December 2010

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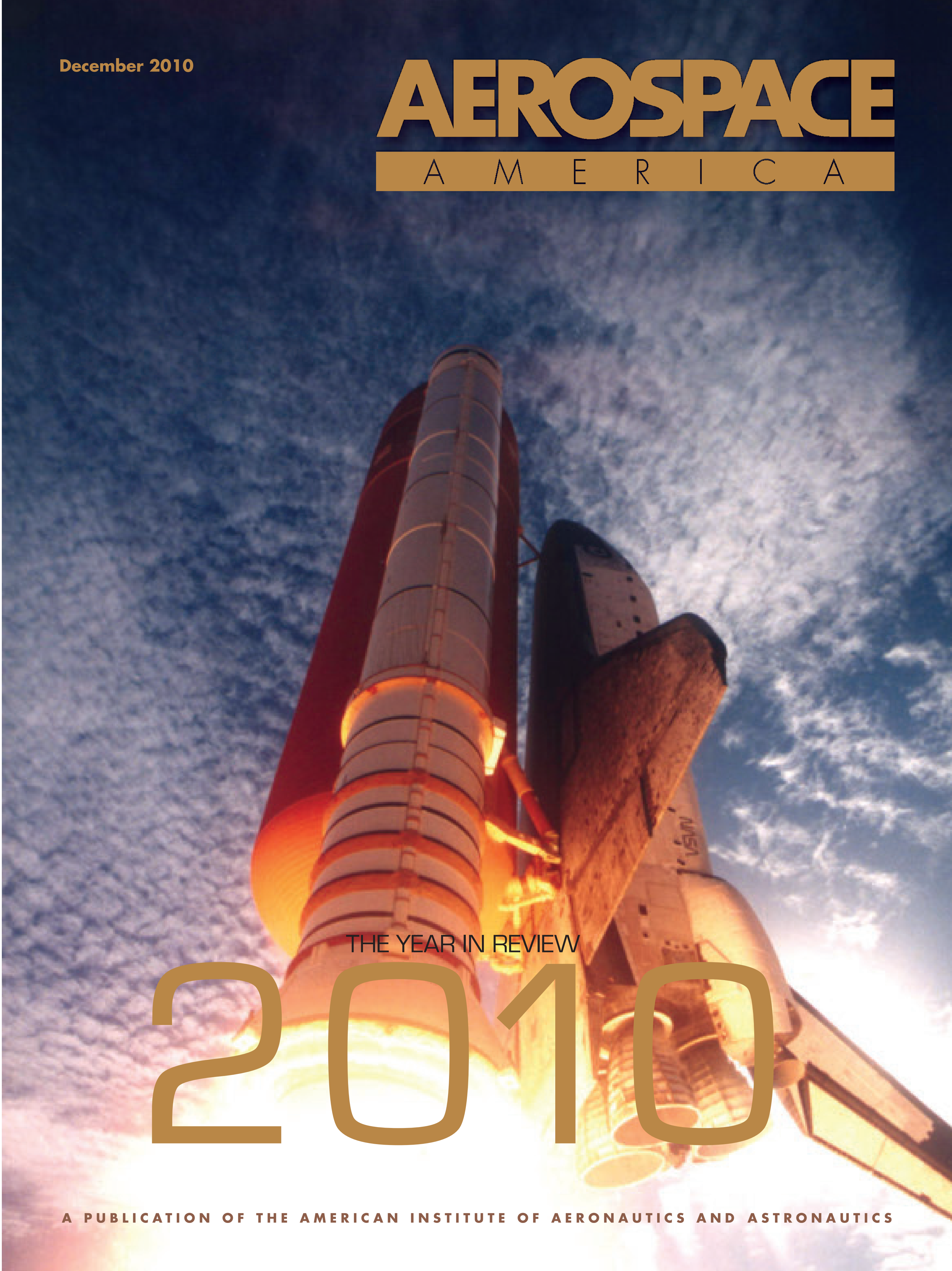

THE YEAR IN REVIEW 2010

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AEROSPACE
AMERICA

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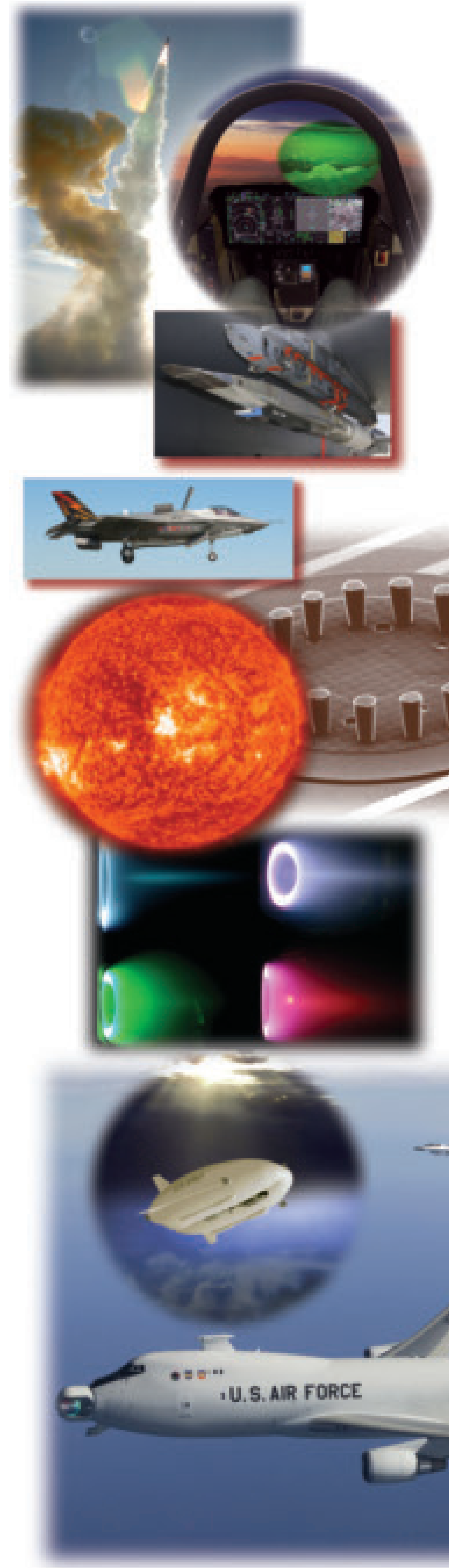
BULLETIN



Cover: The space shuttle is approaching the end of a storied career as 2010 draws to a close. NASA photo.

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AIAA
American Institute of Aeronautics and Astronautics

Editorial

Flying into history

The end of the first decade of the 21st century also marks the dénouement of one of the most significant eras in the history of human spaceflight. This month's scheduled launch of the space shuttle Discovery will be its last, and only one or possibly two launches remain for the entire program.

Just a few years after the world held its collective breath as Neil Armstrong set foot on the Moon, Apollo launches became old hat, and the national interest waned. As that program ended, the search for a reusable system to replace Apollo led to various designs and configurations. When trade studies first began in 1969 between NASA and industry, chief among the requirements were a fully reusable crew vehicle and launcher and a 14-day maximum turnaround time. A ceiling of $5.1 billion was set for development of the entire system.

As with all government programs, reality, practicality, and compromise soon set in. But if the space shuttle that was approved as a national program by Congress and President Nixon was not the system NASA imagined or the Defense Department wanted, it was still a magnificent notion.

Less than 10 years after the presidential nod, on April 12, 1981, the first operational shuttle orbiter, Columbia, was launched into space. STS-1 was commanded by John Young, a Gemini and Apollo veteran, and piloted by Robert Crippen, a rookie astronaut.

The history of the space shuttle since that first flight has been one of great accomplishment and devastating tragedy. The loss of Gregory Jarvis, Christa McAuliffe, Ronald McNair, Ellison Onizuka, Judith Resnik, Dick Scobee, and Michael J. Smith aboard the Challenger on January 28, 1986, dealt a body blow to both the space program and the national psyche. A second shuttle loss, the Columbia explosion on February 1, 2003, cost the lives of Michael P. Anderson, David M. Brown, Kalpana Chawla, Laurel Clark, Rick D. Husband, William C. McCool, and Ilan Ramon and once again cast the fate of the program in doubt.

But the shuttle and the indomitable astronauts who participated in this great adventure will also be remembered for remarkable feats of skill and courage. It is the shuttle and its crews that we have to thank for assembling the international space station, now complete and set to act as a national laboratory until at least 2020, and for the breathtaking glimpses of the universe provided by the Hubble Space Telescope, its optics corrected and its instruments updated by spacewalking engineers. The list of accomplishments goes on, but the shuttle will not.

No less significant than the end of the shuttle program is the end, at least for the moment, of independent U.S. access to space. Once the unrivaled leader in human space transportation, this country, for at least the next few years, will become just another paying customer, buying seats on someone else's ride.

In the growing field of spacefaring nations, the U.S. may no longer dominate, but there is no doubt that we still have the capability to be the leader. Nevertheless, unless we firmly support current development efforts, we may indeed become irrelevant.

Elaine Camhi
Editor-in-Chief

Design engineering

Technology advances in design engineering emerged in many products and design concepts this year. Model-based design (MBD) and advances in multidisciplinary optimization have had more influence on the design process, while rapid manufacturing processes continue to evolve to lower costs and increase performance of components and systems.

The AFRL/DARPA/Boeing/Pratt & Whitney Rocketdyne X-51A WaveRider, designed using a multidisciplinary design optimization (MDO) approach, successfully flew at a speed of nearly Mach 5 for almost 3 min, powered by a hydrocarbon-fueled dual-mode scramjet. Vehicle angle of attack, tail deflection angles, drag, and thrust measured in flight were all very close to predictions, validating the MDO design approach used by Boeing.

The avionics in the F-35 cockpit take significant advantage of COTS components and subsystems.

Looking to the future, an innovative air-breathing vehicle concept was designed by Astrox, ASC/XR, AFRL, and Boeing to be the reusable second stage of a two-stage-to-orbit launch system boosted by a reusable rocket first stage. The second stage is powered by rocket-based combined-cycle (RBCC) engines fueled by methane and LOX/hydrogen. The vehicle has innovative design features such as twin 3D inward-turning inlet flow paths and engines mounted on the vehicle upper surface to shield them from dense, high-temperature air during atmospheric entry. These features enable the vehicle to avoid the engine thermal protection and/or management challenges normally present during unpowered flight.

The X-51A was a significant step forward in proving the viability of hypersonic RBCC engines. A completely reusable launch system could someday dramatically reduce the cost of access to space.

The F-35 Joint Strike Fighter avionics take significant advantage of COTS components and subsystems. The design engineers of the avionics systems have implemented design processes that not only satisfy requirements with today's components but also allow for faster integration and qualification of future components because COTS hardware is used.

Taking an MBD approach and using higher order software languages can enable the performance of components and their interfaces to be well defined and implemented. The performance of these parts and subsystems can be verified easily in simulation, and new components can be evaluated before they are procured. Along with using standard interfaces, this approach can reduce the time it takes to certify new components from three or four years to as little as six months. This not only lowers the cost of integrating new components but also allows rapid insertion of new hardware to address the major problem of obsolescence when using COTS hardware.

Rapid prototyping has been a staple of engineering development for more than two decades now. Advances in materials, speed, and parts accuracy have transitioned this process from just prototyping to low-quantity or early production parts. Newly developed materials and processes will be replacing conventional manufacturing for some components and materials using additive processes. Analysis by companies such as Northrop Grumman has shown a 35-45% reduction in the total cost of a part.

Parts made with materials such as titanium, nickel, and aluminum high-performance alloys are now being manufactured with a variety of additive processes. These include direct metal laser sintering, selective laser sintering, selective laser melting, and others. These parts retain the properties of their conventionally manufactured counterparts and can be heat treated and finished using the same processes. They require little or no additional machining processes and, in some cases, can be manufactured with thinner walls than traditional forgings and castings, reducing component weight. As materials and additive manufacturing processes continue to improve, more and more opportunities for lowering cost and increasing component performance will arise.

by **E. Russ Althof**

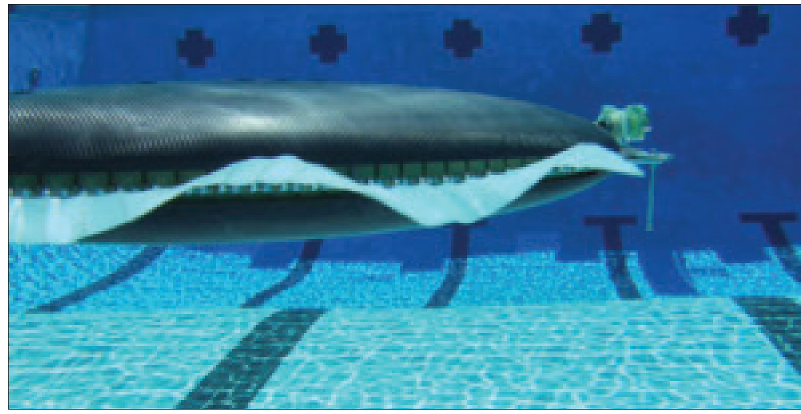
Adaptive structures

NextGen Aeronautics, University of Illinois, Texas A&M, and NES Technologies are using a new technique called targeted energy transfer to mitigate the limit cycle oscillation of transport wings at transonic flight speeds. Energy from a wing bending vibration mode is transferred to a nonlinear energy sink to reduce the oscillation. NASA and Penn State aerospace engineering researchers are addressing high-cycle fatigue in turbomachinery using semipassive, tunable piezoelectric damping with energy harvesting, which accounts for the effects of high-*g* environments.

Structural health monitoring technologies are progressing in many areas. Arizona State University, funded by AFOSR (Air Force Office of Scientific Research) along with AFRL and NASA Glenn, developed and tested a prognostics health management framework by integrating online/offline information with prognostic tools based on system identification and Bayesian for structural health monitoring. This framework can identify the nucleation of damage at the grain level and track its growth until structural failure has been established. The University of Michigan, sponsored by NASA, has been characterizing guided waves for structural health monitoring of composite sandwich structures. Researchers have used radar transducers for efficiently interrogating a complete structural surface from a central location.

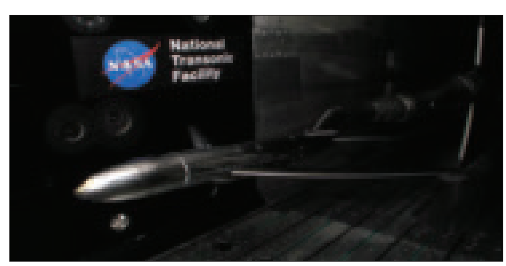
Adaptive structures are being used for flow control and propulsion in the air and at sea. The University of Michigan has demonstrated that cellular structural smart material actuator architectures created by continuous, interlocked loops of stranded active material produce distributed actuation that can actively manipulate the local surface of the aircraft wing to improve flow characteristics. The University of Quebec in Montreal, in collaboration with Bombardier Aerospace, Thales Canada, the Institute of Aerospace Research-National Research Council, and Ecole Polytechnique, developed a morphing wing that has smart material actuators and changes its shape to reduce the drag and to improve the laminar flow region on the wing. This morphing wing was successfully controlled in open and closed loop, using kulite sensors for flow transition and pressures measurement.

Active twist rotor blades for helicopter main rotors are needed for individual blade control. The benefits of such control are noise reduction, decreased vibrations, and reduced drag in forward flight. Even the maximum takeoff weight could be increased by using the additional twist statically. The German Aerospace Center has designed, manufactured, and tested several such active twist blades in recent years, using MFC (macro-fiber composite) actuators integrated into the blade skin and GFRP (glass fiber-reinforced polymer) as a structure.



Funded by DARPA, NextGen Aeronautics conducted a demonstration of an undulating side-fin propulsion system that mimics a cuttlefish.

The University of Maryland, along with different branches of the Army, is also working on blade control of helicopter blades. The team is developing and testing applications of pneumatic artificial muscle actuators. These high-performing, lightweight, robust actuators are proving their effectiveness and scalability in both high-frequency, on-blade control of trailing-edge flaps for helicopter rotor blades and low-frequency, heavy-lifting applications for robotics. DARPA has funded NextGen Aeronautics to develop an underwater demonstrator vehicle focusing on undulating side-fin propulsion that mimics a cuttlefish.



Active damping is used on the wind tunnel sting to help increase data quality.

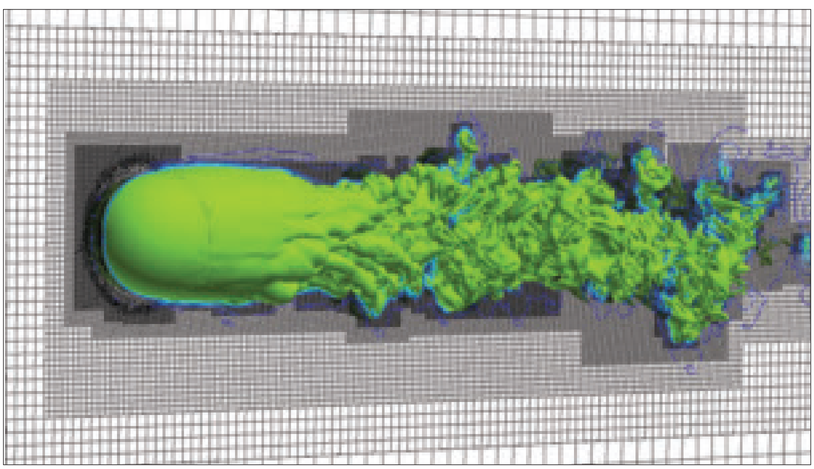
The Adaptive Structures Team in the Air Vehicles Directorate is continuing to investigate perching micro air vehicle concepts, having completed vehicle simulations using full 3D vortex particle aerodynamics with separation. Optimal trajectories and trajectory-following control schemes are being studied. Initial wing mechanisms have been designed and built, and indoor flight testing on basic nonmorphing vehicles has begun.

by **David Voracek**

Meshing visualization and computational environments

The impetus for developing overset grid methods, which were introduced 25 years ago, was the need to reduce the grid-generation challenges for structured meshes around complex geometries. Unstructured grid technology has mitigated the need for this capability somewhat. However, the overset grid method's ability to generate and assemble grids for bodies in relative motion has proven to be advantageous for unstructured grids as well.

