National Aeronautics and Space Administration

Research and Technology

Accomplishments




for NASA Dryden Flight Research Center

2008–2009

summary

table of *contents*

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Note: Cover shots are all NASA photos


NASA photo

NASA Dryden Flight Research Center is a diverse and technically focused organization with the skills and capabilities to achieve our mission of advancing science and technology through flight. This report highlights many of the research and technology efforts we accomplished in 2008 and 2009. We are proud of this work, and I thank you for taking the time to read it and share in our accomplishments.

As NASA's premier installation for atmospheric flight research and operations, Dryden plays a vital role in carrying out the agency's missions. Our work contributes to developing advanced technologies for the next generation of aerospace vehicles, improving the utilization and efficiency of the National Airspace System, and increasing our understanding of the planet. The technical capabilities that we have assembled for this work represent an important asset not only for NASA and the commercial aerospace industry but also for industries that appear at first glance to have no connection with aeronautics research and development (R&D).

For example:

- Our unique, state-of-the-art facilities, which conduct world-class flight research, incorporate advanced and innovative processes that are applicable to other areas—from bridges, sailboats, and wind turbines to automobiles, medicine, and software.
- Technologies developed by and for Dryden to address NASA mission needs have been applied to truck and RV design (see page 22), solar cells, machinery monitoring, automotive manufacturing, hearing aids, hand tools, electric motors, computer systems, window insulation, and much more.
- Our pilots, engineers, scientists, and technicians have successfully participated in some of the nation's most complex flight research programs and projects, tapping into and enhancing their expertise in everything from computational analysis to climatology and power systems.

Our future appears bright, and we strive to continue our long tradition of relevant, cutting-edge research and technology work. For more information on our projects or services, or to learn more about how your technologies and needs align with our efforts, please contact us.

Bradley C. Flick
Director, Research and Engineering Directorate
NASA Dryden Flight Research Center

With smoke from the Lake Arrowhead area fires streaming in the background, NASA's Ikhana unmanned aircraft heads out on a Southern California wildfires imaging mission.

NASA photo

The remotely piloted Ikhana aircraft flew over much of California in July 2008 to gather information that was used to help fight more than 1,000 wildfires burning within the state. Of particular note was the data gathered by the Ikhana on the multiple fire "complexes," consisting of fires covering many miles of territory. The Ikhana flights that originated at NASA Dryden used a sophisticated sensor developed at NASA's Ames Research Center, located about 300 miles to the northwest. NASA and the U.S. Department of Agriculture's Forest Service partnered to obtain imagery of the wildfires in response to requests from the California Department of Forestry and Fire Protection, the California Governor's Office of Emergency Services, and the National Interagency Fire Center.

"NASA's emergency imaging gives us immediate information that we can use to manage fires, identify threats, and deploy firefighting assets," Gov. Arnold Schwarzenegger said. "I thank NASA for providing us with this important firefighting tool."

This interagency partnership was recognized by the Federal Laboratory Consortium for Technology Transfer (see page 21).

Dryden Flight Research Center provides support to all NASA missions across the entire agency.

Located at Edwards Air Force Base in California, the Center pursues R&D spanning a wide variety of fields involving aircraft, environmental and earth science, celestial observations, electronic sensors, propulsion, instrumentation, and much more.

NASA Dryden's Research and Engineering Directorate performs the tasks necessary to safely and successfully accomplish the Center's flight research and test missions. From concept development and experiment formulation to testing, data collection and analysis, and systems integration, NASA Dryden's extensive R&D is pushing the aerospace envelope.

Supporting this R&D work is a range of facilities, including:

- More than a dozen piloted and autonomous airborne laboratories that benefit from excellent year-round flying weather
- Fabrication, machine, and sheet-metal shops whose master craftsmen frequently work with exotic alloys and composites
- Dryden Aircraft Operations Facility, which has more than 210,000 square feet of hangar space and an equivalent amount of space for offices, labs, conference accommodations, and storage, making it ideal for collaboration among private industry, visiting scientists and researchers, and aviation-related activity
- A flight loads laboratory that conducts thermal and mechanical-load studies, including ground vibration testing, of structural components, instrumentation, and complete flight vehicles (see page 13 for more about the innovative Starr Soft Support technology that emerged from this lab)
- An aircraft integration facility that offers extensive simulation capabilities, including high-fidelity real-time and batch flight simulation capabilities; closed-loop, hardware-in-the-loop, and vehicle-in-the-loop verification and validation testing; and routine aircraft maintenance

The Starr Soft Support technology

Research Aircraft Integration Facility

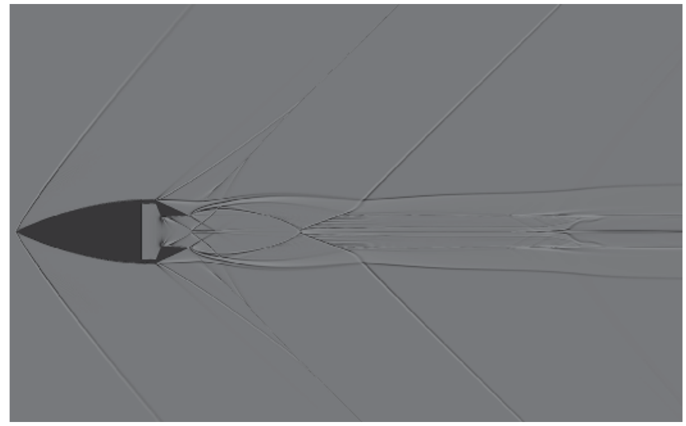
Dryden Aircraft Operations Facility

more information

Read on to learn more about NASA Dryden's R&D related to:

- Aircraft Design and Modeling
- System Performance and Safety
- Shape Prediction and Modeling
- Aircraft-Specific Research

research *and development*



Above: A CFD shadowgraph visualization of imperfectly expanded jet plume effects

At left: Aeroservoelastic modeling

Aircraft Design and Modeling

NASA Dryden Flight Research Center's highly integrated team of engineers has expertise in design and analysis, ground testing, and flight testing. Their work on airframe structures draws upon four primary capabilities:

- Thermal/Structural ground test, analysis, and flight research
- Flight envelope expansion, including static loads and flutter
- Substantial ground test capability
- Development of advanced sensor technology for flight and ground testing, including structural health monitoring

These engineers have pioneered new research in aircraft design and modeling (see pages 10–11), such as:

- Flutter modeling and analysis
- Aeroelastic and aeroservoelastic modeling, analysis, and optimization of flight vehicles
- Ground vibration testing and structural dynamics modeling
- Lift and Nozzle Change Effects on Tail Shock (LaNCETS) flight research

This cutting-edge research benefits NASA in many ways.

Because flight safety is the most critical issue in NASA's flight research program, ***flutter modeling and analysis*** is a priority. NASA Dryden engineers constantly strive to decrease flutter by updating and improving existing software, finite element analysis (FEA) models, and other analysis tools.

Aeroelastic and aeroservoelastic analysis offers two primary benefits: it helps to reduce flutter, and it leads to a more efficient design-optimization cycle. Computational fluid dynamics (CFD) analysis tools advance the state of the art in aeroelastic calculations and predictions. These tools further improve flight safety and enhance aircraft design.

Ground vibration modeling and testing allow engineers to update and refine existing structural dynamics models. Their work minimizes uncertainties in flutter analysis, fine tunes existing models, and improves flight control design.

