Center
Titusville, FL
321/267-5601

Bridget Smalley
University of Houston/NASA Technology Center
Houston, TX
713/743-9155

Joanne Randolph
Business Technology Development Center
Huntsville, AL
256/704-6000, ext. 202

Julie A. Holland
NASA Commercialization Center/California State Polytechnic University
Pomona, CA
909/869-4477

Martin Kaszubowski
Hampton Roads Technology Incubator
Hampton, VA
757/865-2140

Ann Lansinger
Emerging Technology Center
NASA Business Incubator
Baltimore, MD
410/327-9150

Small Business Programs

Carl Ray
NASA Headquarters
Small Business Innovation Research Program (SBIR/STTR)
202/358-4652
cray@hq.nasa.gov

Paul Mexcur
Goddard Space Flight Center
Small Business Technology Transfer (SBIR/STTR)
301/286-8888
paul.mexcur@pop700.gsfc.nasa.gov

NASA-Sponsored Commercial Technology Organizations

These organizations were established to provide rapid access to NASA and other federal R&D agencies and to foster collaboration between public and private sector organizations. They also can direct you to the appropriate point of contact within the Federal Laboratory Consortium.
To reach the RTTC nearest you, call 800/642-2872.

Ken Dozier
Far West Technology Transfer Center
University of Southern California
Los Angeles, CA 90007
213/743-2353

James Dunn
Center for Technology Commercialization
Westborough, MA 01581
508/870-0042

David Bridges
Economic Development Institute
Georgia Institute of Technology
Atlanta, GA 30332
404/894-6786

Gary F. Sera
Mid-Continent Technology Transfer Center
Texas A&M University
College Station, TX 77840
979/845-8762

Charlie Blankenship
Technology Commercialization Center, Inc.
Newport News, VA 23606
757/269-0025

Marty Kress
Great Lakes Industrial Technology Center
Battelle Memorial Institute
Cleveland, OH 44070
216/898-6400

Joseph P. Allen
National Technology Transfer Center
Wheeling Jesuit University
Wheeling, WV 26003
800/678-6882

Dan Winfield
Research Triangle Institute Technology Applications Team
Research Triangle Park, NC 27709
919/541-6431

Events/ Books

Events

The NASA Advanced Medical Technology Symposium: New Directions in Advanced Medical Systems will be held February 11–13, 2003 at the Doubletree Hotel in Pasadena, California. The guest speakers will include speakers from NASA Headquarters and several NASA Field Centers.

More information about this event will be available in the November/December issue of *Innovation* or visit *https://register.rti.org/nasamedical/*

Books

New Book Highlights Unique NASA Facility

"We Freeze to Please," the slogan for NASA Glenn Research Center's Icing Research Tunnel (IRT), is now also the title of a new book, the latest addition to the NASA History Series.

The newly published book, "We Freeze to Please: A History of NASA's Icing Research Tunnel and the Quest for Safety," tells the story of this unique facility that has made unparalleled contributions to a specialized area of aeronautics research that affects virtually all who fly.

The book is on sale from the US Superintendent of Documents and from the NASA Information Center. Details on ordering the book are available at *http://history.nasa.gov/what.html*

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