Recently there has been significant progress in incorporating unstructured overset grid capabilities in legacy flow solvers. Using the DiRTlib overset communication library, several unstructured grid flow solvers, including USM3D, AVUS, and FUN3D, have been successfully converted to overset grid solvers. The PUNDIT package provides a similar capability that handles the grid assembly in addition to the interpolation and communication of the overset fringe data.



Vorticity isosurface from a sphere at a Reynolds number of 800 was solved using the Helios dual-mesh overset approach.

Recent development of the SUGGAR++, Overture, and PUNDIT grid assembly programs enables users to construct overset unstructured meshes, extending the applicability of overset technology beyond that of Pegasus 5 and other popular programs that apply to structured grids only. To provide an interactive grid assembly capability similar to that of the Chimera grid tool, an effort was initiated to develop a prototype graphical interface and a process that combines grid generation and assembly into one package, adding an initial capability to the Gridgen software.

A conjugate Navier-Stokes/heat-conduction design and analysis procedure demonstrated the use of overset grids in a multidisciplinary environment for analysis of film-cooled turbine airfoil sections. The cooling plenums internal to the airfoil and the thermal barrier coating layer were automatically constructed, and computational grids for the main flow path, cooling plenums, turbine walls, thermal barrier coating, and cooling tubes were generated. Embedded overset grids were used for the cooling tubes, allowing for arbitrary placement without requiring regridding of the main flow path, turbine walls, or cooling plenums.

Adaptive mesh refinement (AMR) is becoming an important tool for improving solution accuracy. A feature-driven Cartesian AMR approach for overset grids has been developed for the Helios flow solver that detects flow features and introduces high-resolution Cartesian grids in the identified regions. An AMR approach using cell refinement for tetrahedral grids has been used with SUGGAR++ to improve the interpolation stencils within overset regions by reducing the number of fringe cells with poor quality interpolation. An unstructured grid AMR method has also been developed that resolves turbulent flows by freezing the viscous layers near the no-slip wall and adapting away from the boundaries. Using both solution- and adjoint-based adaptation, far-field flow features were resolved with no a priori knowledge for both a supersonic nozzle plume and a turbulent flat plate.

In applying anisotropic AMR in 3D, problems often arise, such as the loss of anisotropy and the necessity to limit the minimum mesh size when discontinuities are present. A continuous mesh framework based on theoretical developments demonstrating that a field of metric tensors completely models a discrete mesh, and that the notion of interpolation error can be well defined, was proposed and demonstrated.

Terabytes of data can be generated as mesh size and solution complexity increase, thereby posing a challenge to the CFD practitioner to identify important flow physics. A method for extracting flow features concurrent to CFD code execution has been developed using intelligent software agents. This approach was shown to correctly identify vortex cores throughout solution convergence. Postprocessing time-dependent data can be even more daunting. RCAAPS, recently developed and demonstrated as a component of Fieldview, enables a user to interactively adjust the inputs to the acoustic code PSU-WOPWOP and easily create time history and spectral plots of aeroacoustic data.

by **Greg D. Power, James S. Masters,** and **Vincent C. Betro**

Survivability

In February the Missile Defense Agency performed two tests using high-energy lasers that succeeded in destroying two missiles in two separate trials. Later, there were some unsuccessful tests. The laser, a directed-energy weapon of multimegawatt strength, is fired from an airborne modified Boeing 747 aircraft. The laser beam acquires the target and keeps contact with it for several minutes, long enough to heat up the missile's solid or liquid fuel, resulting in an explosion. Efforts are now under way to use a solid laser instead of the current chemical oxygen iodine liquid laser, to reduce the size and weight of the apparatus used on the 747.

In addition, this spring the Navy tested a smaller fiber-optic directed-energy laser of about 32-kW power, fired from on board a ship to destroy enemy unmanned surveillance drones by frying the drone wires, cables, and control mechanisms, resulting in the drone's eventual loss of control or destruction. At least four drones were destroyed in these tests. Clearly, countermeasures for this new lethal weapon must be developed quickly to reduce the vulnerabilities of U.S. strategic missiles and bomber aircraft to unfriendly forces. This laser weaponry no longer belongs to science fiction; it is now a real threat that will very likely be faced in the not too distant future.

The Joint Cargo Aircraft, an Air Force/Army/Navy joint program, completed its live fire test and evaluation (LFT&E) phase. This included testing for the hydrodynamic ram effect on the wing structure, and the effectiveness of the engine nacelle fire detection and suppression systems. These tests paved the way to authorizing low-rate production.

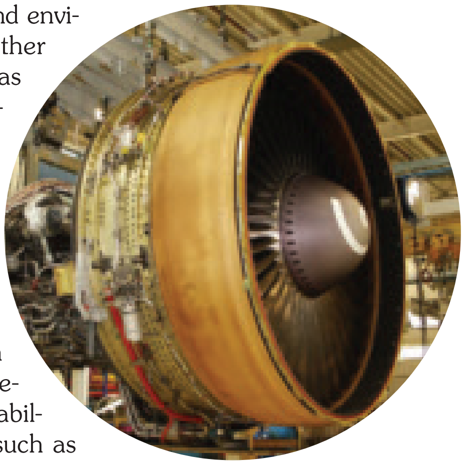
The Joint Strike Fighter program investigated fire initiation and sustainment within the aircraft undercarriage dry bays. The results of the investigation were used to ascertain minimum vulnerability to missile fragments. The results have also been used to identify and rectify deficiencies in the fire simulation prediction model.

The reliability enhancement and reengining program of the C-5 Galaxy strategic airlift plane also completed its LFT&E phase. The results cleared various issues identified in the test and evaluation master plan.

This year the Dept. of Homeland Security and the Joint Live Fire Program Office sponsored and initiated a comprehensive program to evaluate the damage caused by shoulder-fired surface-to-air missiles impacting the CF6 high-bypass turbofan engine, common on widebody aircraft. Organizations supporting program execution include NASA Langley, the Air Force, the Navy, and General Electric Engine Company.

The C-5 Galaxy completed its LFT&E phase.

The Orion crew exploration vehicle is a modular manned vehicle conceived and designed for the Moon-based Constellation program and envisioned for use in other space programs as well. Orion must protect its crew during orbiting, reentry into Earth's atmosphere, and landing. This spring NASA completed the Phase-1 safety review for the Orion crew capsule. This review covered survivability/ safety features such as the heat shield's location behind a solid structure, and the use of a very tough coating for protection against high-speed impact by micron-sized solid particles of space debris and meteoroid dust. In addition to the numerous thermal tests, arcjet testing was used for over 100 hypervelocity impact tests performed to characterize the resulting coating damage.



A program to evaluate the damage caused by shoulder-fired surface-to-air missiles impacting the CF6 engine, common on widebody aircraft, was initiated.

Other safety design features of Orion include use of two separate propulsion systems in parallel, to withstand leaks or malfunctions, and duplicate umbilical lines (power and fluids) bundled separately and with sufficient separation distance.

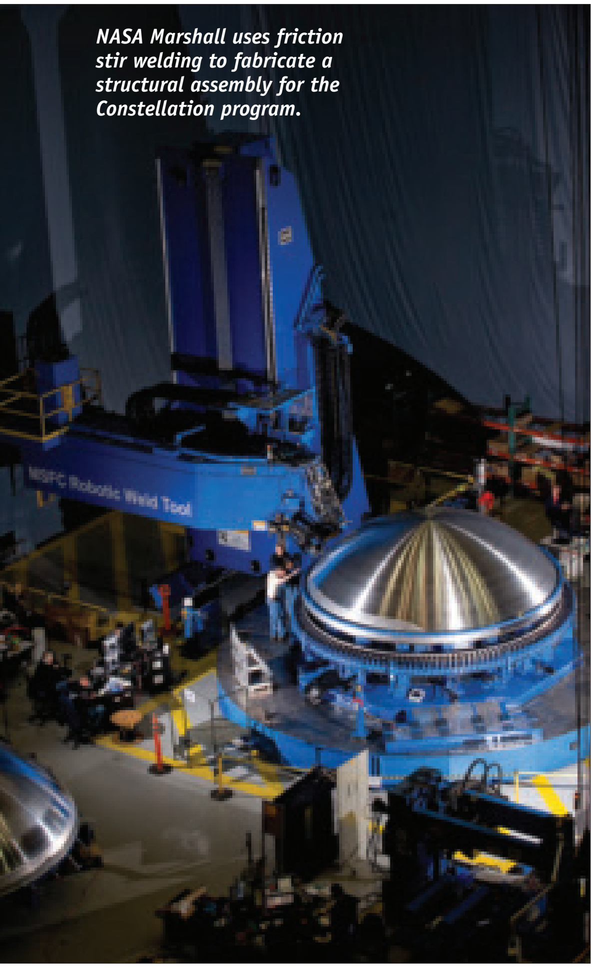
by **Ameer G. Mikhail, Alex G. Kurtz, Jaime J. Bestard,** and **Meghan S. Buchanan**

Materials

by **Edward H. Glaessgen**

Recent advances in the manufacture and characterization of materials by NASA, DOD, the FAA, academia, and industry will lead to lighter and more durable aerospace structures.

In the area of advanced composites, nonautoclave manufacturing of these materials continues to be of interest because of significant cost advantages compared with autoclave-based manufacturing. However, components made using nonautoclave processing have lower fiber volume fractions and inferior properties compared with those of autoclave-cured parts. The Non-Autoclave Manufacturing Technology program is a Boeing/DARPA/AFRL effort aimed at overcoming the deficiencies of nonautoclave processing. The goal is to develop large, complex aerospace-quality components with structural lives greater than 5,000 hours while greatly reducing manufacturing costs.



NASA Marshall uses friction stir welding to fabricate a structural assembly for the Constellation program.

The initial work focuses on maturing the materials, processes, tool family, and fabricator experience so that the resin (Cycom 5320), vacuum-bag-only prepreg, and a family of accompanying materials are ready for use in service applications. A manufacturing demonstration article with feature-based subcomponents was completed successfully in March 2009 with nondestructive and destructive testing revealing autoclave-equivalent physical and mechanical properties.

Phase-1 additional effort and Phase-2 plans are envisioned to mature the nonautoclave manufacturing technology to a TRL 6 (technology readiness level 6), ready for transition to prototype, flight test, and/or production use.

In addition, the Automobili Lamborghini Advanced Composite Structures Laboratory at the University of Washington (UW), together with Boeing, the FAA, and Hexcel, is conducting extensive research on HexMC, a high-performance discontinuous (chopped) carbon fiber/epoxy system for primary structures. Although the raw material cost of these chopped-fiber systems is about the same as that of the unidirectional prepreg from which they are derived, their adoption can be justified by their suitability for molding into complex configurations, lower manufacturing costs, and higher production rates. The Boeing 787 utilizes HexMC for several structural applications, including the window frames and intercostals. The research at UW focuses on creating a certification methodology based on the development of material allowables and analysis methods that can capture the mechanics of complex structures made of HexMC.

Among products made of new metallic materials, nickel-titanium shape memory alloy (SMA) actuators are being considered for noise reduction applications on commercial aircraft. NASA Glenn, under work funded by the agency's subsonic fixed-wing project, is developing both low-temperature and high-temperature SMAs for long-term use in aircraft engines. As part of this activity, long-term constant load creep test data have been generated on binary stoichiometric nickel-titanium at temperatures between room temperature and 200 C, with test times in the range of several months to over a year. Variable stress and temperature tests, designed to mimic service conditions, have also taken place. The results are expected to provide designers and analysts with the valuable long-term data they need for understanding and predicting the stability of SMA actuators in many commercial applications.

In addition, NASA Marshall has recently fabricated several friction stir welded (FSW) structural assemblies in support of the Constellation program, including four 18-ft-diam bulkhead domes and two 27.6-ft-diam barrel sections. The spun-formed domes were friction stir welded to forged "y" rings using a new self-reacting process completed with a friction pull plug weld closeout. The FSW bulkhead domes make up the face-sheets of a composite structural assembly that forms the bulkhead between the liquid hydrogen and liquid oxygen tanks on the Ares I upper stage. Testing of the assemblies will include characterization of the barrel sections for their shell buckling response at NASA Marshall as part of an overall NASA Langley-led effort aimed at characterizing the response of large-scale launch vehicle components.

Structures

NASA Glenn is doing research in upgraded nanofiber matrices and their subsequent use in composites reinforced with conventional fibers, which has produced enhanced composite responses with up to two times the buckling load and comparable decreases in the first natural frequency. These are computed results only; however, some recent data indicate that the results are reasonable. The implication is that knowledge and judicious computation methods reduce or eliminate experimental data completely.

In a carefully planned extreme test inside Boeing's Everett, Washington, plant, engineers bent the wings of a 787 Dreamliner ground-test airplane until the load was more than one-and-a-half times anything the jet will experience in service, the company says. By the end of the test, the wing had deflected upward from the horizontal by about 25 ft. This "ultimate load" wing stress test is a dramatic milestone in the process of obtaining FAA certification so the airplane can be used for passenger flights.

In a similar test in January 1995, Boeing bent the wings of the 777 beyond ultimate load until they broke in an explosive burst at 154% of the anticipated in-service maximum load, destroying the test plane. Unlike the traditional 777 aluminum wings, the Dreamliner's wings are made of more flexible carbon-fiber-reinforced plastic and would be expected to keep bending far beyond the certification mark without breakage.

Could studying the structural properties of moth wings give the U.S. military a strategic edge on the battlefield of the future? Researchers at the Air Force Institute of Technology (AFIT) think so and hope that their studies will help to realize the Air Force's vision of operating insect-sized micro air vehicles (MAVs) by 2030. These vehicles, essentially miniaturized flying robots, will be an order of magnitude smaller than current operational MAVs. Moreover, unlike their fixed-wing and propeller-driven predecessors, they will achieve flight by flapping their wings. In fact, if the vision is fully realized, they will so closely mimic the behavior of their biological inspirations that they will be able to carry out operations in plain sight. Having these insect-like characteristics will make them ideally suited for covert operations in urban, indoor, and tight corridor spaces. The AFIT/MAV team has set out to develop a high-fidelity structural model of an insect wing. When completed, this groundbreaking model could serve as a baseline for future design studies and ultimately shed new light on the nature of insect flight.

Boeing engineers bent the wings of a 787 ground-test airplane until the load was more than one-and-a-half times anything the jet will experience in service.

Advances in synthesis, manufacturing, and modeling techniques are continuing to drive nanocomposite research closer to use in aerospace structural applications. Research on carbon nanotube-, silica nanoparticle-, and nanoclay-reinforced polymer nanocomposites has brought insight into the clustering, damping, interfacial, thermal transport, electrical transport, and mechanical property characteristics of these materials. Work at MIT continues to focus on facile processes for creating large-scale bulk structured materials with nanoscale order, to take advantage (where possible) of nanoscale physics. Multiscale methods in modeling crack-tip conditions have continued to improve understanding of the atomic-level behavior of metallic nanocomposites for use in aerospace structures. Exploratory research has begun developing pillared-graphitic structures for improved thermal transport in aerospace materials. Excellent thermal conductivity and mechanical integrity are provided in three dimensions.

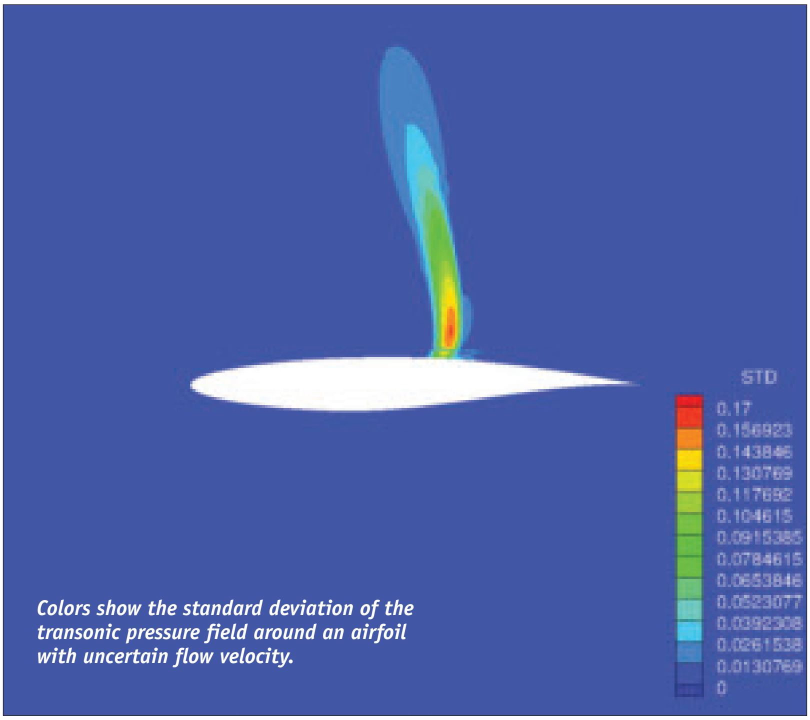
AFRL, Trinity University, and the University of Kentucky are studying the FURL (flexible unfurlable and refurlable lightweight) solar sail payload to learn its capability for dozens of deployment-retraction cycles on-orbit. A thin membrane sheet is unfurled and refurled using a single rotational actuator coupled with a set of four self-deployable triangular retractable and collapsible booms attached to a perimeter spar structure, each constructed from a carbon-fiber-reinforced polymer. The full-scale 10-m^2 flight-like prototype has undergone environmental deployment testing, shape surveys, deployment kinematic measurements, and structural analyses in an effort to demonstrate that this payload is ready to serve as a propellant-free thrust source for Earth-orbiting spacecraft.

by **Harry H. Hilton**

Nondeterministic approaches

As modeling and simulation become more important and are more widely used for development, design, and certification of aerospace vehicles, there is widespread and growing recognition that the use of nondeterministic approaches is essential.