The ***LaNCETS*** flight research measures shock waves generated by supersonic aircraft to validate models of sonic boom. Flight test results allow engineers to develop and validate improved tools that predict and minimize sonic boom.

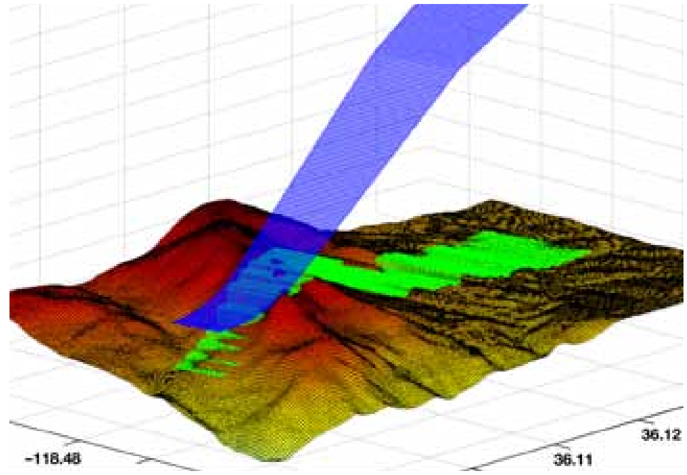
This work has applicability beyond flight safety, health monitoring, design optimization, and supersonic travel. NASA Dryden's R&D capabilities in this area also can be applied to other structures, such as suspension bridges, tall towers or chimneys, and power lines.

NASA Dryden's state-of-the-art aircraft modeling and design capabilities are available to help universities and companies further their research objectives.

System Performance and Safety

NASA Dryden Flight Research Center's flight systems engineers develop and enhance hardware, software, and avionics and control systems. Their work on mission-critical and flight-critical systems focuses on five primary capabilities:

- Flight systems development (single and multi-channel)
- Flight software management and development
- Design, development, test review, and analysis
- Unmanned aerial vehicle (UAV) systems design and development
- Intelligent systems verification and validation



An Auto-GCAS predicted trajectory over simulated terrain

These engineers support many critical NASA programs, including the Stratospheric Observatory for Infrared Astronomy (SOFIA); Orion; and supersonic, subsonic, and aviation safety programs. Recent work on flight systems has focused on the following areas:

- Testing and verifying functionality of the Orion crew module
- Upgrading the automatic ground collision avoidance system (Auto-GCAS)
- Developing adaptive and fault-tolerant flight control systems

Orion Launch Abort System

The Orion crew module's launch abort system makes it possible for the crew to escape from the launch rocket should something go wrong on the pad or during the ascent to orbit. Dryden engineers conducted numerous tests of the launch abort system, including weight and center-of-gravity measurements; vibration and acoustics tests; and readiness tests for the flight control, antenna, pyrotechnic, and ground control systems in order to achieve optimal system performance, ensuring safety of the crew.


Orion launch abort system

Ground Collision Avoidance

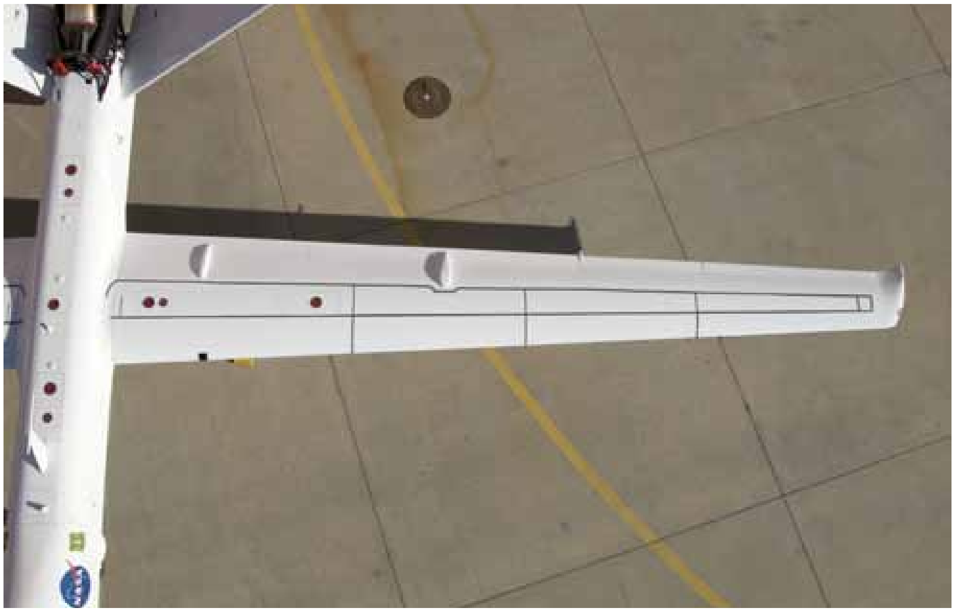
Auto-GCAS is a system designed to prevent a collision when the pilot cannot do so, whether because of spatial disorientation, target fixation, loss of situation awareness, or loss of consciousness. Ground collision avoidance software uses aircraft navigation positional information, the global positioning system (GPS), and digital terrain elevation data to constantly calculate an aircraft's position relative to the Earth. It then calculates the amount of time available before impact and handles the maneuver required to prevent a collision with the ground. Dryden engineers have tested, evaluated, and improved this software to help reduce safety mishaps in aviation.

Flight Control Systems

Current flight control systems are not capable of "learning" how to adapt to new flight conditions, including damage to the aircraft, mechanical failures, weather disruptions, or turbulence. On-the-ground simulations provide valuable data, but only NASA Dryden's flight tests can fully validate state-of-the-art flight control algorithms. This research will be used to further refine adaptive and fault-tolerant flight control systems, benefiting all classes of airborne vehicles.

NASA Dryden's work on aircraft system performance and safety helps all pilots—be they commercial, fighter, transport aircraft, or spacecraft—to fly safer missions.

Note: All images on these pages are NASA graphics.



Fiber optic sensors attached to the wing of the Ikhana (Predator B)

Shape Prediction and Monitoring

NASA Dryden Flight Research Center's engineers have developed fiber optic shape sensors capable of accurately determining aircraft wing shape in real time without affecting performance and without the need for structural modifications. This is a major breakthrough for flight control. Monitoring an aircraft structure with sensors and using a computer to manipulate flight control surfaces to compensate for stresses on the wings enables the possibility of adaptive wing control, which would greatly improve the efficiency and performance of an aircraft. Furthermore, the system relies on virtually weightless optical fibers, each approximately the diameter of a human hair, yielding dramatic improvements in fuel efficiency and operating costs.

The system uses fiber optic sensors to measure surface strain and the Ko displacement theory to determine the wing shape:

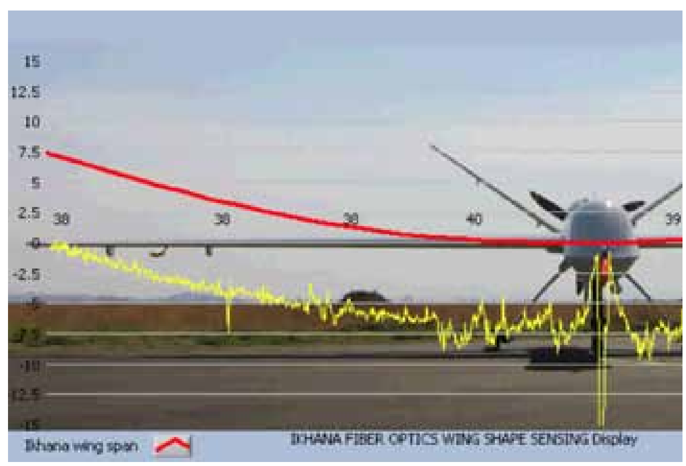
- The optical fibers are applied to an airframe surface or interior.
- When shape changes cause these fibers to bend, the stretching and compression within the fiber sections are measured using fiber Bragg gratings (FBGs) embedded in the fiber.
- A measurement system tracks this strain along the entire length of the fiber, using ultra-efficient algorithms, and the information can then be used to determine the shape of the structure in real time.