There is always variability in the inputs of any simulation. This variability must be captured as uncertainty in the simulation results so that the potential for undesirable outcomes can be quantified and managed. In comparing the results of a model to a physical experiment, the uncertainty in both the model predictions and the experimental results must be considered quantitatively to determine the accuracy of the model.



Colors show the standard deviation of the transonic pressure field around an airfoil with uncertain flow velocity.

Nondeterministic approaches are widely used in the growing area of multiscale modeling of materials. Multiscale material models seek to develop material engineering properties from the random arrangement of the microstructure and distributions of the constituent properties. While multiscale modeling is already being successfully developed using common materials where variabilities are well characterized, its real power will be for emerging engineered materials such as FGMs (functionally graded materials).

There is growing use of CFD simulation models to quantify the uncertainty due to inherently random variables using nondeterministic approaches. Such approaches have been applied to both incompressible and compressible flows, and to internal and external flows. The desire to extract useful statistical information about the flow from simulations has driven the development of probabilistic methods to efficiently identify the impact of uncertainties on model results. One such example of uncertainty quantification is SESC (simplex elements stochastic collocation), based on a simplex elements discretization of the probability space and an adaptive grid refinement strategy. This methodology has been demonstrated in compressible flow and gas turbine engine applications.

Establishing the credibility of models by comparing them to experimental data that also contain uncertainty and variability requires the use of nondeterministic approaches. With critical decisions often made solely on the basis of simulation results, using engineering judgment alone to validate a simulation with experimental data will not be sufficient. A quantitative comparison of the results is possible only with nondeterministic techniques. In the end, the goal of these simulations is to determine the probability that the aircraft, or other system, will perform as desired.

Recognizing the increasing application of nondeterministic analysis in modeling and simulation, the Southwest Research Institute has developed a new software tool named CENTAUR (collection of engineering tools for analyzing uncertainty and reliability). This software is also the probabilistic engine in the NESSUS (numerical evaluation of stochastic structures under stress) general-purpose probabilistic analysis code. CENTAUR can be called from many programming languages and software programs, making the tools easily accessible to any simulation.

In addition, Southwest Research Institute, in collaboration with four major gas turbine engine manufacturers, released an update to its DARWIN (design assessment of reliability with inspection) program for nickel materials and for surface damage. DARWIN, which is sponsored by the FAA, is a probabilistic damage tolerance design code for turbine engine rotor disks that contain undetected material anomalies.

by **Eric Tuegel**
and **Shyama Kumari**

Structural dynamics

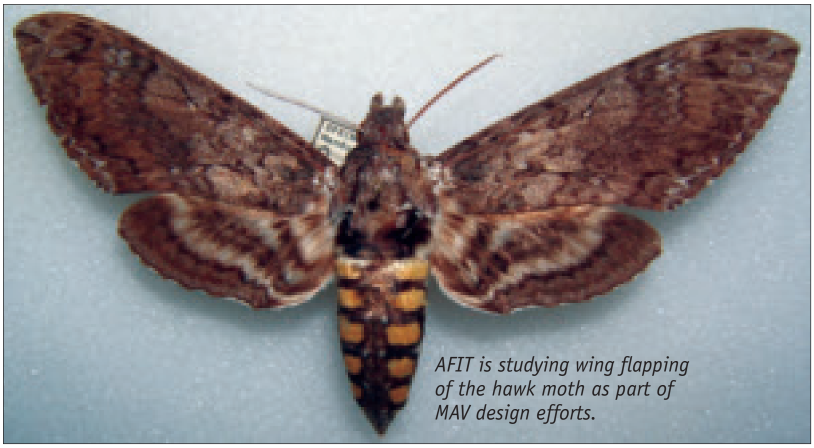
NASA's 327-ft 1.8-million-lb Ares I-X flight test vehicle was successfully launched from Kennedy Space Center on October 28, 2009. This was the first flight test for an Ares I crew launch vehicle. Important data were obtained on ascent loads, vehicle control, separation, and first-stage reentry dynamics.

Boeing partnered with NASA Langley, under an Air Force contract, to verify the flexible aircraft structural design process and resulting joined-wing SensorCraft airframe design. An actively controlled, dynamically scaled 12-ft-span model of the aircraft was tested in Langley's Transonic Dynamics Tunnel. The tests, concluded this year, addressed the issues of aeroservoelastic stability in the presence of low frequency modes, gust load alleviation for buckling stability, and airframe weight. The support system allowed the model to be flown in the test section with free pitch and plunge motions.

This year Gulfstream conducted ground vibration tests on its latest flagship offering, the G650 business jet. It is the world's fastest civil aircraft and has the longest range of any traditional business jet. The plane was suspended on bungee cords in place of the landing gear. Excitation was through six electromagnetic shakers attached to each wing tip, horizontal tail tip, and engine nacelle. For the flight flutter testing of the aircraft, shaker vanes were attached to each wing tip and horizontal tail tip. For the entire flight envelope, up to the maximum dive of 0.99 Mach and maximum operating altitude of 51,000 ft, no aeroelastic instabilities were detected. FAA certification is expected in 2011.

Sandia National Laboratories developed new techniques for experimental dynamic substructuring and investigated sensor integration in wind turbine blades. The modal testing group developed methods to couple experimental modal models with finite-element (FE) models. Components difficult to model can be tested to produce experimental models that are coupled to validated FE models. Sandia's Wind and Water Power Dept. embedded aerodynamic and strain sensors and accelerometers in Sandia-designed blades and flew them in the field. The field results are supporting aerodynamic and structural modeling for active blade control and health monitoring.

The Air Force Institute of Technology (AFIT) is investigating the possibility of incorporating vertical stabilizers in reusable launch vehicles. The ExFIT (experimental fin tip) program, created for this purpose, has generated a scale model of a wing tip with a vertical stabilizer. These fins were flown successfully in April as the payload on the cadet-built Air Force Academy FLVIII sounding rocket. The fins were exposed to a Mach 3+ environment for 10 sec. The data returned from the fin-mounted sensors will be used for evaluating numerical models. Future flights will expose the fins to higher speeds and altitudes.



AFIT is studying wing flapping of the hawk moth as part of MAV design efforts.

X-HALE, an 8-m-span UAV developed at the University of Michigan in collaboration with AFIT, is an aeroelastically scaled very flexible aircraft. The objective is to collect data on the craft's nonlinear aeroelastic response in the presence of the six rigid-body degrees of freedom. The data will be used for validation of the coupled aeroelastic and flight dynamic analyses of very flexible aircraft. Several flight tests are expected in 2011.

AFIT is investigating the hawk moth (Manduca sexta) as an ideal biological species to study for micro air vehicle (MAV) design properties. Modeling and frequency experimentation reveal that the species has a system identifiable characteristic—the study of a specimen is representative of the species. The flapping of the hawk moth's wing is being studied.

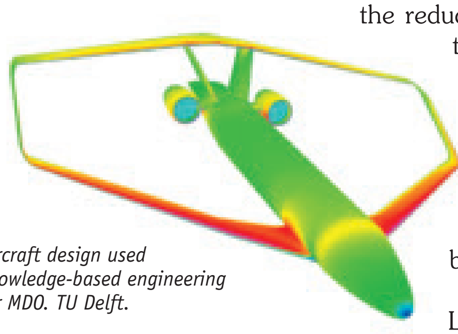
The University of Florida is developing tools for modeling and controlling aeroservoelastic systems. This involves parametrization of the control effectors and optimizing their time-varying values to maximize performance. Flapping-wing MAVs and morphing aircraft are being investigated using both CFD and wind tunnel data.

The first flight test of NASA's Ares I-X test vehicle provided important data on ascent loads, vehicle control, separation, and first-stage reentry dynamics.

by **Suresh Shrivastava**

Multidisciplinary design optimization

Multidisciplinary design optimization (MDO) can be defined as a framework of methods and tools for the optimization of complex systems involving coupled, often competing, disciplines. This year, as in previous years, researchers have focused on core issues such as the reduction of computational costs, the development of design space visualization tools, and uncertainty propagation. It is also noteworthy that several collaborations between academia, industry, and research centers have been formed.



Aircraft design used knowledge-based engineering for MDO. TU Delft.

The Air Force Research Laboratory (AFRL) Collaborative Center for Multidisciplinary Sciences (CCMS), comprising Virginia Tech, Wright State University, and the University of Maryland, completed its first full year in developing MDO techniques to enable the quantitative technology assessment of three vehicle concepts: sensorcraft, micro air vehicles, and supersonic long-range strike vehicles. Technical and strategic advisory committees, consisting of members from industry, government, and academia, reviewed and approved the research plans for the joint effort between the CCMS and AFRL Multidisciplinary Science and Technology Center.

In the Netherlands, Delft University of Technology has developed a new knowledge-based engineering (KBE) modeling system, called DARWING, to support the MDO of complex wing systems. DARWING links a parametric geometry modeling core with a set of external aerodynamic, structural, and flight mechanics analysis codes. In collaboration with the University of Pisa, this framework has been used to optimize the propulsion and flight control systems of boxed-wing aircraft. DARWING was developed using the GDL KBE system of Genworks International.

Researchers at Queensland University of Technology, the Australian Research Centre for Aerospace Automation, and the International Center for Numerical Methods in Engineering are collaborating on advanced evolutionary methods for uncertainty-based MDO. Their methods use advanced Pareto-Hybrid Nash games, asynchronous evaluation, multifidelity models, and parallel computing to speed up the capture of global solutions.

The University of Leeds in the U.K., in collaboration with Rolls-Royce, has developed new multidisciplinary optimization capabilities for solving large-scale problems arising in turbomachinery design. They were successfully applied to engine design projects with over 100 design variables, extremely large computational costs per simulation, numerical noise, and occasional simulation failures.

The Optimal Design Laboratory at the University of Michigan proposed a novel paradigm for design validation during the optimization process. In addition,the team developed methodologies for allocating consistency constraints in augmented Lagrangian coordination, managing reduced representations of functional responses, and designing hybrid electric fuel cell vehicles under uncertain enterprise considerations.

MIT has developed new Bayesian-based methods for multifidelity MDO. An approach for managing the fidelity of disciplinary models in MDO uses global sensitivity analysis together with Bayesian estimation theory, while a provably convergent multifidelity optimization method is achieved through Bayesian model calibration and a trust region model management.

Researchers at Iowa State University's Virtual Reality Applications Center are developing a visual design space exploration tool using contextual self-organizing maps to rapidly gain an understanding of the design space and its properties.

Penn State University and the Applied Research Laboratory are collaborating on the use of multidimensional data visualization techniques and trade space exploration to support product platform design and product family optimization.

Phimeca Engineering and the French Institute of Advanced Mechanics in Clermont-Ferrand, France, are investigating the use of Kriging surrogate models for the optimal design of submarine imperfect pressure shells under reliability constraints. The challenge is to minimize the computational cost by reducing the total number of nonlinear finite element analyses while gauging the effect of simplifying assumptions on the final design.

Finally, researchers at the University of Bath, U.K., have developed a robust topology optimization technique offering optimum designs that are less sensitive to variations in loading conditions. This is implemented using the level-set approach, which creates and merges openings to find the optimum topological solutions.

by **Samy Missoum**

STRATEGY FOR SUCCESS

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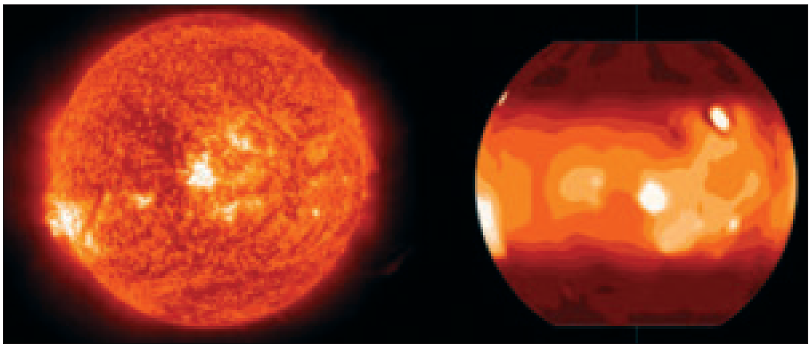
Plasmadynamics and lasers

Space plasma heliophysics progressed markedly this year, with growing improvements in quantitative solar observations and theoretical understanding of Sun-Earth interconnections. With so many of society's activities dependent on space-based infrastructure for everything from communications to navigation to financial transactions, these advances are vitally important to developing forecasting capabilities that minimize our vulnerability to solar storms, eruptions, and their disruptive effects.



A synthetic emission image from the SOHO extreme ultraviolet imaging telescope (EIT Image 304 of Carrington Rotation 2009) is compared with a data-driven global 3D resistive MHD simulation (courtesy University of Alabama, Huntsville, Center for Space Plasma & Aeronomic Research). The bright areas in the middle and left of the image correspond to active regions 10486 and 10488, which are associated with several large flares and coronal mass ejections.

Most notable was the February launch of the Solar Dynamic Observatory (SDO) for NASA's Living With a Star program, as a complement to its Solar and Heliospheric Observatory (SOHO) and Solar Terrestrial Relations Observatory (STEREO) spacecraft. The first spectacular images returned by SDO revealed an astounding degree of detail and insight into the inner plasmadynamic processes of the Sun. Early results show that the magnetic field is more dynamic and dominant than previously thought. Continued observations are likely to revolutionize our scientific views, particularly our understanding of how the magnetic field is generated and converted into solar flares and energetic mass ejections. Other observational spacecraft now in the works include China's Kuafu space buoy, which will be stationed at the L1 Lagrange point to sample the solar wind.

Naturally, these solar observations are providing an impetus to the development of reliable predictive capabilities. Modeling and simulation of solar activity have long been difficult because of the thorny physics of solar plasma and magnetism, factors complicated even further by an intricate magnetohydrodynamic coupling with the Earth's magnetic field. However, the growing base of observational data has led to much progress, and we may anticipate improved forecasting tools as we emerge from an unusually deep solar minimum and transition into an expected maximum of solar activity in 2011-2012.

There was significant movement in the area of laser technology development, where the continuous trend for the past decade has been toward electrically powered laser technology, be it solid-state or gas media. Commensurate with this trend is the AFRL Directed Energy Directorate's recent demonstration of a flowing diode-pumped alkali laser (DPAL) system, which combines the electrically powered, diode-pumped attributes of solid-state lasers with the heat transport and beam-quality attributes of gas lasers. Building on previous static-cell DPAL demonstrations by Lawrence Livermore National Laboratory, General Atomics, the Air Force Academy, and the University of California San Diego, the AFRL experiment demonstrates the ability to flow heat in the gain media away from the laser resonator region, a critical milestone for development of this technology.

The field of aerooptics is seeing considerable activity in the areas of in-flight testing, wind tunnel experiments, and CFD simulation. The DEBI-XFR (directed energy beam improvement by expanding the field of regard) program has teamed AFRL's Air Vehicles Directorate with Boeing and the University of Notre Dame. The team is progressing with experiments and CFD simulations of a quarter-scale turret (a hemisphere on a cylindrical base type) with a conformal window, exploring active and passive flow control devices. Suction is being used as a "best that can be done" flow control baseline for comparison with other flow control approaches (developed by AFRL, Boeing, Georgia Tech, and Notre Dame) that may offer some integration advantages.

In recent years some attention has been directed toward the aerooptic effects of attached turbulent boundary layers, as these will affect airborne free-space communication systems. The efforts at Princeton and at Notre Dame provide examples of the new knowledge developing in this area. Also, new instrumentation for measuring aerooptical aberrations as long time-resolved, time series of wavefronts at very high bandwidth has continued to develop. Princeton's pioneering approaches of combining lenslet arrays with high-speed CCD cameras have now become common tools in the laboratory. While these devices offer new avenues for studying both aerooptics and fluid mechanics, the real-time capabilities are still somewhat limited.

by **Ron J. Litchford** and **Timothy J. Madden**

Fluid dynamics

This year saw many exciting developments in fluid dynamics over a range of flow regimes and scales. Of particular interest were accomplishments in flow control, supersonic and hypersonic flow, roughness effects, low Reynolds-number flows, and wind turbines.