This system is capable of acquiring a large number of accurate surface strain, temperature, and displacement measurements in real time for large structures that are undergoing a wide range of displacements during operation. It has been useful in monitoring airframe deflections during high-load situations, such as turbulence and hard landings, and could prove useful in controlling wing and stabilizer flutter.

Within aviation, this system improves the safety of future aircraft and spacecraft and could be a key component in an integrated vehicle health management system. In addition, fiber optic shape sensing research has a wide variety of uses beyond the aerospace industry, including:

- Minimally invasive surgical devices
- Cabled remote-vehicle tracking, such as in collapsed buildings or mineshaft search and rescue
- Three-dimensional underground drilling direction monitoring
- Towed sonar array position tracking
- Wind energy

This system's technologies are available for licensing.



Real-time display of the wing's deformed shape on the ground-based pilot's computer screen

The fiber optic shape sensing team has been honored by NASA for its pioneering work in this area (see page 20).

Note: All images on these pages are NASA photos.

Aircraft-Specific Research

NASA Dryden Flight Research Center conducts innovative flight research that continues to expand its world-class capabilities, with special expertise in research and testbed platforms, science platforms, and support aircraft.

Recent flight projects have relied on high-performance aircraft such as the F-15B, the X-48B blended wing body aircraft, and the Stratospheric Observatory for Infrared Astronomy (SOFIA).


F-15B

High Performance Aircraft

NASA Dryden researchers use high-performance aircraft, such as the F-18, F-15 and the F-16XL to study the effects of various aircraft modifications on sonic boom signatures. Recent research investigated ways to reduce sonic boom magnitude, reduce noise disruption in areas where aircraft reach supersonic speeds, and improve design tools for better predictions. Commercial companies currently developing supersonic aircraft will face stringent regulation with respect to sonic booms, and NASA Dryden's research data can help them minimize the impact of sonic booms and streamline the design process.


X-48B

X-48B

The X-48B is used to study the structural, aerodynamic, and operational advantages of the blended wing body aircraft—a cross between a conventional airplane and a flying wing design. The goal is to achieve increased performance in efficiency, maneuverability, stability, and control for hybrid wing body configurations. The flight test data have led to improved computational and analysis tools. Flight tests also help researchers to determine whether the X-48B design has potential as a long-range military transport aircraft.


SOFIA

SOFIA

Scientists and technicians eagerly await the first science mission of NASA's SOFIA. Dryden engineers have conducted numerous flight tests on SOFIA, analyzing the aerodynamics of closed- and open-door flights, to ensure that the observatory is fully operational and safe for the scientists who will operate the 17-ton infrared telescope on board. SOFIA will provide breakthrough scientific data and enable world-class astronomical observations for the worldwide science community.

NASA Dryden's aircraft are available for use by commercial, academic, and government labs.

DRYDEN'S AIRCRAFT

NASA Dryden Flight Research Center takes on a vast array of complex and critical flight research projects that often require the use of highly specialized and cutting-edge aircraft. NASA Dryden offers the following platforms.

Research and Testbed Platforms

F-15B: Provides long-term capability for flight research experiments
F/A-18: Performs versatile research duties

Science Platforms

DC-8 Airborne Laboratory: Promotes and supports science operations
ER-2 High-Altitude Platform: Flying laboratory in the Sub-Orbital Science Program
Global Hawk: Conducts long-duration, high-altitude environmental science missions with autonomous, piloted operation
Gulfstream III UAVSAR: Tests and evaluates new radar, and gathers scientific data on geological events (see page 21 for information about an award-winning project)
Ikhana (Predator B): Supports Earth science, advanced aeronautical technology development, and R&D designed to improve the utility of unmanned aerial systems
SOFIA: Readies for 2010 launch as the world's largest airborne telescope

Support Aircraft

F-18 Chase Aircraft: Helps maintain total flight safety during specific tests and maneuvers
Gulfstream III (G-III): Serves as a cost-effective, multi-engine companion proficiency trainer aircraft
Super KingAir: Provides mission support, pilot proficiency, and a testbed for flight research experiments
T-34C: Accompanies research flights for photography, for video data collection, and as safety chase
T-38 Talon: Used for proficiency and mission support flights

r&d *projects*

Project	Research Focus
Aircraft Design and Modeling	
Aeroelastic Uncertainty Analysis Toolbox	Building an aeroelastic uncertainty analysis toolbox
Distributed Aerodynamic Sensing and Processing Toolbox	Creating a distributed aerodynamic sensing and processing toolbox
Reduced Uncertainties in the Robust Flutter Analysis of the Aerostructures Test Wing	Tuning the finite element (FE) model to minimize uncertainties in flutter analysis
Aeroservoelastic Stability Analysis of the Aerostructures Test Wing	Analyzing aeroservoelastic stability
Basis Function Approximation of Transonic Aerodynamic Influence Coefficient Matrix	Optimizing the process of transonic aircraft design
Application of Approximate Unsteady Aerodynamics for Design Optimization	Developing an aerodynamic influence coefficient (AIC) matrix for aeroelastic analysis and design optimization
Updating Finite Element Model of the Aerostructures Test Wing Using Ground Vibration Test Data	Creating a more efficient and accurate structural dynamics FE model
CFD Analysis of LaNCETS Nozzle Jet Plume Effects on Sonic Boom Signature	Studying computational fluid dynamics (CFD) of how the nozzle exhaust jet plume affects a supersonic aircraft's sonic boom
Using Inner Loop Thrust Vectoring Control Laws for Lift and Nozzle Change Effects Flight Research	Determining the effects of lift distribution and nozzle area ratio changes on tail shock strength
System Performance and Safety	
Orion Abort Flight Test Crew Module and Adapter Cone Shaker Test	Testing of Orion crew module launch abort system
Testing the Orion CEV Launch Abort System Ascent Abort Flight Test	Verifying the functionality of the launch abort system of the Orion crew exploration vehicle (CEV)
Real-Time Decompression and Local Map Rendering from a Highly Compressed Digital Terrain Map	Decompressing maps for automatic ground collision avoidance system (Auto-GCAS)
Automatic Collision Avoidance Technologies Flight Tests	Testing automatic collision avoidance technology
Adaptive Feedforward Control for Gust Loads Alleviation, Modal Suppression, and Flutter/Limit Cycle Oscillation Prevention	Designing an adaptive feedforward feedback control framework
Shape Prediction and Monitoring	
Extension of Ko Straight-Beam Displacement Theory to the Deformed Shape Predictions of Curved Structures	Applying Ko displacement theory to shape predictions of curved structures
Application of Ko Displacement Theory to Deformed Shape Predictions	Calculating movement of Ikhana wing during flight
Aircraft-Specific Research	
Handling Qualities Prediction of an F-16XL-Based Reduced Sonic Boom Airplane	Predicting the handling qualities of a reduced-sonic-boom airplane design
SOFIA Closed- and Open-Door Aerodynamic Analyses	Analyzing aerodynamics of closed- and open-door flight of Stratospheric Observatory for Infrared Astronomy (SOFIA) aircraft
X-48B Aerodynamic System Identification	Using flight test maneuvers to gauge stability and control of X-48B aircraft

For more details about these R&D projects, see the *2008/2009 Research and Engineering Annual Report*, available online at http://dtrs.dfrc.nasa.gov/

Findings/Accomplishments	Benefits for NASA	Other Uses
Created computationally efficient methods to predict flutter	More accurate prediction and decreased risk for flutter instability	✓
Measured unsteady aerodynamic loads in real time and correlated them with structural response	More advanced computational modeling, better flutter prediction techniques, and improved design and development of flight vehicles	
Improved accuracy of flutter analysis	Increased flight safety and improved flight control system design	✓
Formulated an automatic loop-breaking test to determine aeroservoelastic stability	Improved tools used for analyzing flutter safety	✓
Verified a methodology that performs aeroelastic calculations more efficiently	Enhanced design approaches for aircraft that travel at transonic speed	✓
Increased accuracy and reduced computation time of flutter speed prediction on the Aerostructures Test Wing (ATW)	More efficient design optimization cycle	✓
Updated and refined the FE model using ground vibration test data	Better predictions of aircraft instability and flutter	✓
Confirmed that nozzle flow of F-15-type aircraft provides significantly more reduction in sonic boom strength than other nozzles	Improved analysis for the Lift and Nozzle Change Effects on Tail Shock (LaNCETS) Project	
Provided data allowing engineers to compare results with pre-flight prediction tools and update those tools	Better aircraft stability and control with the changes in lift distribution and plume shape	
Recommended a vehicle damping schedule to control excess motion and oscillation	Improved system performance and development of additional methods to abort a launch	
Improved ability to separate the crew module from a failed launch vehicle	Enhanced safety of the crew in the event of a failure during launch	
Designed, developed, documented, and successfully tested decompression software	Improved tools for airplane pilots to determine ground proximity and avoid a ground collision	✓
Tested, evaluated, and improved collision avoidance software	Reduced incidence of ground collision in aviation	
Developed new methods for suppressing aircraft structural vibrations	Better tools for identifying, controlling, and reducing structural vibrations during flight	
Modified equations to provide accurate shape predictions for any curved beam, up to 90° arc	More accurate shape predictions using fiber optic strain sensors	✓
Provided accurate predictions of bending and torsion	Improved tool for monitoring in-flight deformed shapes of wings	✓
Obtained data showing aircraft designers to what extent the airplane could be modified to reduce sonic boom without affecting handling qualities	Reduced sonic boom for increased and better supersonic travel	
Developed models needed for open-door flight tests	Enhanced airborne observatory designed to complement space- and Earth-based telescopes	
Developed, modified, and validated computational and analysis tools for parameter identification maneuvers	Increased efficiency and maneuverability for hybrid wing body configurations	

innovative *technologies*

The innovative technologies developed at NASA Dryden Flight Research Center have applications far beyond their original purpose. These technologies are available for use by non-NASA organizations, including commercial entities. For more information about licensing these and other NASA Dryden technologies, contact us at 661.276.3119 or DFRC-Technology@nasa.gov.

Sound Shield

Jet engine noise reduction has become an important aspect of aircraft design. The sound shield is a low-cost apparatus capable of blocking or attenuating noise generated by aircraft traveling at subsonic speed. This patented technology improves upon earlier technical solutions in that it decreases sound waves "upstream" of the aircraft. It also may reduce wear and fatigue of aircraft components and offers a low-cost design that does not affect aircraft efficiency or performance. The sound shield may be used in commercial aircraft and high-speed rail.

Guidance and Control for an Autonomous Soaring UAV

Dryden engineers studied the capability of unmanned aerial vehicles (UAVs) to autonomously detect and exploit atmospheric convective updrafts, or thermals. The potential benefits include greater range and duration of flight, thereby increasing a UAV's mission coverage area; reduced noise, which allows the UAV to fly undetected; and less energy consumption. Their patented guidance and control methodology can be used in military drones and in unmanned aerial mapping or surveillance, including resource mapping, geophysical exploration, mapping or surveillance in harsh or dangerous environments, traffic information and/or control, and law enforcement.

Cable Tensiometer for Aircraft

Many aircraft employ numerous cables to make very sensitive adjustments while in flight. Cable tensiometers can be used to determine, in real time, the precise tension on aircraft cables. However, commercially available tensiometers are not well-suited for use on an aircraft because they cannot accommodate fixed-end cable systems, they are too heavy, or their measurements are too imprecise. This patented technology offers a lightweight, precise, and repeatable device well-suited for use on commercial or non-commercial aircraft.

Improved Process for Using Surface Strain Measurements to Obtain Operational Loads for Complex Structures

Dryden engineers have developed a patent-pending method for accurately determining wing shape using Fiber Bragg Grating (FBG) sensors. The technology offers real-time capability with a refresh rate of 60 cycles per second, is packaged in a compact unit the size of a CD-ROM player, and relies on fiber optic sensors that are virtually weightless. Because the technology has been field tested, it offers less development time and lower cost. The method can be used in a number of applications, including airplanes, wind turbines, medical devices, and automobiles. (See page 8 for more information.)

Real-Time Interactive Sonic Boom Display

This patent-pending software system predicts the location and intensity of shock waves caused by supersonic vehicles. It can be integrated into onboard flight systems or flight control rooms, enabling pilots to take appropriate actions or make the necessary flight adjustments to produce an acceptable boom in the desired location. The sonic boom display provides more accurate predictions, using real-time data, thereby minimizing the impact of sonic boom. This software will be of value to the Federal Aviation Administration, the military, and companies developing commercial supersonic aircraft.

Improved Monitoring of Heat Stress

Dryden engineers have developed an improved and automated algorithm to monitor heat stress in humans. The algorithm relies on standard atmospheric measurements to estimate the effect of temperature, humidity, wind speed, and solar radiation on humans. Heat stress measurements typically are not available, and the instruments are prohibitively expensive. The data provided by this algorithm addresses these problems, benefitting businesses or industries that require outdoor work, and schools and universities that sponsor sporting events or other outdoor activities. This innovative technology is not site specific, and its predictions of heat stress can prevent dangerous exposure to excessive heat conditions.