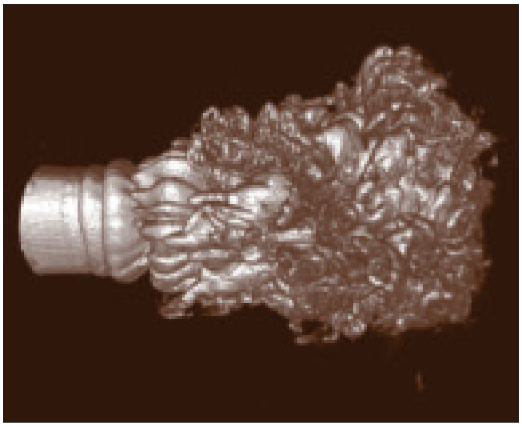
Flow control research is becoming more integrated with flight control and applications involving unsteady flow and flexible wings. Investigators at the Air Force Academy are exploring ways to use closed-loop active flow control to modify the spanwise lift distribution on 3D flexible wings. Gust suppression and energy harvesting techniques for micro air vehicle (MAV) based modern closed-loop control algorithms are under joint development at the Illinois Institute of Technology and Caltech. These efforts have highlighted the importance of low-dimensional models for separated flow dynamics and unsteady aerodynamics. University of Florida researchers have highlighted the importance of 3D effects in flow control for applications related to cavity flows. The team has been able to reduce both broadband and tonal surface pressure components using open-loop strategies in supersonic flows, as well as closed-loop strategies in subsonic freestream conditions.

The Computational Aerophysics Branch at AFRL has used ILES (implicit large-eddy simulations) to investigate the unsteady flowfield structure and forced generation of a rapidly pitching plate at low Reynolds numbers to model a prototypical perching maneuver for MAV applications, as well as deep dynamic stall phenomena induced by the large-amplitude plunging oscillations of an airfoil. Investigators at UCLA have used a vortex particle method to simulate the flow field and force generated by a rapidly pitching plate at low Reynolds numbers. They have also developed a reduced-order model for this flow. LES conducted at AFRL investigated a novel serpentine plasma-based actuation for control of a low-Reynolds-number airfoil representative of MAV applications. When used as a tripping mechanism, plasma actuation created premature transition to a more fully turbulent state, thus eliminating time-mean separation and increasing the lift-to-drag ratio by 20%.

The first research flight under the Hypersonic International Flight Research Experimentation (HIFiRE) project was launched from Woomera, Australia, in March. HIFiRE is a collaborative R&D effort by AFRL and the Australian Defence Science and Technology Organisation. The flight, involving a cone/cylinder/flare payload, gathered data on boundary-layer transition and shock/boundary-layer interaction for Mach numbers up to 6.5, demonstrating a low-cost approach to obtaining unique validation data for critical aerodynamic phenomena that cannot be obtained in existing ground facilities.

NASA and academic researchers have made exciting progress in the area of roughness-induced tripping of high-speed boundary layers, a phenomenon of great importance to hypersonic flight. A combination of quiet tunnel experiments, numerical simulations, and theory has yielded valuable clues into the physical mechanisms underlying tripping.

In-flight measurements involving a controlled roughness element on the shuttle orbiter wing are providing complementary validation data related to roughness effects on transition and turbulence. Laboratory experiments at Texas A&M and Princeton University are clarifying the combined effects of distributed surface roughness and compressibility on turbulence in high-speed boundary layers. Detailed measurements and visualizations revealed the complex wave field generated by the roughness and its damping influence on Reynolds stress in the near-wall region, even leading to a collapse of these Reynolds stress levels at a Mach number of 7.2.



Researchers at Auburn University used a recently developed flow visualization system to capture 3D images of a turbulent jet (Reynolds number 10,200). Visible are the Kelvin-Helmholtz instability waves responsible for the initial formation of axisymmetric ring vortices near the nozzle exit, the emergence of counterrotating streamwise vortex pairs, and the complex, nonlinear interaction between these vortices that leads to fully developed turbulence in the far field.

Researchers at the University of Illinois at Urbana-Champaign have shown that low-order models of roughness representative of the in-service damage to real turbine blades yield flow conditions almost identical to the fully rough case. This could prove critical to developing predictive models for a wide range of surface damage effects.

Los Alamos National Laboratories performed several large-scale numerical simulations of wind turbine farms. These unique simulations include effects of surface terrains, atmospheric boundary layers, and rotating blades, enabling high-fidelity predictions for purposes of wind farm siting and performance optimization.

by **Michael W. Plesniak**

Guidance, navigation, and control

by **Luisella Giulicchi, Daniel Clancy,** and **Leena Singh**

LISA Pathfinder, precursor to the ESA/NASA Laser Interferometer Space Antenna mission aimed at the first in-flight test of gravitational wave detection metrology, successfully completed test and validation of its space-based drag-free control system.

SpaceX successfully drop tested Dragon, its free-flying reusable spacecraft. A second demonstration will test the launch and separation from a Falcon 9 launch platform, the Dragon's guidance and navigation systems, and the heat shield.

An innovative drag-free attitude control system has enabled the GOCE (gravity field and steady-state ocean circulation explorer) satellite to map the Earth's gravity field geoids with unprecedented accuracy. GOCE achieves drag-free flight by using a rear-mounted electric ion propulsion system that generates low thrust in the satellite flight direction. The system automatically produces continuous thrust to compensate for buffeting effects from the residual air encountered by the satellite in its 250-km-altitude orbit. GOCE also is the first spacecraft to fly drag free in LEO using electric propulsion.

Thales Alenia Space-France presented its baseline attitude and orbit control system design approach for critical operational modes requiring fine precision pointing with fully deployed flexible appendages. The method uses H-infinity and μ-analysis techniques for the design and analysis of flexible satellite control laws. This technique is applied to Thales telecommunication satellites that present large structural bending modes because of flexible arrays and fuel slosh. The technique has been successfully deployed and evaluated on 15 SpaceBus4000 telecom platforms launched since 2003.

GOCE's innovative drag-free attitude control system has enabled it to map Earth's gravity field geoids with unprecedented accuracy.

The Automatic Ground Collision Avoidance System (Auto-GCAS) successfully demonstrated the capability to prevent accidents caused by nuisance fly-ups in a full range of tactical flying scenarios on the AFRL/NASA F-16 testbed. Auto-GCAS features a pilot-activated recovery system to enable recovery of aircraft in the event of pilot disorientation, and a time-varying trajectory prediction algorithm (TPA) to anticipate a false fly-up and synthesize an optimal recovery climb profile. TPA is designed to operate to minimum clearance requirements given aerodynamic parameters for the aircraft and its onboard stores, and the aerodynamic flight variables.

A typical air combat maneuver (ACM) test involved an aircraft in nearly inverted flight wherein bank angle was effectively indeterminate; Auto-GCAS autonomously commanded a pull-up to recover the aircraft. In low-altitude, high-speed ACM dive tests, the autopilot roll-through logic successfully demonstrated fast recovery of the aircraft to prevent aircraft inversion and the required (approximately 5 *g*) fly-up without false fly-ups. Auto-GCAS also safely and successfully performed several high-speed, low-altitude (100-150-ft) strafing runs. The software is being tuned to extend the safe flight corridor to supersonic, low-altitude terrain-masking flight regimes through rugged and highly variable terrain.

NASA Langley performed autopilot flight tests on its GTM (generic transport model) aircraft, a fully controllable, 5.5% dynamically scaled remotely piloted, jet-powered aircraft. Recent flight tests evaluated an L1 all-adaptive flight controller with a single nominal design point at an aerodynamic trim condition in the heart of the normal flight envelope. A test focusing on the poststall regime demonstrated that this adaptive autopilot could enable the research pilot to more accurately obtain and hold a desired angle of attack.

AFRL recently awarded a program to develop sense and avoid (SAA) technologies for unmanned aircraft systems (UAS) in formation flight. The flight tests will demonstrate sensing of noncooperative intruders and safe avoidance maneuvers of the UAS formations.

The Missile Defense Agency and the Pacific Fleet successfully executed tests of the next-generation Aegis ballistic missile defense weapons system, designed to engage longer range, more complex target ballistic missiles. These tests, designed to evaluate detection, tracking, fire control, discrimination, kill-assessment, and reengagement decision functions, involved tracking and simulated engagements with several short-range, separating, ballistic missile targets. The tests also assessed sensor and telemetry data from the recently launched Space Tracking Surveillance System satellites.

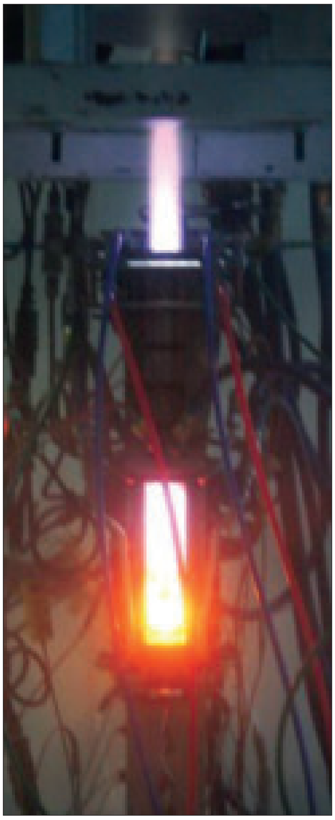
Aerodynamic measurement technology

Researchers at the Laboratory for Turbulence Research in Aerospace and Combustion (LTRAC) at Monash University in Melbourne, Australia, led by Julio Soria, have been collaborating with researchers from the Engine Measurement Techniques group, led by Chris Willert at the German Aerospace Center's (DLR) Institute of Propulsion Technology, on ultra-high-speed Schlieren imaging of supersonic jet flows at up to 1 MHz. The work makes use of recent advances in light emitting diode (LED) technology that has resulted in high-power, single-chip devices that provide luminous radiant fluxes exceeding several watts. Developments at DLR by Willert and by Boleslaw Stasicki have increased the instantaneous light emission of these LEDs, operated in pulsed current mode to levels comparable to those of photographic (xenon) flash units, making them a suitable light source for ultra-high-speed instantaneous Schlieren imaging.

Unlike commonly used xenon flash units, an LED can be triggered within tens of nanoseconds at rise times on the order of 100 nsec, thereby enabling stroboscopic illumination at megahertz rates. The LED driving electronics were synchronized to the ultra-high-speed 1-MHz Schlieren imaging system developed at LTRAC by Daniel Mitchell, Adam Risborg, and Soria to provide time-resolved Schlieren visualizations of an under-expanded supersonic jet impinging on a flat plate. Compared to images obtained with a xenon white light flash, the nearly monochromatic green light of the LED results in much crisper flow features with superior repeatability in intensity, without any speckle artifacts commonly found with laser illumination.

Ronald K. Hanson's research group at Stanford University is providing tunable diode laser absorption sensor technology for the new NASA/AFOSR (Air Force Office of Scientific Research) Center for Hypersonic Combined Cycle Propulsion at the University of Virginia, led by James McDaniel and Christopher Goyne. In the first year, Stanford performed time-resolved gas temperature and combustion product water vapor measurements with a 250-kHz measurement bandwidth in the model scramjet at the University of Virginia. Stanford also developed a velocity sensor for precision velocity measurements and tested it in the Direct Connect Hypersonic Combustor Test Facility at NASA Langley. Time-resolved measurements in the Mach-2 flow quantified the startup time of this blowdown facility, and spatially translated measurements have been used to validate NASA's CFD simulations.

Researchers at Auburn University have used planar laser induced fluorescence of acetone vapor to measure the 2D density field of the separated flow behind a hemisphere. In these experiments, liquid acetone was injected into the supply stream of a blowdown transonic wind tunnel. The acetone evaporated, forming an acetone vapor/air mixture that expanded through the nozzle and into the 4x4-in. cross section. A UV laser sheet using the fourth harmonic output of an Nd:YAG pulsed laser was used to induce fluorescence of the acetone molecules, with the resulting signal being directly proportional to the flow density.



A model scramjet at the University of Virginia uses Stanford tunable diode laser sensors for monitoring the temperature and degree of combustion completeness in the combustor exhaust.

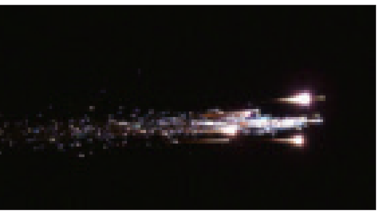
JAXA (the Japanese Aerospace Exploration Agency) has developed a magnetic suspension and balance system (MSBS) that eliminates the need for a physical model support. The MSBS avoids interference due to supports in wind tunnel tests, revealing the true aerodynamic characteristics of the model, especially at high angles of attack (AOA) and for large-scale separated flows.

JAXA succeeded in demonstrating the world's first 6-degree-of-freedom (6-DOF) force measurement of an aircraft model at a 15-deg AOA in a 20-m/sec airflow while levitating the wing-body-type AGARD-B model in a 60x60-cm low-speed wind tunnel, practically doubling the previous 6-DOF measurement record of 8 deg AOA. This was accomplished by increasing the power of the drag coil, enabling the aircraft model to be suspended at up to 35 deg AOA, theoretically. JAXA began research on the MSBS in 1986, independently developing the present system, which succeeded in the world's first full 6-DOF simultaneous control and force measurement. It has been in practical use since 2000.

by **Thomas P. Jenkins** and the **AIAA Aerodynamic Measurement Techniques Technical Committee**

Astrodynamics

by **Ryan S. Park**

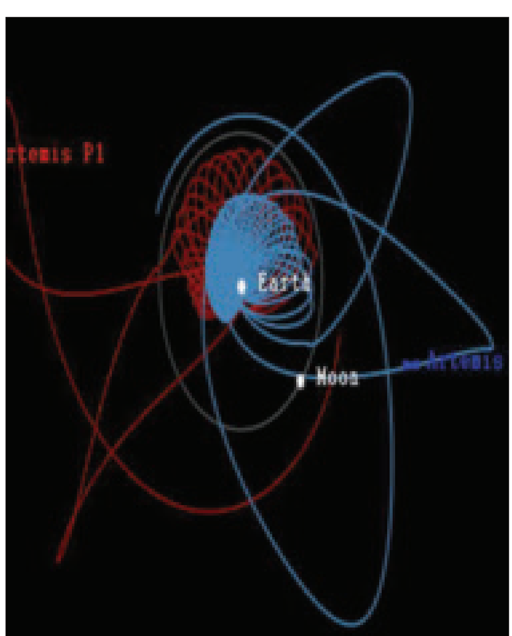


The Hayabusa capsule, which returned to Earth after a seven-year journey to asteroid Itokawa, is seen on the right, leading the debris and disintegration of the spacecraft. Courtesy JAXA/NASA.

In February, a challenging mission to the Moon was cleared for mission implementation. NASA approved sending two of the outer THEMIS (time history of events and macroscale interactions during substorms) probes into lunar orbits to make measurements of the lunar wake, magnetotail, and solar wind through 2012. This new mission is named ARTEMIS (acceleration, reconnection, turbulence, and electrodynamics of Moon interaction with the Sun), and implementation was carried out in collaboration with University of California-Berkeley, JPL, and NASA Goddard. ARTEMIS is the first mission to consider placing an Earth-orbiting constellation into a lunar constellation.

Given the limited resources and scheduling, finding a practically feasible mission design was an extremely challenging task. After a series of orbit-raising maneuvers at Earth, both probes followed low-energy transfer trajectories into Lissajous orbits around Earth-Moon Lagrange points. After lunar orbit insertions, targeted for April 2011, the probes will orbit the Moon for 18 months. This will be followed by controlled crashes of both probes onto the lunar surface.

Also in February, NASA announced the second extension of the international Cassini-Huygens mission to explore the Saturnian system until 2017, the time of summer solstice in Saturn's northern hemisphere. The extended-extended mission (XXM), called the Cassini Solstice Mission, enables study of the seasonal and other long-term weather variations. The 155 orbits of the XXM tour are designed to maximize the number of satellite flybys, especially encounters with moons Titan and Enceladus. The final phase of the tour is in many ways similar to the Juno mission at Jupiter, which would provide unique opportunities to investigate the Saturnian magnetosphere and gravity field in depth. In June, the Cassini spacecraft performed the lowest Titan flyby of the entire mission at an altitude of only 880 km.



ARTEMIS, which will orbit the Moon for 18 months beginning in April 2011, followed a low-energy transfer trajectory. Courtesy UC-Berkeley/NASA Goddard/JPL.

On April 15, President Obama delivered a major space exploration speech at Kennedy Space Center. A new element of his plan is to launch a human mission to an asteroid by 2025; this would serve as a stepping-stone to a crewed orbital mission to Mars in the mid-2030s, with a landing as a follow-up. Because of this new vision, the astrodynamics aspects of sending and returning crewed missions to near Earth objects are being studied closely by many space organizations.

JAXA launched two missions, Akatsuki and IKAROS (interplanetary kite-craft accelerated by radiation of the Sun), aboard an H-IIA 202 rocket on May 20. The Akatsuki spacecraft, also known as Planet-C, will arrive at Venus this month and will study its atmosphere and surface. IKAROS is a solar sail technology demonstration mission using a 200-m^2, 0.3-mm-thick polyimide experimental sail. The sail was successfully deployed on June 10, making IKAROS the first fully operating interplanetary solar sail mission. The spacecraft, solely powered by sunlight, is currently on a six-month cruise to Venus.

On June 13, Japan's Hayabusa spacecraft made its glorious return to Earth after a seven-year journey to the asteroid Itokawa. The Hayabusa mission is the first Earth return of a low-thrust spacecraft. On its return trajectory the craft surmounted a number of challenging obstacles and managed to land in the South Australian Outback while the bus broke into pieces and created a spectacular fireball.

Also in the area of small-body exploration, ESA's Rosetta spacecraft successfully flew by asteroid 21-Lutetia, the largest asteroid visited by a spacecraft, at a distance of 3,162 km on July 10. The EPOXI (extrasolar planet observation and deep impact extended investigation) mission encountered its final destination, comet Hartley 2, on November 4. The flyby occurred at a radius of 700 km and comet relative velocity of 12.3 km/sec.