Model for an Aerial Refueling System

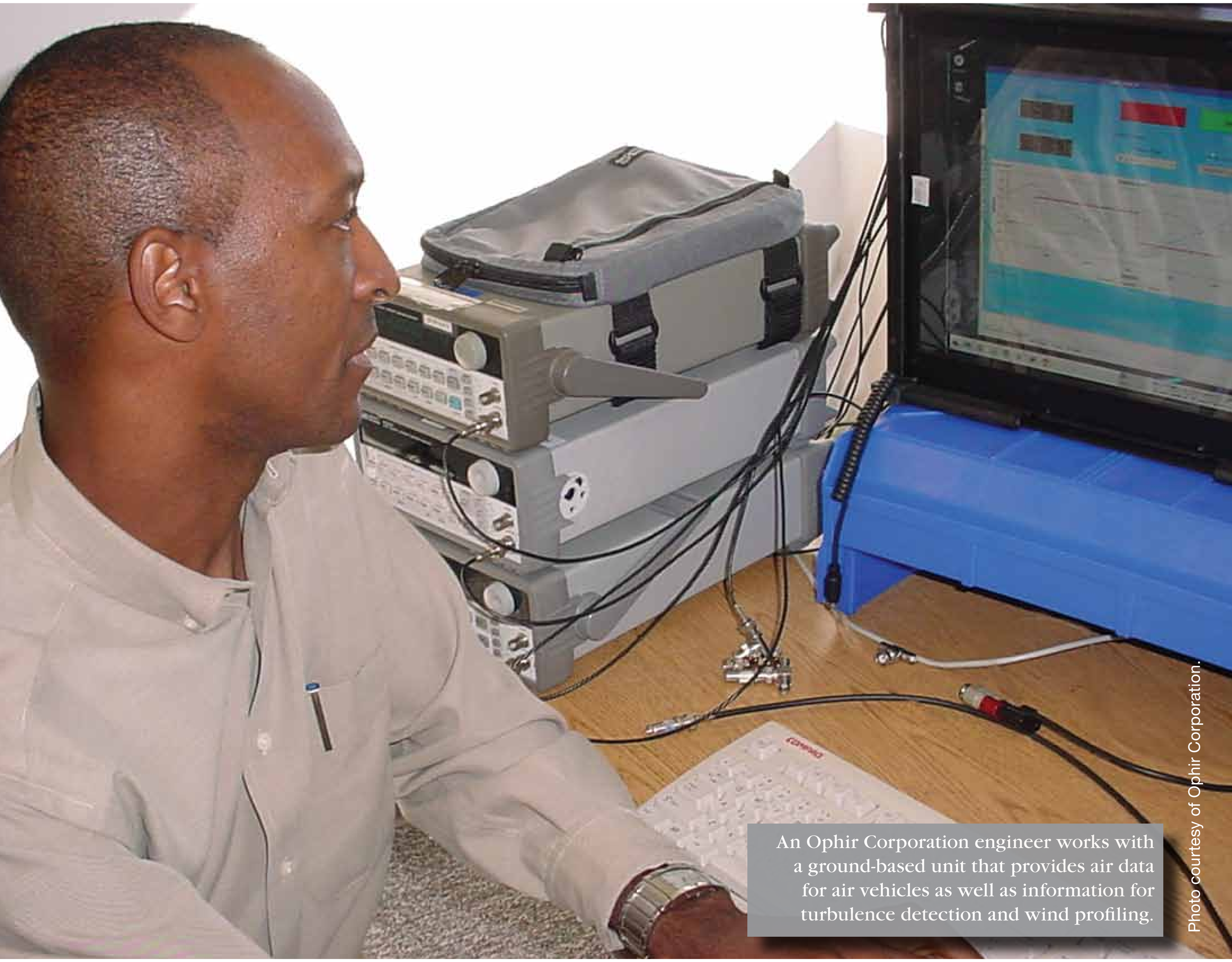
As the use of UAVs has grown, there exists a greater need for automated aerial refueling. Dryden engineers conducted flight tests to study hose-and-drogue system dynamics, and then they used that data to develop a flight-test-validated model. This validated model will help in the future design of automated aerial refueling systems for UAVs. Autonomous aerial refueling would enable UAVs to travel farther distances and hover over critical targets for extended periods of time. An automated aerial refueling system can be used on military drones and in unmanned aerial mapping or surveillance.

Starr Soft Support

NASA Dryden's world-class aircraft testing facility now offers the most advanced aircraft isolation system currently available. The Starr Soft Support technology is used for weight and measurement tests, control surface free-play tests, and structural mode interaction. Unlike traditional critical-lift operations, the Starr Soft Support isolation system enables an aircraft to float in mid-air, without the need for personnel to lift it into place or stand beneath the suspended aircraft. Starr Soft Support provides an automated aircraft jacking capability, significantly reducing testing risk, time, and costs.

Issued Patents	**Inventors**
Aeronautic Sound Shield - U.S. Patent No. 7,407,131	Stephen Corda, Mark S. Smith, and David D. Myre
Improved Guidance and Control for an Autonomous Soaring UAV - U.S. Patent No. 7,431,243	Michael Allen
Method for Real-Time Structure Shape-Sensing - U.S. Patent No. 7,520,176	William Ko and Lance Richards
Improved Process for Using Surface Strain Measurements to Obtain Operational Loads for Complex Structures - U.S. Patent No. 7,715,994	Lance Richards and William Ko
Filed Patent Applications	**Inventors**
Real-Time Interactive Sonic Boom Display	Edward Haering and Ken Plotkin
Smart Material Coated Fiber Bragg Grating Sensors	Michael Emmonds, Lance Richards, Mohanchandra Panduranga, Greg Carman, and Sunny Karnani

the role of *small business*



An Ophir Corporation engineer works with a ground-based unit that provides air data for air vehicles as well as information for turbulence detection and wind profiling.

Photo courtesy of Ophir Corporation.

Ophir Corporation, of Littleton, Colorado, has been working with NASA since 1985 on a variety of projects, mostly through the Small Business Innovation Research (SBIR) program. Recently, Ophir has held Dryden-based SBIR contracts to provide proof-of-concept laboratory testing of a new approach to optical air data systems.

Traditionally, air data is measured with several probes that are mounted on an aircraft, including immersion temperature probes and pitot airspeed probes, as well as with flush-mounted static pressure ports. Ophir addressed the problem of determining the characteristics of the air outside of the boundary layer of an aircraft. This development included the use of a single sensor to replace the conventional air data sensors that are prone to such failures as icing and the plugging of pitot tubes. An optical air data sensor now provides the potential for important benefits to high-performance aircraft. These include measurements in difficult aircraft attitudes, potentially higher update rates, and reduced calibration and maintenance costs.

For more information about this SBIR success, visit http://spinoff.nasa.gov.

Technological innovation is the overall focus of NASA's Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs. These programs are vital to the achievement of NASA missions and to the nation's prosperity and security. They contribute to the economic engine that drives hiring and other growth for small businesses—the backbone of the U.S. economy and the future for U.S. technology development.

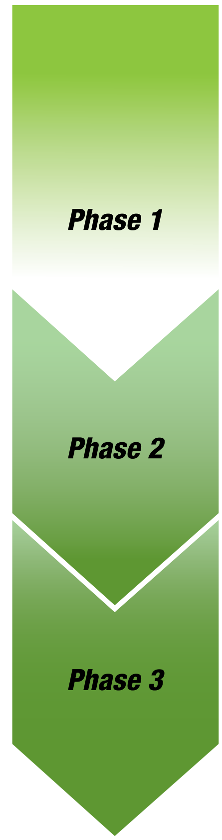
NASA's SBIR/STTR programs provide opportunities for small, high-technology companies and research institutions to participate in government-sponsored R&D efforts in key technology areas. In SBIR contracts, the small business operates independently; STTR contracts involve a research institution partnering with a small business to develop a technology.

The SBIR/STTR programs fund R&D and demonstrations of innovative technologies to fulfill NASA needs. These needs are described in the annual SBIR/STTR solicitation. Innovations receiving SBIR/STTR funding also have significant potential for successful commercialization.