Aeroacoustics

This year the "war on noise" advanced the physical understanding, prediction, and reduction of aerodynamically generated noise.

Future aircraft concepts with aggressive technology goals continued to mature. NASA Langley, in collaboration with Boeing, UC Irvine, MIT, and United Technologies Research Center (UTRC), is preparing for aerodynamic and acoustic testing of the hybrid wing body concept. The design shows potential for producing cumulative noise reductions of up to 42 EPNdB (effective perceived noise decibels) and consuming 25% less fuel than a Boeing 777. Wyle Labs conducted a study and recommended a research plan to assess the complex human response to low-frequency and infrasonic noise generated by the NASA-designed large civil tiltrotor.

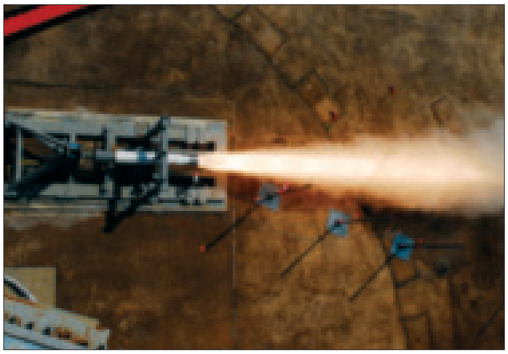
NTS (National Technical Systems), Russia, and Boeing explored the fundamentals of airframe noise predictions on a rudimentary landing gear model. The model was one of four problems at the first Benchmark Problems for Airframe Noise Computations workshop. Noise calculations via CFD simulation and the Ffowcs Williams-Hawkings method did not confirm the expected dominance of wall-pressure contributions at low Mach numbers. Experimental and computational investigation continues.

Jet noise research on source identification and modification attracted significant interest. UTRC investigated modifications of large-scale turbulence structures by chevron-type nozzles for subsonic and supersonic heated flows. Flight effects for supersonic nozzles at freestream Mach numbers up to 0.4 expand on available classical databases. General Electric demonstrated large eddy simulation (LES)-based design differentiation capability over a range of subsonic nozzle configurations at the LES for Jet Noise Prediction workshop at NASA Glenn. CRAFT Tech used LES for predicting supersonic jet noise at takeoff/landing for carrier-borne strike aircraft. The simulations agreed with test data including observed twin screech tones and broadband associated shock noise.

ATA Engineering developed a continuous-scan acoustical holography system, with support from AFRL. Experiments conducted at Penn State demonstrated that the new continuous-scan signal processing can deliver "effectively infinite" spatial resolution, enabling high-frequency measurements using fewer transducers than are traditionally used by fixed-array techniques.

With support from NASA, University of Illinois at Urbana-Champaign researchers performed the first-ever computational optimal aeroacoustic control of a turbulent Mach-1.3 jet. The team used an adjoint-based optimization methodology with LES. The controlled jet was 3.0 dB quieter in the peak radiation direction without increasing the sideline radiated noise. Experimental verification of the predicted controller's performance is planned.

Cavity noise control efforts advanced on many fronts. Digital Fusion, Kord Technologies, and the University of Tennessee Space Institute, with support from AFRL, investigated a modified rod-in-crossflow device in cavities representative of the F-35 weapons bay, using direct eddy simulations and experiments. Initial results indicate that the modified device would be effective even in the supersonic regime. Resesarchers at the University of Florida, with support from AFOSR, investigated the effects of open- and closed-loop control on the cavity flow field. Open-loop experiments using steady leading-edge blowing showed nearly 50% reductions in unsteady pressure fluctuations at Mach 1.4 conditions. Closed-loop studies on subsonic (less than Mach 0.6) conditions used a zero-net mass-flux piezoelectric actuator array with different feedback control algorithms, achieving about 20% reductions.



An ASMAT horizontal RATO motor characterization test is conducted at NASA Marshall.

In the area of rocket noise, NASA Marshall characterized the ballistic profile, ignition transient, internal acoustics, and far-field acoustic pressure response of several full-scale solid rocket motors including Ares I-X, SRTMV-N1, and the RSRMV-DM2. Ares I scale-model acoustic test (ASMAT) testing, which began this year, is a 5% subscale test series that uses 18 rocket-assisted takeoff (RATO) solid rocket motor test firings. Each vertical ASMAT test incorporates over 120 high-frequency acoustic instruments to capture internal motor, ground, and liftoff acoustics; ignition overpressure; and spatial correlation measurements for source location. Data from these tests will be used to determine full-scale acoustic launch environments and corresponding sound suppression systems for NASA Kennedy.

by **David Alvord** and **Abraham Meganathan**

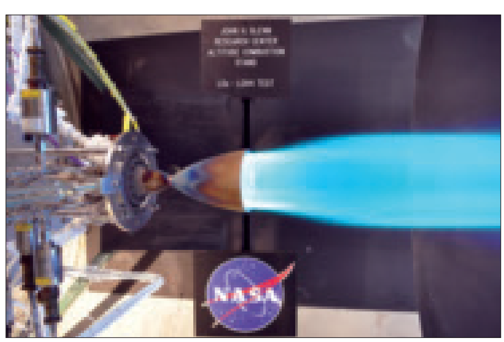
Ground testing

by **Julien Weiss**

This year has seen significant progress in testing capabilities at major ground test centers. New facilities have been commissioned to address specific testing needs, and existing facilities have been upgraded to provide customers with more data while maintaining or reducing overall test costs. In addition, facilities around the world have continued to develop new testing methodologies and measurement techniques to enhance understanding of flow physics and to provide engineers with greater insights into the performance of their test articles.

Cavitation of the space shuttle main engine LOX inducer is observed under off-design conditions.

Despite these positive developments, a combination of uncertain workloads, limited budgets for maintenance, and an aging infrastructure have continued to erode the availability of state-of-the-art ground test facilities throughout the U.S. The list of defunct facilities has grown with the decommissioning of the Langley Full-Scale Tunnel and the demolition of the North American Trisonic Wind Tunnel, which closed in 2007. Representatives of NASA, DOD, and U.S. industry are continuing discussions to address the decline of existing test infrastructure.



An Aerojet 100-lbf engine undergoes testing in the NASA Glenn Altitude Combustion Stand.

At NASA Glenn, the open rotor propulsion rig, originally conceived in the 1980s, was refurbished to help industry develop new engines based on unducted turbofan technology. In addition, the Altitude Combustion Stand began operation. This new state-of-the-art facility is capable of testing gaseous hydrogen, gaseous oxygen, liquid hydrogen, liquid oxygen, and liquid methane rocket engines up to 2,000 lb thrust and rocket chamber pressure to 1,000 psia. Two major test facility enhancement projects (adding icing capability to the Propulsion Systems Laboratory and replacing the refrigeration plant and heat exchanger for the Icing Research Tunnel) were also begun and funded as part of the American Recovery and Reinvestment Act program.

At Aerospace Corporation, a new state-of-the-art turbopump cavitation test facility was commissioned. This new water flow facility recently completed qualification testing using a quarter-scale model of the space shuttle main engine low-pressure oxidizer pump and is now fully operational and available for testing.

The Aerodynamics Laboratory of the National Research Council Canada upgraded its 0.9-m 3/4-open-jet, closed-circuit wind tunnel. This will allow aeroacoustic testing to be performed in conjunction with the lab's current aerodynamic capability for aerospace and automotive applications.

The Hypervelocity Wind Tunnel 9 at the Arnold Engineering Development Center in White Oak, Maryland, successfully returned to service after a renovation of the main tunnel controller and the installation of a new state-of-the-art digital control room. The tunnel also implemented a global heat-transfer measurement system that can operate simultaneously with traditional measurement techniques during a continuous-pitch sweep and does not significantly increase the test program's schedule or cost. The resulting global heat-transfer maps offer considerable insight into the aerothermal environment experienced by the test article.

In the U.K., the Aircraft Research Association developed a highly productive pressure sensitive paint (PSP) capability for its 9x8-ft Transonic Wind Tunnel over the full Mach number range. Compared with conventional pressure measurement techniques, PSP provides noncontact, full-field measurements on complex aerodynamic surfaces with high spatial resolution.

Meanwhile, researchers from NASA Langley, Ohio State University, and the University of Iowa implemented a novel megahertz-rate laser-based measurement system in Langley's Mach-10 tunnel to obtain global qualitative and quantitative measurements of the flowfield structure in hypersonic flows.

A team from the Japan Aerospace Exploration Agency used state-of-the-art CFD methods to determine the optimum spacer height required in a half-model wind tunnel test. This final example is typical of the growing integration of high-end computational tools with ground test techniques around the world, offering exciting new possibilities to the ground testing community.

Applied aerodynamics

The NASA Common Research Model (CRM), used in the Fourth Drag Prediction Workshop (DPW-IV, http://aaac.larc.nasa.gov/tsab/cfd larc/aiaa-dpw/) was tested in NASA's National Transonic Facility and 11-ft Wind Tunnel. Preliminary results were presented at the 28th Applied Aerodynamics (APA) Conference. Predictions from DPW-IV participants, summaries, and statistical results were offered in three dedicated sessions. A special CRM experimental data session will take place at the 49th Aerospace Sciences Meeting next January. As a continuation of DPW-IV work, a NASA/Boeing effort extended grid refinements beyond 2 billion points, validating that CFD processes are capable of handling the growth of production-class CFD simulations for many years.

The High Lift Prediction Workshop (HiLiftPW) was created to assess the numerical prediction capability of CFD technology for swept medium/high-aspect ratio wings in landing/takeoff configurations, develop modeling guidelines, and advance the understanding of high-lift flow physics. The first workshop (HiLiftPW-1, http://hiliftpw.larc.nasa.gov), colocated with the 28th APA Conference, used the open NASA trap wing configuration. It attracted 21 participants from eight countries and 18 organizations. Trends due to flap angle were analyzed, and the effects of grid family, grid density, solver, and turbulence model were addressed. A statistical analysis of the CFD collective results was performed.

In an effort concluding last spring, NASA funded six industry/university teams to examine transportation scenarios, advanced aircraft configurations, and revolutionary technology for commercial aircraft of 2030 and beyond. The purpose was to foster innovative approaches to achieve vast gains in efficiency and reductions in environmental impact. NASA will use the defined technology suites and development roadmaps to prioritize future research. A team led by Boeing used a portfolio of ideas to reduce fuel burn by more than 70%. Likewise, a team headed by MIT/Aurora/Pratt & Whitney presented a low-noise aircraft concept estimated to meet fuel burn, emissions, and field-length goals. Supersonics teams, led by Boeing and Lockheed Martin, identified innovative airframe shaping as a viable approach to achieving acceptable sonic boom.

The DOD 12-year CREATE (computational research and engineering acquisition tools and environments) program was established in FY08 to enable major improvements in engineering design and analysis processes. The program seeks to develop and deploy scalable, multidisciplinary physics-based computational engineering products for the design and analysis of ships, air vehicles, and RF antennas. CREATE is a multiinstitutional, multiservice, multiagency, and multidisciplinary program with participation by the Navy, Air Force, Army, OSD, industry, and academia. The Air Vehicles program, CREATE-AV, released two products in FY10, the fixed-wing design tool KESTRELv1.0, and the rotorcraft design tool HELIOSv1.0.

A Boeing-led team used a portfolio of innovations to design an craft that could provide a 70% increase in fuel economy.

NVIDIA and other graphics hardware vendors have invested in GPUs (graphics processing units) that are designed to be massively parallel accelerators to conventional CPUs. Recent GPU performance achievements for aerodynamics applications have been reported by several noted organizations including BAE Systems, George Mason University, Stanford, Oxford, and Cambridge. Growing interest in GPUs for CFD is evident from the increasing number of relevant papers at conferences. Commercial software has progressed, and practically every major software vendor has a GPU initiative, with some having released products this year.

The Boeing 787-8 flight test program has validated several innovative aerodynamic drag-reduction technologies, including a trailing-edge variable camber system designed to optimize the loading of the wing, nacelle cowls designed for natural laminar flow and reduced viscous drag, and a simple-hinged flap combined with drooped spoilers.

A new approach for predicting boundary-layer transition in CFD analysis and design of laminar flow aircraft has been developed at NASA Langley. Called MATTC, this empirical method gives detailed information on boundary-layer modal growth, but with greatly reduced computational resources relative to existing methods. It is currently being extended and evaluated in a cooperative effort with the DLR in Germany.

by **Andrew McComas** and **Stephen LeDoux**

Atmospheric flight mechanics

The Global Observer approaches its landing site at Edwards AFB during its first flight. Copyright AeroVironment.

NASA completed the first pad abort flight test of the Orion launch abort system (LAS) on May 6. The test met the flight test objectives, including propelling the crew module a safe distance away from the launch pad and assessing the stability and control characteristics of the launch abort vehicle. The test also determined the performance of the abort, jettison, and attitude control motors within the LAS, demonstrated the abort event sequencing, and obtained structural loads and acoustics data at the LAS and crew model interface.

Orion's LAS provides an emergency escape system for the crew if a life-threatening issue arises either on the launch pad or during the vehicle's ascent to orbit. The abort flight tests use uncrewed vehicles, although the vehicles have outer mold lines and mass properties similar to those of the production Orion crew module and LAS. Data from the abort flight tests will allow NASA to validate key abort models for LAS performance, parachute system performance, separation aerodynamics, and separation mechanism performance.

Boeing completed Flight 80 of the X-48B on March 19 and its stated Phase-1 flight test objectives. The program achieved edge-of-envelope maneuvers, including stalls, sideslips, and departure limiter assaults. A final report was drafted and submitted to NASA and AFRL customers on May 28, and a Phase-1 technical out-brief took place on August 5.

The X-48B flight vehicle and ground control station (GCS) began an extensive maintenance and upgrade program that includes a continued airworthiness structural inspection, installation of an upgraded flight control computer, overhaul of the parachute and recovery systems, as well as software upgrades for both the aircraft and GCS.

The X-48B resumed flight tests with a checkout flight in September to perform its Phase-1.5 follow-on test maneuvers, including single-surface parameter identification evaluations and a flying testbed evaluation of the SPT15 turbofan engine intended to power the X-48C in 2011.

AeroVironment successfully completed the first flight of the Global Observer stratospheric unmanned aircraft system from Edwards AFB in August. The aircraft flew the initial 1-hr flight on battery power as a precursor to later flights using the hybrid liquid-hydrogen/electric propulsion system. Global Observer is designed to fly at altitudes of 55,000-65,000 ft for durations of five to seven days and serves as a platform for communication and sensor payloads.

Northrop Grumman was awarded $517 million to develop up to three long-endurance multi-intelligence vehicle (LEMV) systems for the Army. LEMV is a new hybrid airship weapons system and will be deployed in Afghanistan in 2011.

The Navy UCAS-D X-47B completed its slow and medium-speed taxi tests at Northrop Grumman's production plant in Palmdale, Calif. It is currently undergoing preparations for its first flight at Edwards AFB this month.

NASA Global Hawk completed four science flights over the Pacific Ocean in April as part of the Global Hawk Pacific mission, a joint NASA-NOAA project with Northrop Grumman support. Fitted with 11 science instruments, the craft acquired and transmitted data that have not previously been accessible through either manned flights or satellites. The flights also marked the first time a Global Hawk has flown as far as 85° north latitude.

On September 2, the UAV supported a science research flight over Hurricane Earl to better understand how tropical storms form and develop into major hurricanes.

Solar Impulse, the first manned airplane designed to fly continuously without fuel, performed its maiden flight on April 7 and flew for 26 hr solely on solar energy. The final goal of this project is to demonstrate the potential of renewable energy by a five-stage flight around the world in 2013.

by **Mujahid Abdulrahim, Bruce Owens, Peggy S. Hayes,** and **Michael Kisska**

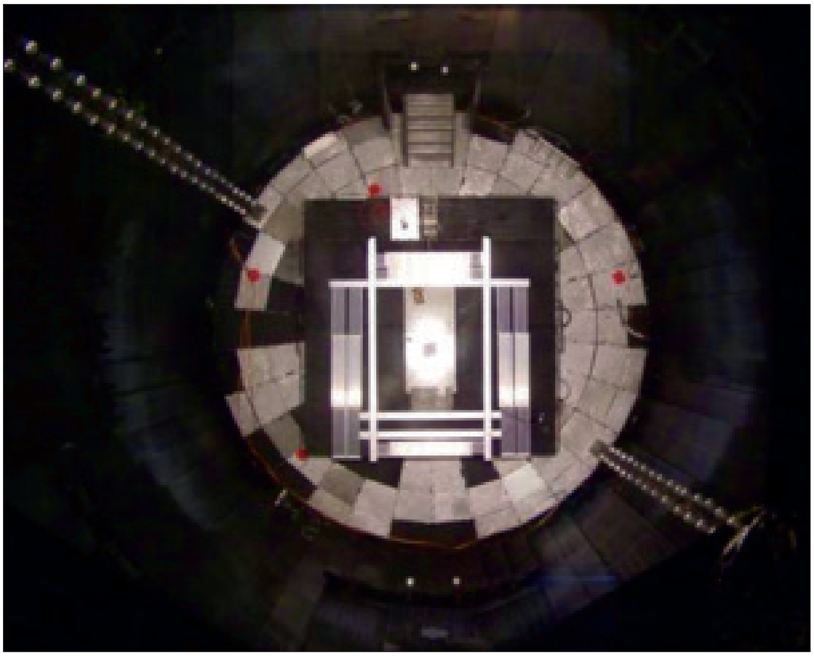
Atmospheric and space environments

McGill CFD Lab and Newmerical Technologies International intensified their development of 3D in-flight icing tools embedded into the system now known as FENSAP-ICE. They have developed a truly unsteady in-flight ice accretion methodology that dispenses with deciding how many time intervals to take during ice accretion. In addition, the two groups have developed reduced-order models to analytically explore the entire FAA In-Flight Icing Certification envelope and identify worst-case icing and worst-case performance conditions using only a few 3D simulations. Finally, they have demonstrated arbitrary Eulerian Lagrangian mesh movement algorithms that permit the calculation of long-time ice accretion without the need for remeshing.

NASA and the Instituto Nacional de Técnica Aeroespacial (INTA) in Madrid conducted an experiment to obtain droplet breakup data on an airfoil configuration. The experiment used an airfoil model in the rotating rig test cell at INTA along with a monosize droplet generator. High-speed imaging was used for observing the interaction between the droplets and the airfoil as well as droplet deformation and breakup. Tracking software was used to measure the droplet displacement and calculate velocity and acceleration. The velocity and acceleration, together with experimental values of the air velocity at the locations of the droplets, were used to calculate the Weber, Reynolds, and Bond numbers and drag coefficients along the droplet path. This is the first time that a systematic study of droplet deformation and breakup has been conducted for droplets approaching the leading edge of an airfoil, and the first time that the important parameters have been directly measured and/or calculated along the path of the droplets from initial deformation to breakup and contact with the airfoil.

A checkout test was conducted in the Arnold Engineering Development Center's Mark 1 thermal vacuum chamber to complete reactivation of the liquid nitrogen (LN_2) cooling system. The Mark 1 is a 42-ft-diam, 82-ft-high space environment simulation test chamber. The requirement for the shroud cooldown was to provide a test environment that was cooler than 100 K, and temperatures as low as 86 K were achieved. An infrared camera was used to view the progression of LN_2 through the cooling panels. The checkout was successful in satisfying test objectives and restoring the chamber's thermal test capability.

Scientists at NASA Marshall and the Air Force Research Laboratory, using data from the floating potential measurement unit on the ISS, have shown that charging events averaging less than 1 min in duration sometimes occur when the ISS is coming out of eclipse.



The Mark 1 thermal vacuum chamber, viewed from the top, is a 42-ft-diam, 82-ft-high space environment simulation test chamber.

The events may be of high amplitude and seem to be caused by abnormally high electron current collection on ISS conductors when adjacent insulators are as yet uncharged by the daytime plasma. The events also seem to be affected by the earthly weather conditions at the point where the Sun is rising for ISS. Partly cloudy conditions may lead to complex charging signatures in time, with clear patches leading to a high, open-circuit voltage and corresponding to charging peaks in the floating potential probe output on the measurement unit.

AIAA has published an updated version of the *Guide to Reference and Standard Atmosphere Models* as AIAA-G-003C-2010. This document provides a summary for more than 78 national and international reference and standard atmosphere models. The guide has been used extensively as a source document for information on models pertaining to aerospace engineering applications. It includes new contributions solicited from several model developers, both national and international. (Copies may be obtained at www.aiaa.org without charge to AIAA members.)

by **Dustin Crider** and the **AIAA Atmospheric and Space Environments Technical Committee**

Modeling and simulation

Aviation safety experts are turning to the modeling and simulation community for help in reducing loss of control in flight (LOC-I) accidents, the leading cause of aviation fatalities. Multiple government agencies and international organizations, including the AIAA Modeling and Simulation Technical Committee, have partnered to form the International Committee for Aviation Training in the Extended Envelopes (ICATEE). This group has taken a dual-stream approach to addressing both short-term and long-term solutions to the problem of LOC-I accidents: The ICATEE training and regulations group has created a training matrix that identifies the requirements for improving pilot awareness, recognition, avoidance, and recovery as part of their skill sets. The intention is to take a graduated approach to incorporating these recommendations and to use existing hardware as much as possible as well as advanced tools for academic training.

ICATEE's research and technology group has been reviewing training device fidelity with a particular focus on the aerodynamic databases in the extended envelope. The group has also been making recommendations that could improve the realism of flight training within the cockpit environment itself.

ICATEE has been making recommendations that could improve the realism of flight training within the cockpit environment.

One major current shortcoming is the ability of simulator-based scenarios to reproduce the surprise factor during training. While technology can help to increase the realism of the simulator, even safety-critical events become mundane when they recur during training. Thus the role of the instructor and the development of appropriate scenarios are both helpful.

Another area of great interest is the fidelity of the simulation "atmosphere" inside the cockpit. Both type-specific and generic scenarios based on real events are being created for use in simulation training. These scenarios are intended to provide more realistic workload and increase the surprise factor in training. The research working group of ICATEE will help guide efforts to develop additional training methods and technologies, both in simulation and on board the aircraft, that may reduce the number of LOC-I accidents.

To improve safety, ICATEE's training and regulations working group is developing strategies that may include additional flight training and other regulatory changes for early career pilots, as well as changes in the training aids themselves.

As air traffic management is being defined in the Next Generation (NextGen) program, simulation is playing a large role in the establishment of the system requirements. It will also play an important role in the testing of the new guidance algorithms that will enable NextGen.

In addition to its work in support of aviation safety, the simulation industry continues to develop more cost-effective simulation capabilities based on commercial-off-the-shelf products, particularly for visual systems. Greater use of the growing capabilities of GPUs (graphical processor units) is increasing the overall capabilities and fidelity of simulation. High-rate LED flat panel displays also offer the possibility of further reducing visual system transport delays. Continuing research focuses on increasing the fidelity and training transfer of simulation motion systems.

Areas where the aerospace simulation industry has seen improvement, such as predictive modeling, motion control, human perception and action, and system design, are also seeing increased spinoffs to other sectors. These include telerobotic surgery, rehabilitation research, and solutions to help the disabled and injured. A major facility for these activities is the Toronto Rehabilitation Institute.

by the **AIAA Modeling and Simulation Technical Committee**

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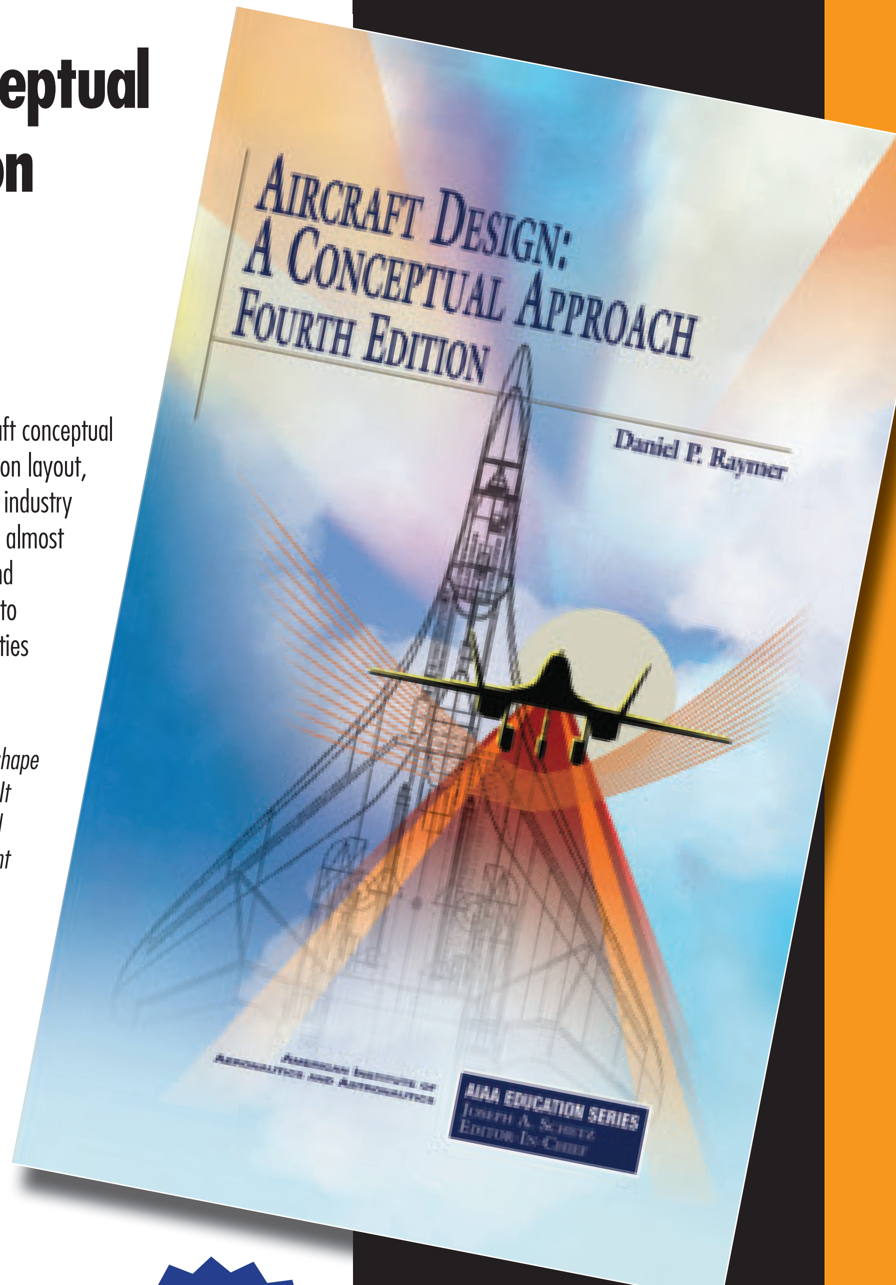

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Lighter-than-air systems

Northrop Grumman will build the long-endurance hybrid airship for the Army.

The Army Space and Missile Defense Command awarded Northrop Grumman a $517-million contract to develop three LEMV (long endurance multiintelligence vehicle) hybrid airship systems. The basic LEMV performance requirements include a three-week endurance, an optionally unmanned, 20,000-ft operating altitude, a 2,500-lb payload, 16 kW of payload power, an 80-kt dash speed, and a 20-kt stationkeeping speed. A five-year period of test and support will include delivery in 18 months, followed by test and demonstration in Afghanistan.

Other members of the development team include Hybrid Air Vehicles in the U.K., which has been testing a one-sixth-scaled version; ILC Dover, which will fabricate the nonrigid envelopes, Warwick Mills, supplier of the fabric; AA1, furnisher of UAV control systems software; and SAIC, which will provide the ground environment for processing and dissemination of sensor data.

E-Green Technologies has acquired rights from 21st Century to develop the Bullet 580 airship. It will carry a NASA and Old Dominion University payload to measure moisture content in soil. E-Green currently flies a 125-ft scaled version.

SAIC plans to develop several Skyship nonrigid airships with envelope volumes of 80,000 ft^3 (currently operating), 138,000 ft^3, and 185,000 ft^3. Each could be piloted or remotely controlled. They would carry payloads of 1,000 to 2,000 lb. A 1.5 million-ft^3 cargo transport airship also is under study.

SAIC has teamed with Zeppelin Luftschifftechnik in Germany to produce a new multipurpose airship, the MPZ 07, a pilot-optional version of the semirigid NT-07.

This year Deutsche Zeppelin-Reederei, which began operations in 1997, carried its 100,000th passenger. Zeppelin has developed a long-distance kit that includes additional fuel tanks and transfer equipment. It was demonstrated during a 24-hr 40-min flight covering 783 n.mi. NT-07 airship No. 5, with 15 passenger seats, is under construction. Zeppelin bought NT-07 No. 2 from Japan's Nippon Airship, which has ceased operation. No. 2 probably will be rebuilt in Friedrichshafen, Germany.

American Blimp (ABC) has downsized its organization, both in Oregon and at its Lightship Group in Florida. Current activities include development of a heavy fuel engine pod, Delta Hawk, for retrofit on the A-170 airship. A new Lightsign and an A-60R engine upgrade are under development. The ABC-built Navy MZ-3A was flown from Yuma, Arizona, to Mobile, Alabama, to assist in monitoring the Gulf of Mexico oil spill.

TCOM LP has developed a new tactical aerostat system designated 22M. It will carry double payloads at twice the altitudes and twice the power of the 17M tactical used in Iraq. TCOM has been awarded contracts for 13 of the 22M systems.

Lockheed Martin received a $133-million contract for eight aerostat persistent threat detection systems (PTDS) in October 2009. They will be used in Afghanistan and Iraq. ILC Dover will have delivered a total of 40 PTDS envelopes to Lockheed Martin by the end of this year. In addition, ILC Dover will deliver 420,000-ft^3 and 275,000-ft^3 aerostats for Tethered Aerostat Radar Systems supplied to Lockheed Martin.

Airship Ventures, based at the former Moffett Field Navy base, assisted scientists from the SETI Institute and NASA in studying the salt ponds and microscopic organisms in San Francisco Bay during October 2009. In May of this year the NT-07 flew from Moffett Field to San Diego to establish a new class record for the 10-hr, 459-mi. flight.

Sanswire took receipt of its 111-ft STS-111 (Stratellite) multisegmented airship from the TAO organization in Germany. Sanswire has developed its 126-ft SkySat for testing and demonstration to potential customers by Global Telesat.

Digital Design and Imaging Services has built a balloon-supported "9-Eye" camera, which it uses for documenting surveillance tower placement.

by **Norman Mayer**

Flight testing

NASA successfully launched the Ares I-X development flight test vehicle in October 2009, demonstrating excellent control of the first-stage flight of the booster, whose tall, slender design had been planned for use in the Constellation program. This launch was followed in May by a successful demonstration of the capsule abort system, using solid-rocket control motors.

In further testing of vehicles for access to space, the Air Force successfully launched the X-37B orbital test vehicle on an Atlas V rocket in April. Designed to be a reusable spaceplane, the X-37B is a test platform for experiments in space.

Another success in flight testing occurred in May when the X-51 scramjet-powered WaveRider was dropped from a B-52 and set a record for the longest hypersonic flight ever, flying at Mach 5 for about 3 min.

In February the Airborne Laser Testbed, a modified Boeing 747-400 fitted with a powerful chemical laser and a precise targeting system, successfully demonstrated the first shoot-down of a ballistic missile during boost phase using a directed-energy weapon.

The Joint Strike Fighter program continued testing in January with the first in-flight engagement of the F-35B STOVL (short takeoff/vertical landing) propulsion system. The first vertical landing took place in March. The carrier variant (F-35C) made its first flight in June, bringing all three planned variants (conventional, carrier, and STOVL) into the flight testing phase.

The Stratospheric Observatory for Infrared Astronomy (SOFIA), a modified Boeing 747SP with a 100-in.-diam reflective telescope, made its first in-flight night observations. SOFIA flew at altitudes of 35,000 ft, above most of the atmospheric water vapor problems that hinder ground-based observations. When operational, the usual altitudes for observations will be between 41,000 ft and 45,000 ft. The observatory will carry a maximum of 20 crewmembers for missions lasting up to 8 hr.

Solar-powered aircraft began breaking endurance records this year. The piloted Solar Impulse flew on solar power for 26 hr in July, and the Zephyr UAV flew at 60,000 ft, remaining aloft for two weeks. Zephyr's flight broke the previous unmanned airplane endurance record of over 30 hr, set by a Global Hawk in 2001, as well as the manned flight endurance record set in 1986 by the Voyager, which stayed aloft for nine days.

NASA flew the first research mission with its Global Hawk on a 14-hr flight over the Pacific Ocean, from the Dryden Research Center nearly to Alaska and back, flying at altitudes in excess of 60,000 ft. The research airplane carries 11 instruments to sample the air and profile the dynamics and meteorology of the atmosphere.

The Boeing 787 Dreamliner flight test fleet passed the 1,000-hr mark in June. Gulfstream introduced a new airplane, the G250, and conducted the first flight test in December 2009. Scaled Composites' SpaceShipTwo completed a crewed "captive carry" flight test aboard WhiteKnightTwo in July, and followed that with the first piloted gliding flight of SpaceShipTwo in October after it was released from WhiteKnightTwo at an altitude of about 45,000 ft.

Launch of the Ares I-X development flight test vehicle took place on October 28, 2009.