Three-Phase Funding

The SBIR/STTR programs provide funding in three phases:

- Phase 1 SBIR contracts last up to 6 months and provide maximum funding of $100,000. The duration of STTR Phase 1 contracts is typically 12 months, also with a maximum funding of $100,000.
- Phase 2 SBIR/STTR contracts focus on the development, demonstration, and delivery of the proposed innovation. Contracts usually last for 24 months, with maximum funding of $600,000, although Phase 2 Enhancement (2-E) contracts also are available. Under Phase 2-E contracts, NASA may use SBIR/STTR funds to match up to $150,000 of non-SBIR/STTR investment, extending an existing Phase 2 project for up to 4 more months to perform additional research.
- Phase 3 contracts are funded from sources other than the SBIR/STTR programs and may be awarded without further competition.



COTR Appreciation

Contracting officer's technical representatives (COTRs) dedicate time to ensuring that the R&D being pursued under SBIR/STTR contracts remains well aligned with NASA's technical needs. Their hard work is much appreciated by the Center and the Agency.

Martin J. Brenner	Christine V. Jutte
Bruce Cogan	Syri Koelfgen
Michael Delaney	Sunil Kukreja
Starr Ginn	Mark Mangelsdorf
Kajal Gupta	Chan-gi Pak
Ed Haering	Mark Pestana
Phil Hamory	Nalin Ratnayake
Larry Hudson	Craig Stephens
Tom Jones	

contact us

For more information about the SBIR/STTR programs at NASA Dryden Flight Research Center, contact:

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sbir/sttr *phase 2 awards*

The following Phase 2 projects—all of which can benefit NASA, military and commercial aerospace, and even other industries—are currently underway.

SBIR Projects

project: **Fused Reality for Enhanced Flight Test Capabilities**
company: **Systems Technology, Inc. (STI) of Hawthorne, California**

The Fused Reality (FR) flight system will allow a virtual environment to be integrated with test aircraft. The system design enables aerial refueling, formation flying, approach and landing, or other tasks to be accomplished without additional aircraft or risk of operating in close proximity to the ground or other aircraft. For the first time, the dynamic motions of the simulated objects will be directly correlated with the responses of the test aircraft. The resulting product will offer benefits to NASA, the Department of Defense, and commercial aviation.

project: **Aeroelastic Uncertainty Analysis Toolbox**
company: **STI of Hawthorne, California**

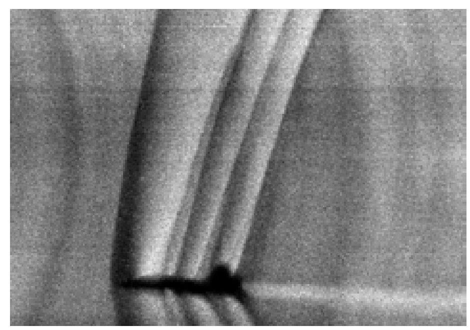
The analytical prediction of aeroelastic phenomena—flutter, limit-cycle oscillations, buffeting, buzz, undesirable gust response, and others—in the transonic regime requires high-fidelity, yet computationally expensive, simulation models. STI is developing methods that reduce the existing computational time limitations of traditional uncertainty analysis. The STI–Aeroservoelastic Robustness Toolbox will use computational unsteady aerodynamic and structural finite element models from a variety of sources, making it a valuable asset for the NASA, military, and commercial efforts for the design, analysis, and test of air vehicles.

project: **Piezoelectric Structural Microsensor Technology for Extreme Environments**
company: **TRS Ceramics, Inc. of State College, Pennsylvania**

TRS Ceramics is working to meet NASA's needs for high-temperature piezoelectric crystal (HTPC) sensors for high-temperature sensor applications, such as propulsion component structure health monitoring. The company is characterizing prototypes of highly sensitive HTPC microsensors for temperature, stress, and acceleration measurements at temperatures up to 2,000°F (nearly 1,110°C). Because of their low profile, simple structure, high sensitivity, quick response, and high reliability, HTPC microsensors will significantly advance NASA, military, and industrial applications. Uses include controlling and health monitoring of turbine engines and improving performance and maintainability of power production facilities.

project: **An All-Electronic, Adaptive, Focusing Schlieren System for Flight Research**
company: **MetroLaser, Inc. of Irvine, California**

This project is developing the next generation of schlieren for aircraft in flight (SAF) systems. SAF obtains schlieren images of aircraft as they fly past the edge of the sun. The original technique, which involved recording images with a time delay and integration (TDI) camera using slit masks that conformed to the edge of the sun, was fraught with problems due to alignment challenges. However, these problems can be solved using a synthetic TDI method—that is, recording the aircraft transit of the sun on high-speed video and then computationally performing the TDI process. Such SAF systems are less sensitive to movement of the observation platform and can be used with non-cooperative targets with unknown flight paths and velocities.



project: **Innovative Self-Powered and Self-Contained Sensor Array for Separation Detection**
company: **Rolling Hills Research Corp. (RHRC) of El Segundo, California**

Because separated flow can dramatically increase drag, RHRC is developing a self-contained, self-powered, robust flight test sensor array to determine separation accurately, efficiently, and cost-effectively. The system is based on tufts attached to individual bimorph piezoelectric sensors. The self-contained, reusable blanket array can be quickly and easily applied to surfaces without the need for wiring, external power, or remote viewing. The system is well suited to aircraft and other types of vehicles—from automobiles to trains, buses, and trucks—and could be applied to internal ductwork for heating, ventilation, and cooling (HVAC) systems or even automated yacht sail-trimming systems.

project: **Aircraft Nodal Data Acquisition System (ANDAS)**
company: **Waddan Systems of Northridge, California**

The ANDAS technology is designed as a cement-and-forget device for the test and measurement of airplanes during flight as well as on ground with various simulated loading scenarios. The system employs very thin (135 µm) hybrid microminiature sensor assemblies (MSAs) cemented at several nodes on the aircraft. Measuring pressure, temperature, acceleration, and surface strains, the MSAs transmit the data to the host module plugged into a PC. The technology could be utilized in lightweight, flexible, and unstable aircraft structures. It also can be used in hard-to-access or remote nodes in power plants, vehicle engines, medically implanted devices, and more.

project: **Adaptive Feedforward Feedback Control (AFFC) Framework**
company: **Zona Technology, Inc. of Scottsdale, Arizona**

This AFFC framework is designed to suppress an aircraft's structural vibrations and to increase the resilience of the flight control law by reducing atmospheric-induced vibrations. Applied as an additive perturbation of the flight control system, the AFFC will suppress any undesired aeroelastic/aeroservoelastic interactions and prevent the onset of flutter/limit-cycle oscillation instabilities. The project is expected to help NASA achieve an integrated flight control system resilient to failures, damage, and upset conditions unforeseen during the aircraft's development. Non-aircraft applications for this technology include noise-cancellation headphones, computer server fans, and automobiles.