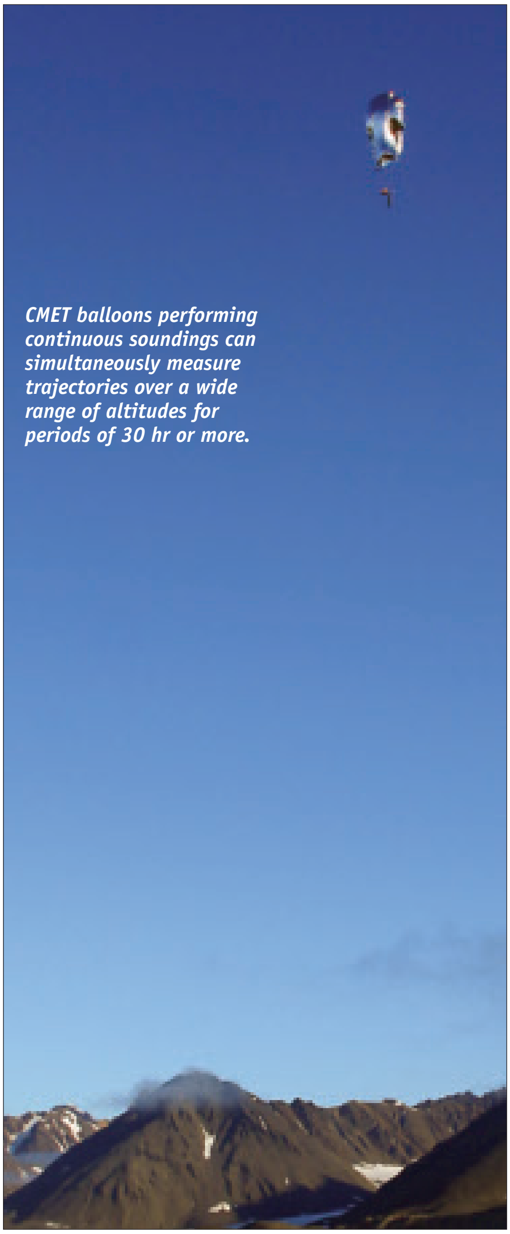
In rotorcraft testing this year, the Sikorsky X2 demonstrated its high-speed capabilities, setting an unofficial record of 250 kt with its coaxial rotor and pusher-prop configuration. Kaman's autonomous K-MAX cargo resupply vehicle demonstrated autonomous and remotely piloted capabilities that included delivering sling loads and cargo loads of 3,000 lb flying 150-n.mi. round trips. A sensor system to enable helicopter landings in dust "brownout" situations was tested in full brownout conditions at the Yuma Proving Ground, Arizona, in September 2009 aboard an EH-60L. The 3D-LZ system consists of a dust-tolerant ladar sensor with a display symbology system that enables a pilot to land or identify unsafe conditions and execute a go-around during brownout conditions.

by **Jay Brandon**

Balloon systems

This year brought progress in planetary ballooning, controllable small balloons, and recovery systems. These advances are stretching the boundaries of traditional balloon mission concepts.

A JPL team conducted a successful aerial deployment and inflation flight test on a 5.5-m-diam prototype Venus balloon. The balloon was deployed and inflated with 7 kg of helium gas while descending under a parachute with aerodynamic conditions comparable to those at Venus. Although the balloon was not later released for free flights, all other steps in the process were demonstrated, and the balloon was recovered, inspected, and found to be undamaged. This result demonstrates further maturing of the balloon technology required at Venus for a long-duration, cloud-level balloon capable of carrying a 45-kg payload.



CMET balloons performing continuous soundings can simultaneously measure trajectories over a wide range of altitudes for periods of 30 hr or more.

Near Space Corporation (NSC) has developed a new large/heavy-lift balloon capability. This effort allowed for a fresh look at scientific balloon paradigms and led to some significant new approaches, including use of a staged, packed-parachute recovery system. The system uses a drogue chute for the initial high-speed stabilized descent, followed by the deployment of one or more main chutes to slow the descent before impact. The new recovery system significantly reduces the descent time from altitude, the potential landing footprint, shock loads, and oscillation of the payload. It is applicable to payloads with masses ranging from a few hundred to several thousand pounds.

by the **AIAA Balloon Systems Technical Committee**

NSC's high altitude shuttle system (HASS), which has defense, science, and commercial applications, continues to progress toward becoming operational. HASS fully integrates an innovative tactical launch system with a special high-altitude UAS for payload recovery. The system allows launches to be performed in winds of up to 30 kt with a two-person crew from undeveloped sites (including ships). The design of the HASS shuttle UAV was optimized for high-altitude payloads and their semiautonomous return to predetermined landing locations. To date, NSC has conducted over 100 HASS flights, returning payloads of up to 30 lb.

Smith College has continued to develop controlled meteorological (CMET) balloons for use in atmospheric research. These balloons, although similar in size to standard rawinsondes, carry sophisticated sensors, have long-duration flight capability, and can repeatedly change altitude on command via satellite. Recent analyses demonstrate that CMET balloons performing continuous soundings can simultaneously measure trajectories over a wide range of altitudes for periods of 30 hr or more.

This new technique, which was found to be more accurate than transport models in predicting plume location, has applications in air-pollution and atmospheric process studies and for tracking hazardous plumes in near-real time. In an August study directed by the Norwegian Meteorological Institute, five CMET balloons were flown from Ny Ålesund, Norway (78.9° N), reaching new milestones for flight time (192 hr) and number of balloons in the air at one time (four) as they dispersed over the North Atlantic and Arctic Oceans.

NASA's flight program had its successes and challenges this year. Six flights were conducted from Antarctica. The CREAM (cosmic ray energetic and mass) mission achieved over 37 days' flight duration, thus providing over 155 days of cumulative exposure for the project. The BARREL (balloon array for RBSP relativistic electron losses) project flew four test flights in preparation for a 40-flight campaign in 2012. The increased-volume superpressure balloon failed going into float. After an investigation, changes were made in the design and another balloon was fabricated for testing this month.

The Australia campaign supported two missions: The TIGRE (Tracking and Imaging Gamma Ray Experiment) mission flew for 57 hr, and the Nuclear Compton Telescope mission suffered a mishap during launch.

General aviation

Piper introduced the PiperSport early this year, a slightly modified version of a light sport built by Czech Sport Aircraft.

After being granted an allowable weight increase this summer, Terrafugia has redesigned the Transition roadable aircraft into a production prototype.

General aviation sales continued to decline this year, but did so at a lesser rate than last year. Total shipments for the first half of this year were down 10% from last year. However, in the same period last year they were down 46% from the previous year, and 42% for all of 2009. Billings actually increased slightly this year, a significant change from 2009, when they declined for the first time in over a decade. Deliveries of high-end business jets accounted for the increased billings, although shipments of all business jets dropped 14% from last year.

The biggest change in deliveries was for piston aircraft. Last year they had declined 54%, but for the first half of this year the figure was only 2%. Cirrus actually delivered more airplanes than in the same period last year, with 127 units, and was the largest producer of piston aircraft.

Piper, under new ownership by Imprimus, is expanding internationally. It is again emphasizing entry-level singles, having delivered 30 Warriors and Archers so far this year, versus two last year. In a surprise move, in January the company introduced the PiperSport, a light sport aircraft (LSA) manufactured by Czech Sport Aircraft. The first model under the Piper name was delivered in April. The company is also proceeding with full development of the PiperJet.

At present, the very light jet market as originally conceived appears to be dormant, but larger models that are more in the light-jet class are doing quite well. Both the Embraer Phenom 100 and the Cessna Citation Mustang are top sellers among all jets. Earlier this year Cessna announced the rollout of the 300th Mustang, although production was downsized at midyear. The HondaJet continues in development, as do the single-engine Diamond D-Jet and the Cirrus Vision.

Large jet development also continues. The Gulfstream G650 is in flight testing and claims a cruise speed of Mach 0.925, slightly edging out the 0.92 record of the Cessna Citation X. In addition, the Gulfstream G250 midsize is on schedule for spring 2011 certification.

Tecnam of Italy is becoming a significant player in the general aviation market. Best known as a major producer of LSA, the company received FAA certification this spring for the twin Rotax-powered retractable P2006T. This year the firm also introduced the P2008, a top-of-the-line LSA with composite fuselage. The company is proceeding to expand it into a four-place certifiable airplane with a 180-hp Lycoming engine.

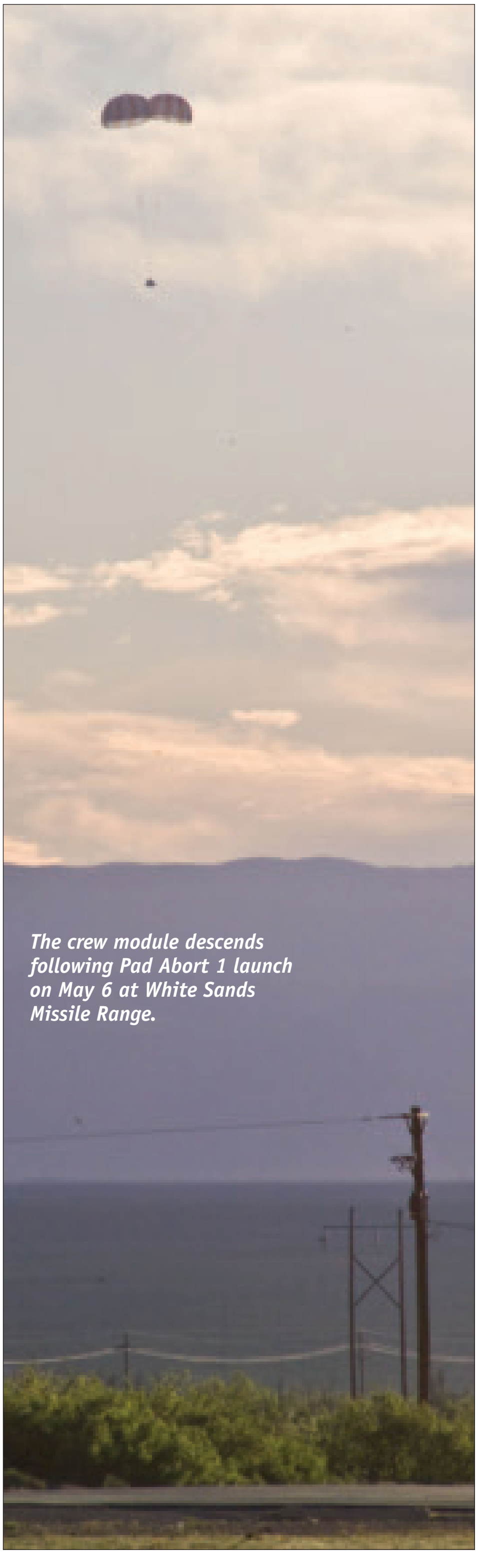
Light sport deliveries were down this year, but the industry is holding its own, especially with both Piper and Cessna now producing LSA. A number of companies have responded to complaints about high LSA prices by offering economy models. Legend introduced the Classic J-3 for under $95,000, and Flight Design is displaying its CTLS Lite at $20,000 under the standard model. The company also announced a new version of the CT designed specifically for glider tow, the CTLS HL (for high lift).

In June the FAA granted an allowable increase of 110 lb in gross weight to the Terrafugia Transition roadable airplane. This should allow the aircraft to incorporate features that enable it to meet federal highway safety standards and still qualify as an LSA. A redesigned production prototype has already been developed, and vehicle deliveries are anticipated late next year.

The general aviation industry still appears to be in a slump, and layoffs continue. Mooney has shut down all new production, doing only customer service work with its remaining 55 employees. Hawker Beech is depending on military contracts to offset its declining business aircraft sales. Still, industry analysts remain optimistic and expect a turnaround soon.

by **Hubert C. "Skip" Smith**

Aerodynamic decelerators



The crew module descends following Pad Abort 1 launch on May 6 at White Sands Missile Range.

by **Elsa Hennings**

This was an extremely busy year for parachute development, both for space applications and for precision aerial delivery. NASA's Orion crew exploration vehicle parachute assembly system (CPAS) was successfully demonstrated in May at White Sands Missile Range as part of a launch abort system test. CPAS consists of two mortar-deployed drogue parachutes, which slow the crew module during reentry into the Earth's atmosphere, followed by three mortar-deployed pilot parachutes that in turn deploy three 116-ft final descent main parachutes. The CPAS team has been performing component and subsystem tests since 2006, but the recently conducted Pad Abort 1 test marked a significant milestone in the demonstration of the complete recovery system, which functioned flawlessly.

SpaceX recently completed its first Dragon spacecraft drop test. The purpose was to test the deployment of the Dragon recovery system as well as recovery operations ahead of the first scheduled launch later this year. The recovery system includes two drogue parachutes to begin deceleration and stabilization of the spacecraft, followed by three main parachutes that reduce the capsule's speed to the desired landing descent rate. This test, conducted in August off the coast of California, was a complete success.

Alliant Techsystems, together with NASA, the Army, and United Space Alliance, broke the record for the largest single load extracted from a C-17 aircraft as they successfully tested an Ares I drogue parachute. In this test, conducted at the Yuma Proving Grounds, a record weight of 78,000 lb was deployed. Following release, the test article was allowed to accelerate to a predetermined velocity before the 68-ft-diam drogue parachute was deployed. This parachute is designed to reorient and decelerate the first-stage booster to an acceptable speed before the three main parachutes are deployed. The test exercised the drogue parachute to its intended 450,000-lb design load for the Ares I first stage.

Pioneer Aerospace began an effort to design, build, and test the descent system for ESA's intermediate experimental vehicle (IXV). The IXV project is part of the ESA Future Launchers Preparatory Program. The IXV reentry system is a technology platform to verify in-flight performance of critical reentry technologies. The lifting-body-shaped IXV weighs approximately 1,900 kg and is 5 m long and 2 m wide. The IXV descent system consists of a mortar-deployed pilot, a supersonic ribbon drogue, subsonic ribbon drogue, and ringsail main parachute. The IXV launch, reentry, and final 6-m/sec water landing is planned for 2013.

A Blizzard autonomous networked aerial delivery system (ADS) was developed by the Aerodynamic Decelerator Systems Center at the Naval Postgraduate School. Because of its smart guidance and control algorithms, even with strong winds this ultralightweight ADS proved quite reliable and exhibited a superb performance of 40 m circular error probable. Such performance allows the development team to proceed with the demonstration of unique applications for aerial delivery, such as precise delivery of an autonomous ground robot, landing on a moving platform, and deployment from the stratosphere.

In Europe, the FASTWing CL Project, largely funded by the European Commission and conducted by a consortium of eight European companies and institutions, was completed successfully, with a total of 21 drop tests of payloads weighing between 6,500 and 13,000 lb. Using a 3,225-ft^2 tapered parafoil and ultracapacitor-powered actuators, the system navigated autonomously to the target, showing an average glide ratio of 4:1.

The SPADES 1000 Mk2 system, developed by NLR and Dutch Space in the Netherlands, has been sold to the Netherlands Defense Forces and is presently undergoing system qualification.

For more information, go to: https://info.aiaa.org/tac/AASG/ADSTC/default.aspx.

V/STOL

In two major highlights for the year, both the F-35B Joint Strike Fighter and the X2 helicopter set very important speed records.

Lockheed Martin's milestone flight occurred on June 10, when an F-35B piloted by a U.S. marine became the first of the JSF production STOVL (short takeoff/vertical landing) aircraft to fly faster than the speed of sound. The aircraft accelerated to Mach 1.07 on the first in a long series of planned supersonic flights. The ultimate requirement is Mach 1.6. "For the first time in military aviation history, supersonic, radar-evading stealth comes with short takeoff/vertical landing capability," said Bob Price, Lockheed Martin F-35 USMC program manager.

On the significance of the flight, the program manager said, "The supersonic F-35B can deploy from small ships and austere bases near front-line combat zones, greatly enhancing combat air support with higher sortie-generation rates."

The Mach 1.07 record was achieved on the 30th flight of the F-35B STOVL variant known as BF-2. The pilot, Marine Corps Lt. Col. Matt Kelly, climbed to 30,000 ft and accelerated to Mach 1.07 in the offshore supersonic test track near NAS Patuxent River, Md. Future testing will gradually expand the flight envelope out to the aircraft's top speed of Mach 1.6, which the F-35 is designed to achieve with a full internal weapons load of more than 3,000 lb.

By August 31, the F-35B STOVL jets undergoing flight testing at Patuxent River had completed 122 flights, broken the sound barrier, and logged 10 vertical landings for the year. The flights of the four STOVL jets (BF-1, -2, -3, and -4) represent more than half of the 233 total F-35 flights for the year to date. The STOVL jets logged 26 flights in August, their highest monthly total so far. Flight rates will increase further when BF-5, the final test jet, enters airborne testing late this year.

On June 10, an F-35B reached a record speed of Mach 1.07.

The year's other, equally significant milestone was Sikorsky's record-breaking X2 flight on September 15, in which the company's X2 Technology Demonstrator achieved 250 kt true air speed in level flight and fulfilled the program's primary objective. All loads, vibrations, and temperatures were within limits, and the speed was limited only by power available. The aircraft hit 260 kt in a shallow dive immediately following the level flight record. Testing was at the company's West Palm Beach facility.

"The real significance of this record flight is that X2 technology can [now] be applied to new designs using the knowledge learned. The era of high-speed, low-disk-loading helicopters has arrived and will change rotary-wing aviation forever," says Sikorsky engineer Tom Lawrence.

During the buildup flights to the record run of the Sikorsky X2, the aircraft was modified to improve its handling qualities. A small horizontal surface was added to the ventral fin to improve longitudinal stability, and the fly-by-wire control laws were tuned to improve damping. The active vibration control system was also adjusted to maintain low vibration levels in the cockpit. As a result, the aircraft was easy to fly at 250 kt and should be capable of achieving higher speeds.

Work is currently under way to add an interhub fairing, sometimes called the sail fairing, to reduce the drag of the exposed upper rotor shaft. With this addition, it is expected that the X2 will achieve speed increases of 10-15 kt. Further flight testing is planned into next year.

A significant contribution to the X2's milestone flight was the use of piloted simulation. This allowed changes in control laws or configuration to be assessed before being implemented and made it possible for the X2 to reach 250 kt in only 17 flights.

by **E.R. Wood**

Aircraft design

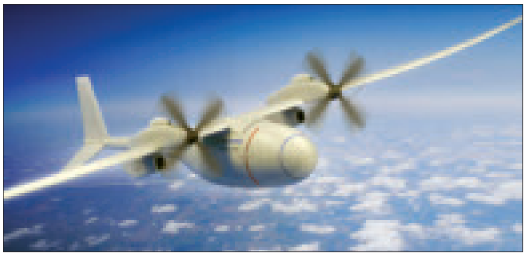
The SolarEagle is designed to carry a 1,000-lb payload in continuous flight for five years.