STTR Projects

project: **Aerospace Vehicles Flight Dynamic Modeling and Simulation**
company: **Advanced Engineering Solutions, Inc. of Ormond Beach, Florida**
research institution: **Oklahoma State University**

Air-breathing hypersonic flight vehicles (AHFVs) are expected to enable safe, affordable, routine travel to low Earth orbit. Advanced Engineering Solutions has evaluated relevant current simulation capabilities, developed aerothermoelastic-propulsion simulation of AHFVs and other flight vehicles, and generated a set of recommendations for multidisciplinary simulation capability. Now, working with Oklahoma State University, the company is extending these efforts to include acoustics. The result will be an independent, multidisciplinary design and analysis tool, primarily employing numerical, finite element–based computer codes in aerodynamics, thermal, structures, propulsion, controls, and more. The technology is expected to be applicable to mechanical, marine, and civil engineering uses.

project: **Reusable, Oxidizer-Cooled, Hybrid Aerospike Rocket Motor for Flight Test**
company: **Rolling Hills Research Corp. of El Segundo, California**
research institution: **Cal Poly Corporation**

This technology involves using nitrous oxide (N_2O) to provide the cooling required for reusable operation of an aerospike nozzle in conjunction with an N_2O-HTPB hybrid rocket motor. HTPB, or hydroxyl-terminated polybutadiene, is a synthetic rubber that is used as a binder in solid rocket motors and as a fuel in hybrid rocket motors. The technology will enable much-needed flight research of aerospike nozzles for use in launch vehicles, sounding rockets, tactical missions, or future NASA single-stage-to-orbit programs. It also could offer benefits to the U.S. military and the numerous companies working to develop inexpensive low Earth orbit launch vehicles.

project: **GVT-Based Ground Flutter Test without Wind Tunnel**
company: **Zona Technology, Inc. of Scottsdale, Arizona**
research institution: **Arizona State University**

This project is advancing the Dry Wind Tunnel (DWT) system—an alternative to wind tunnel–based flutter testing. Researchers successfully demonstrated the validity of the concept and are now bringing it to the next level. The DWT system consists of a ground vibration test (GVT) hardware system—composed of shakers and sensors—and a real-time unsteady aerodynamic force generation software system developed from an aerodynamic reduced-order model. The DWT approach offers several advantages, including cost and time efficiency, and is applicable to flutter envelope expansion and flying quality programs of NASA, military, and civil transport as well as general aviation aircraft.

Note: All images on these pages are NASA photos.

dryden's cutting-edge *expertise*

NASA Dryden engineers and technicians prepare for a simulated flight of an F-18.

NASA photo

NASA Dryden Flight Research Center's Research and Engineering Directorate is responsible for the overall engineering content of flight research projects. The engineering staff provides technical expertise in aerodynamics; guidance, navigation, and control; propulsion; static and dynamic structures; flight hardware and software; flight and ground test instrumentation and data systems; and systems engineering and integration. They apply this expertise to perform concept development; experiment formulation; system modeling and validation; systems analysis; experimental system development and testing; test conduct and support; data collection, analysis, and reporting; and project-level systems integration. They also support the development and continual evolution of engineering tools and test techniques.

The personnel that compose the staff at NASA Dryden Flight Research Center are some of the best in the world. Our researchers and engineers make up a key part of our team of talented, motivated, and innovative employees. These staff members have expertise that is used across six areas of research.

Aerodynamics and Propulsion

Our engineers perform fundamental research in supersonic transition, sonic boom propagation and measurement, and circulation control. Their expertise includes fluid and flight mechanics, air data measurement, and propulsion technologies. They also provide meteorological support, such as forecasting and forensic meteorology.

Aerostructures

This highly integrated team covers the breadth of the airframe structures disciplines and is well versed in structural instrumentation technologies. These talented engineers have experience ranging from extremely lightweight, high-altitude aircraft to transports and high-performance military aircraft to hypersonic vehicles.

Dynamics and Controls

These engineers specialize in research of flight control systems, components, and methodologies and perform stability and controls analysis, handling qualities analysis, and verification and validation testing. They have expertise in flight guidance, navigation, and control as well as flight dynamics.


NASA photo

Starr Ginn, inventor of the Starr Soft Support technology (see page 19) and Deputy Branch Chief, Engineering Directorate


NASA photo

The NASA Dryden 747 Shuttle Carrier Aircraft crew poses in an engine inlet.

Flight Instrumentation

Focused on designing and integrating data acquisition systems for research, support, and one-of-a-kind platforms, these engineers place particular emphasis on providing accurate flight data for research aimed at designing the next generation of flight vehicles.

Flight Systems

Organized into three groups—hardware, software, and systems—these engineers develop and engineer avionics and control systems for flight platforms. They specify design, develop, verify, validate, implement, and support avionics systems for flight. They also have expertise in defining, classifying, and programming software for critical aircraft systems.

Systems Engineering and Integration

With a goal of designing, building, and operating systems in the most cost-effective way possible, these engineers provide technical planning as well as services to help manage requirements, risk, and configuration. These services mainly are provided to large and complex flight and space projects.

more information

Read on to learn more about the achievements of NASA Dryden's personnel:

- Awards
- Conference papers

award *winners*

Exceptional Engineering Achievement Medal

Allen Parker – for significant advancement in the state-of-the-art for advanced, flight-capable fiber optic strain sensing systems

Exceptional Achievement Medals

Jennifer H. Cole – for applications of propulsion-controlled aircraft research using throttles-only control

Edward A. Haering – for development of the supersonic low-boom, no-boom flight research experiment

James A. Lee – for design and execution of a platform precision autopilot for repeat-pass interferometry using an aircraft

Ting C. Tseng – for execution of the first flight and ferry of the SOFIA platform aircraft to NASA Dryden (see page 9 for more about SOFIA)

Exceptional Administrative Achievement Medal

Everlyn Y. Cruciani – for improved publications processes and operations with substantial benefit to the Center

Exceptional Public Service Medal

Florence B. Norman – for sustained exceptional contributions to Dryden's contract and financial management

Group Achievement Awards

Fiber Optic Shape Sensing Team

NASA honored the four-member team that successfully developed and tested innovative fiber optic strain measurement systems and algorithms (see pages 8 and 12): Dr. William Ko, aerospace engineer; Allen Parker, systems engineer; Anthony Piazza, instrumentation specialist; and Dr. Lance Richards, aerospace engineer.

The medal-winning team continues to push the boundaries of this technology, creating more efficient processing algorithms; analyzing how this research might apply to other structures; and handling spinoff inquiries from several industries, including automotive health monitoring, alternative energy, and medical devices. "It's very rewarding working with this team," said Dr. Richards, "and there are many untapped areas still to be discovered with this technology."

Intelligent Flight Control System Project Team

When unforeseen damage or failure occurs in flight, pilots need a system that will automatically diagnose and adapt—instantly, accurately, and in real time. The Intelligent Flight Control System Project team has been awarded a NASA medal for developing a state-of-the-art adaptive flight control system that can correctly identify and respond to dynamic changes in an aircraft and immediately react to maintain optimal flight performance.

The team continues to refine this system to ensure that it performs optimally in every

CONFERENCE PAPERS

2008

46th AIAA Aerospace Sciences Meeting

"Stability and Controls Analysis and Flight Test Results of a 24-Foot Telescoping Nose Boom on an F-15B Airplane," CM Moua, TH Cox, SC McWherter

"The X-43A Six Degree of Freedom Monte Carlo Analysis," E Baumann, C Bahm, B Strovers, R Beck, M Richard

26th Congress of the International Council of the Aeronautical Sciences

"Structural Model Tuning Capability in an Object-Oriented Multidisciplinary Design, Analysis, and Optimization Tool," S-f Lung, C-g Pak

"Multidisciplinary Design, Analysis, and Optimization Tool Development Using a Genetic Algorithm," C-g Pak, W Li

AIAA Guidance, Navigation, and Control Conference

"X-43A Flush Airdata Sensing System Flight Test Results," E Baumann, JW Pahle, MC Davis, JT White

"Flight Results of the NF-15B Intelligent Flight Control System (IFCS) Aircraft with Adaptation to a Longitudinally Destabilized Plant," JT Bosworth

"Platform Precision Autopilot Overview and Flight Test Results," V Lin, B Strovers, J Lee, R Beck

"In-Flight Stability Analysis of the X-48B," CD Regan

8th Aviation Technology, Integration, and Operations Conference

"Large UAS Operations in the NAS – the NASA 2007 Western States Fire Missions," GP Buoni, KM Howell

14th AIAA/CEAS Aeroacoustics Conference

"Initial Results from the Variable Intensity Sonic Boom Propagation Database," EA Haering Jr., LJ Cliatt II, TJ Bunce, TB Gabrielson, VW Sparrow, LL Locey conceivable scenario. NASA engineers fully expect the technology to be used in new experimental aircraft, spacecraft, and eventually commercial airlines.

Gulfstream III UAVSAR Project Team

Members of the Unmanned Air Vehicle Synthetic Aperture Radar (UAVSAR) team were recognized for their development of a highly accurate navigation technique. The Gulfstream G-III flight validated a new, compact, synthetic aperture radar capable of providing precise details about topography and ground motion. Eventually to be used by unmanned aerial vehicles, the radar pod will contribute to our scientific understanding of many significant geophysical events around the world, including global warming, earthquakes, landslides, and volcanic activity. UAVSAR was recently sent to Haiti to make three-dimensional maps of the deformation that caused the magnitude 7 earthquake in January 2010.

Federal Laboratory Consortium for Technology Transfer (FLC): Interagency Partnership Award

Wildfire Research and Applications Partnership

This FLC award recognized the efforts of the Wildfire Research and Applications Partnership (WRAP). WRAP has enabled scientists and engineers at Dryden Flight Research Center, as well as NASA's Ames Research Center, to participate in managing forest fires through remote sensing observations on UAV missions (see page 4). NASA's partners in this project were the U.S. Department of Agriculture's Forest Service Remote Sensing Application Center, the National Interagency Fire Center, and the Federal Aviation Administration.

During missions in summer 2008, Dryden's remotely piloted Ikhana aircraft carried an Ames-developed sensor as it flew over more than 1,000 wildfires burning in California. In one case, the Ikhana flew over a region of Butte County and discovered a hot spot near the town of Paradise. This led to the entire population of 10,000 being put under a mandatory evacuation.

Because of this partnership, wildlife agencies are better positioned to fight wildfires, reduce expenditures, evacuate at-risk populations, and save lives.

2009

47th AIAA Aerospace Sciences Meeting

"CFD Analysis of Nozzle Jet Plume Effects on Sonic Boom Signature," TT Bui

"Design and Calibration of a Flowfield Survey Rake for Inlet Flight Research," DC Flynn, NA Ratnayake, M Frederick

"Ground/Flight Correlation of Aerodynamic Loads with Structural Response," AS Mangalam, MC Davis

"X-48B Flight-Test Progress Overview," TK Risch, G Cosentino, CD Regan, M Kisska, N Princen

AIAA Infotech@Aerospace Conference

"Flight Test Comparison of Different Adaptive Augmentations of Fault Tolerant Control Laws for a Modified F-15 Aircraft," JJ Burken, CE Hanson, JA Lee, JT Kaneshige

"Implementation of an Adaptive Controller System from Concept to Flight Test," RB Larson, JJ Burken, BS Butler, S Yokum

33rd International Symposium on Remote Sensing of Environment

"Cyberinfrastructure for Airborne Sensor Webs," LC Freudinger

"NASA Global Hawk: A New Tool for Earth Science Research," JC Naftel

50th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference

"Updating the Finite Element Model of the Aerostructures Test Wing Using Ground Vibration Test Data," S-f Lung, C-g Pak

AIAA Atmospheric Flight Mechanics Conference

"A Flight Dynamics Perspective of the Orion Pad Abort One Flight Test," J Idicula, PS Williams-Hayes, R Stillwater, M Yates

Fifth International Workshop on the Analysis of Multi-Temporal Remote Sensing Images

"Platform Precision Autopilot Overview and Mission Performance," BK Strovers, JA Lee

AIAA Space 2009 Conference

"First Stage of a Highly Reliable Reusable Launch System," KJ Kloesel, JA Pickrel, EL Sayles, M Wright, D Marriott, L Holland, S Kuznetsov

A cab over engine tractor trailer was leased by NASA Dryden, tested, and modified to reduce aerodynamic drag.

NASA photo

The Space Technology Hall of Fame has honored the work of a team of aerodynamicists at Dryden. Their groundbreaking research over the last 35 years has dramatically improved the fuel efficiency of large trucks and recreational vehicles (RVs) on America's highways.

It all started in 1973 when Ed Saltzman, a Dryden aerospace engineer and avid cyclist, rode his bike to work. As he pedaled along Highway 58, through the Mojave Desert, he was passed by several tractor trailers. Each time a large truck blew by, he felt the push and pull of displaced air and began to ponder ways to reduce the vehicle's aerodynamic drag.

NASA colleagues had been analyzing lift-over-drag ratios on aircraft and early space shuttle designs in the early 1970s. They began to wonder: Can the same aerodynamic vehicle design they had originally developed for space flight technology be applied to the ground transportation industry?

Saltzman and a team of engineers slowly modified a box-shaped mail truck, rounding its corners and edges, sealing the bottom, and adding fixtures known as "fairings." Next, engineers ran tests on a tractor trailer, again rounding corners and edges, but this time they also closed the gap between the tractor and trailer, then added airtabs, a faired underbody, and a boat tail.

All of these modifications cut drag by more than 50% and increased fuel efficiency by 20%. Thanks to Dryden's aerodynamics research, the average U.S. tractor trailer is now 15% to 25% more fuel efficient at highway speeds.

For more information about the Space Technology Hall of Fame, visit http://www.spacetechhalloffame.org.

How to Work with Us.

The Innovative Partnerships Program (IPP) Office brings together the capabilities and needs of NASA Dryden Flight Research Center with those of industry, academia, and other government agencies. The results are innovative solutions as well as opportunities for technology transfer and commercialization. Working with us, companies, universities, and federal labs can license our innovative technologies, tap into our cutting-edge capabilities, access our state-of-the-art facilities, and work with our world-class engineers.

Below is an overview of how you can work with Dryden to achieve your own R&D goals while contributing to the NASA mission.

licensing opportunities

Technology innovations developed for NASA missions can be licensed for use in commercial and other applications.

Obtaining a license involves

- Identifying a NASA technology that addresses your R&D/product challenges
- Filing a license application and commercialization plan
- Negotiating the terms of the agreement

collaboration opportunities

Working together to achieve mutually compatible goals makes for cost-effective, time-efficient, win-win technology-based partnerships.

Forming a partnership agreement involves

- Identifying where your goals, needs, and technologies overlap with NASA's
- Finding a match among NASA's programs, projects, and/or staff
- Negotiating a Space Act Agreement

funded research

Companies—especially small businesses—participating in NASA-funded research can further their own R&D objectives.

NASA's highly competitive three-phase Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs provide an opportunity for small, high-tech companies and research institutions to participate in NASA-sponsored R&D efforts in key technology areas. Projects range from 6-month feasibility studies (Phase 1) to 2-year development efforts (Phase 2) to commercialization (Phase 3). Companies submit proposals in response to an annual solicitation, which is posted online.

For more information, see page 15 or visit http://sbir.nasa.gov.

contact us

For more information about how to partner with NASA Dryden or to access our technology, please contact:

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