The Boeing X-51A WaveRider made history on May 26 by making the longest ever supersonic combustion hypersonic flight. Pratt & Whitney Rocketdyne's hydrocarbon-fueled and fuel-cooled scramjet engine burned for 200 sec, accelerating the vehicle to Mach 5. The X-51A is a major advancement toward sustained-use hypersonic propulsion relative to its predecessor the X-43A, which was powered by an uncooled, hydrogen-fueled scramjet that burned for just 12 sec.

Other key activities complementing scramjet development are under way. Lockheed Martin and Pratt & Whitney Rocketdyne are working on a TBCC (turbine-based combined-cycle) engine, under DARPA's Mode Transition program. The Vulcan engine program has advanced to the second stage, aimed at development and demonstration of a constant-volume combustion (CVC) engine and CVC module integration into a turbine engine.

In the military aircraft segment, the Marines' STOVL F-35B accomplished its first vertical landing, and the Navy F-35C carrier variant achieved its first flight. The Air Force F-35A is undergoing mission systems and weapons testing. Northrop Grumman's Navy E-2D Advanced Hawkeye entered operational service. The X-47B UCAV (unmanned combat air vehicle) is undergoing testing for air vehicle systems/ship systems interface, preparing for its maiden flight.

The hydrogen-powered Phantom Eye can stay aloft for four days with a 450-lb payload



Boeing's solar-electric-powered SolarEagle high-altitude long-endurance (HALE) UAV was selected for DARPA's Vulture program to demonstrate, in 2014, a UAV that can carry a 1,000-lb payload and draw 5 kW of power while flying uninterrupted for five years at above 60,000 ft. The quad-tail 400-ft flying wing design uses highly efficient electric motors and propellers. Energy collected by the solar panels is stored in solid-oxide fuel cells. Boeing is also developing the 150-ft hydrogen-powered Phantom Eye HALE UAV, which can fly up to four days with a 450-lb payload.

Harvard University is developing high-performance insect-size flapping-wing spy vehicles, using a unique fabrication technique to create the insect-scale wings, actuators, thorax, and airframe. The effect of wing design on performance is being investigated through experiments that move the wings at high frequencies, recreating trajectories similar to those of an insect. These include high-speed stereoscopic motion tracking, force measurements, and wing flow visualization.

Military rotorcraft design could get a major boost this year. Sikorsky's fly-by-wire high-speed X2 demonstrator achieved its 250-kt speed milestone, paving the way for the development of faster helicopters. DARPA's Mission Adaptive Rotor program is developing a shape-changing rotor that could offer substantially more payload and range with significantly less noise and vibration. The rotor's blades can "adapt" to a wide range of flight conditions by changing their own parameters. Boeing is studying the Discrotor convertible rotorcraft, which slows the rotor and retracts extendable telescopic blades within the disc as it accelerates, until it morphs into a high-speed (400-kt) swept-wing aircraft powered by variable-thrust ducted propfans.

The truss braced wing (TBW) configuration is promising to be a "green" design that could be used for commercial airliners entering service in 2030. A Virginia Tech-led study for NASA is showing that a TBW aircraft burns 30% less fuel than a B-777. Synergy between the TBW's advanced wing topology, tailless designs, fuselage drag reduction with riblets, fuselage relaminarization, Goldschmied devices, and/or buried engines indicates the potential to achieve more than 70% reduced fuel burn.

Boeing recently produced five ultragreen single-aisle commercial aircraft design concepts. Sugar Volt, a concept featuring a TBW aircraft using an electric battery gas turbine hybrid propulsion system, indicates 70% reduced fuel burn relative to a B-737.

Lockheed Martin produced a low-sonic-boom design concept featuring an "inverted-V" engine-under-wing configuration and canards for supersonic commercial transports.

Another promising concept is Boeing's X-48B blended wing body, which recently completed "limiter assaults" flights, confirming that a robust, versatile, and safe control system can be developed. A modified low-noise version, the X-48C, is being prepared for flight tests in 2011.

by **Dyna Benchergui** and **Charlie Svoboda**

Aircraft operations

This year significant research, including several simulation experiments, advanced the Next Generation Air Transportation System (NextGen) concept.

In the airport surface domain, a NASA experiment tested taxi scheduling algorithms in a human-in-the-loop simulation of a major U.S. airport, using advanced controller advisory tools. The experiment demonstrated the initial feasibility of the algorithms and showed that eliminating stop-and-go operations during taxiing could reduce fuel expenditure on the airport surface by 18%.

In the terminal area domain, NASA simulations increased airport capacity by allowing planes to approach closely spaced parallel runways in low visibility. The TAAPR (terminal area approach procedures research) simulations compared manual and automatic techniques to pair aircraft from different arrival streams to a coupling point 15 n.mi. from the runway threshold. The speed of the trailing aircraft was coupled to that of the lead aircraft to maintain adequate in-trail spacing to the runways.

An FAA/NASA experiment used 22 commercial airline pilots to determine the effect of using Data Comm during busy terminal area operations. Quantitative data were collected on subject reaction time and eye tracking. Oculometer systems simultaneously tracked the Pilot Flying (Captain) and Pilot Monitoring (First Officer) head angle and eye gaze vector. Each crew managed over 200 aircraft and 1,200 voice transmissions. Of particular interest to the FAA were new D-TAXI messages, such as the "Expected Taxi" clearance to be sent prior to gate pushback during departures, and prior to Top Of Descent during arrivals. Crewmembers responded to 95% of the Data Comm messages within 1 min; however, there was general agreement that 2 min was reasonable for response. Eye tracking data indicated a significant increase in head-down time for the Pilot Monitoring when Data Comm was introduced; however, workload was rated as operationally acceptable by almost all crewmembers in all conditions, except at certain points beyond the final approach fix and during certain taxi operations.

NASA, with Boeing and the FAA, continued developing the efficient descent advisor (EDA). It gives controllers maneuver advisories to enable continuous, idle-thrust descent operations in busy traffic. By predicting trajectories over strategic time horizons, EDA provides efficient descents that avoid traffic conflicts while maximizing arrival throughput. Reactions of controllers and pilots were encouraging. To further enable fuel-efficient descents, EDA technology was combined with new automation and procedures in a series of NASA TAPSS (terminal area precision scheduling system) simulations. These combined new time-based metering automation with advanced navigation concepts to enable environmentally friendly descents in high-density airspace.

Human-in-the-loop simulation of the TAPSS were conducted.

NASA investigated function allocation for NextGen, comparing different approaches to separation assurance. Two human-in-the-loop simulation experiments were conducted on homogeneous airborne and ground-based four-dimensional trajectory-based operations. In coordinated simulations, controllers for the ground-based concept at Ames and pilots for the airborne concept at Langley managed the same traffic scenarios under the two different concepts. Results showed no substantial differences in performance or operator acceptability. Mean schedule conformance and flight path deviation were considered adequate for both approaches. Conflict detection warning times and resolution times were mostly adequate, but certain conflict situations were detected too late to be resolved promptly, creating safety compromises and/or unacceptable workloads. Controller feedback was generally positive, although further study is required.

Research in traffic flow management examined more equitable flight planning under capacity restrictions such as adverse weather, using a credits-based concept. The concept establishes airline flight priorities and route preferences, and allows airlines to maintain schedule integrity and flight-connectivity concerns while minimizing fuel consumption. A human-in-the-loop simulation demonstrated feasibility and support for the concept. The FAA and NASA also tested the near-term, Generic Airspace concept. Generic Airspace gives air traffic controllers new tools and information that enable them to become quickly accustomed to new airspace sectors designed for maximum operational efficiency.

A NASA/Navy/Air Force simulation modeled the integration of the Navy's broad area maritime surveillance (BAMS) UAS (unmanned aircraft system) with civilian airspace operations. Results have been used to perfect the BAMS design and validate the modeling and simulation system for future UAS integration studies.

by the **AIAA Aircraft Operations Technical Committee**

Systems engineering

by **Brian Selvy**

Simon Ramo, pioneering physicist and engineer, defined systems engineering as "a discipline that concentrates on the design and application of the whole [system] as distinct from the parts. It involves looking at a problem in its entirety, taking into account all the facets and all the variables, and relating the social to the technical aspect."

Engineered systems have become increasingly complex, and their desired complexity also has been growing at an ever-increasing rate. This poses major challenges for the systems engineer (SE). As noted systems thinker Russell Ackoff stated, "Change itself is constantly changing." Donald A. Schön, another eminent thinker in this field, pointed out that as the rate of change increases, so does the complexity of the problems that face us. The more complex the problems, the longer it takes to solve them. The more the rate of change increases, the more the problems that face us change, and the shorter the life of the solutions we find. Therefore, by the time we find solutions, they often are no longer relevant or effective.

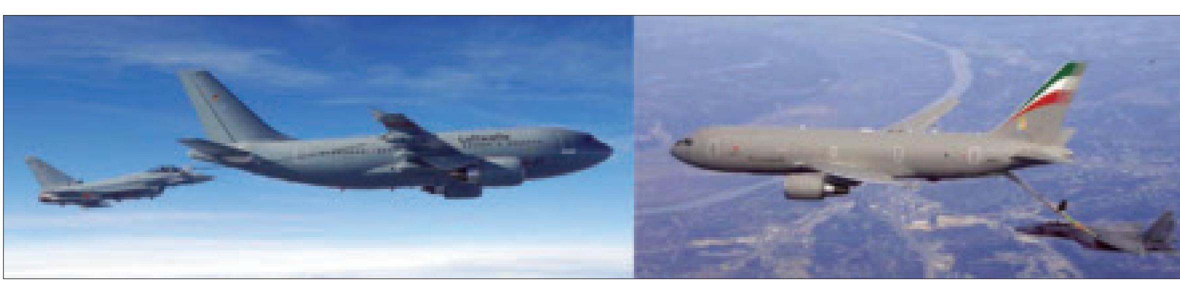
This is becoming prophetic for the SE. The social aspects of systems engineering, particularly the political aspects, are becoming a greater influence on SEs, challenging their ability to develop products and services that are still value added by the time they become operational. U.S. government acquisition is an example of such an influencer. The development cycle for some of the most complex aerospace systems is significantly longer than the yearly congressional budget approval cycles and the tenures of White House administrations and policies.

As each Congress and White House puts its stamp on defense and space policies, the changes cause cyclic disruptions in most major DOD and NASA programs. There is a discontinuity between even the most conservative development cycle and these budget and policy approval cycles. This typically causes out-year cost growth and schedule slippage as programs struggle to reduce near-term spending while policy and budgets are debated. This in turn provides political justification for cancelling programs. And even if a program survives, the end system is less likely to prove useful when it becomes operational, because it must also overcome the accelerating rate of change in the need during the length of the schedule slip. This problem has resulted in billions of dollars being sunk on canceled projects.

SEs emphasize the need for internal program stability, especially in funding and requirements. Often we hear SEs stress the need for well-defined requirements at program inception, and the need to resist changing the requirements set during the development process. This may seem like resistance to change; yet it is resistance to internal program change that is absolutely necessary for managing costs and program complexity in efforts to produce a system that does represent a leap forward in operational capability. It is this actual end product or service that constitutes a capability advancement in an ever-changing world.

The alternative—repeated restructuring and rescoping of a project—increases the likelihood of program cancellation, or at a minimum, cost and schedule creep. Such restructuring may be done with good intention—that is, in an attempt to meet an end user's ever-changing needs—but all too often the result is a system that never achieves operational status because of program cancellation, justified by schedule and cost overruns.

Until government acquisition policy is aligned with the realities of the desired complexity of future systems, there will be a growing gap between the length of time it takes to develop operational system capabilities and the length of policy and budget approval cycles. This will make the SE's job of racing changing needs to the operational finish line ever more challenging.



The Air Force tanker program has gone through several bid-award-appeal cycles.

Computer-aided enterprise solutions

After 10 years of advances in software and hardware technologies, it would be useful to see what has changed and ask the question: Are we doing enough to exploit the technologies we have around us?

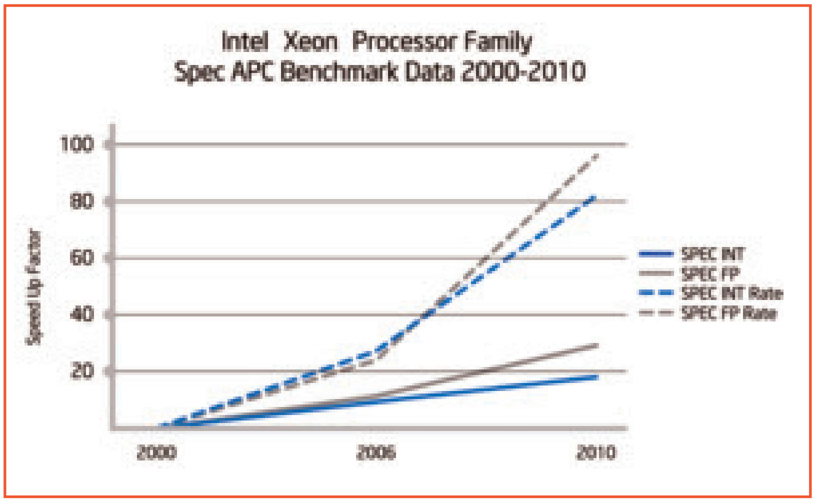
From 2000 to 2005, CAD application performance increased almost fivefold, according to estimates. In the next five years it increased only about threefold. Most CAD applications, being single threaded, exploit only a fraction of the available computational power of today's workstations. Intel and other semiconductor manufacturers moved from increasing clock speeds to maintaining them, adding new instruction and more computational cores. The impact was a leveling off in the performance of serial applications such as computer-aided design.

During the same period, analysis and simulation performance is estimated to have increased by nearly 100 times. This was due mainly to increased core count per processor, new instructions, and faster infrastructure. Complex simulations that took nearly five hours to process in 2003 were now being completed in less than 10 minutes.

Meanwhile, technical computing software vendors were merging and acquiring CAD, meshing, simulation, and analysis companies. They retooled themselves and created comprehensive engineering suites, presenting users with innovative schematic views that tie together CAD with the entire simulation process. The schematics serve as guides to engineers, enabling them to process complex multiphysics analyses with drag-and-drop simplicity. Their intention is to accelerate the user's innovation rate by reducing complexity and increasing system utilization.

Henry Ford said, "There's a better way to do it—find it." With advances in workstation technologies and the integration of CAD, meshing, CAE, and CFD software, there has to be a more efficient way to create, test, modify, and visualize ideas. An interesting process that can be applied to the design process is Boyd's loop, also known as the OODA (observe, orient, decide, and act) loop. Simply defined, Boyd's loop is a decision-making process similar to the plan-do-check-act cycle. The speed of the loop is often an early indicator of a group's ability to deliver an optimal design rather than an adequate design that may cost more to manufacture and maintain and may require more material, significantly affecting product profitability.

OODA in a product design process helps engineers and designers observe a product's behaviors before it is manufactured. With advances in hardware and software technologies, the notion of simulation-based engineering can be used for digitally creating and testing an idea before it is ever real. Rather than exploring one design in a certain time period, engineers can explore significantly more designs. They can ask "What if I did this or that?"



They can orient themselves to new ideas faster, then make a decision and act by asking "What if?" or saying "Wow, I did it." By accelerating an engineer's OODA loop, you have effectively accelerated the art of innovation at your organization.

We live in interesting times; in fact, the technologies presented by software and hardware providers are so fascinating that they are challenging our status quo. They present us with opportunities to work smarter and more efficiently. We now have options to iterate through more ideas in less time. We can move from an adequate to an optimal design. But are we deploying our new "stuff" to support the way we have been doing business all along—in some cases decades? Should we be reviewing our processes and *then* considering options—hardware and software—that will readily enable us to work the way *we* believe is best? After all, *we* are the experts in our product development.

If the definition of insanity is "to do the same thing over and over again and expect different results," isn't it time we accelerate innovation again and explore how we can reinvent the design process using the talents and technologies we have available to us?

by **Bill Abramson, Wes Shimanek,** and **Mike R. Jahadi**

Society and aerospace technology

When the subject of funding for civil space programs is broached, the "public will" or "public mood" is usually cited as well. It is clear that when the public will for a space project is lacking, so too are the needed funds. But conducting an accurate annual national survey on the issue would likely cost as much as running some spaceborne experiments aboard the ISS.

Fortunately, the social sciences have other means at their disposal for gauging the public mood about space. Specifically, a recent analysis of 1,027 space-themed popular songs from around the world has provided a useful gauge of the public mood toward space over time, beginning with the start of the space race. The analysis was performed by Thomas Gangale, an author of this report and a member of the Astrosociology Subcommittee of the AIAA Technical Committee on Society and Aerospace Technology. The analysis reveals some surprising patterns.

Many U.S. and British songs use outer space as a metaphor rather than being specifically about human spaceflight; only a few songs celebrate particular space missions. Science fiction themes are more prevalent, especially *Star Trek* themes. The UFO phenomenon was captured in popular music from the very beginning (1947) and continues today. The first Sputniks inspired a flurry of rockabilly songs. Space jazz was pioneered in the mid-1950s and continued through the 1980s. Surf music also displayed an early affinity for the adventure of spaceflight. "Trek rock" has been a niche for pop groups in both Sweden and the U.S.

By contrast, Soviet songs were specifically about the heroic adventures of the cosmonauts. Even modern Russian music tends to be more grounded in the reality of human spaceflight in Earth orbit, or in the foreseeable possibilities of travel in the inner solar system, rather than in interstellar science-fiction visions set in future centuries.

It appears that the rest of the world mourns America's fading space glory much more than the U.S. itself does. Songs on the subject, particularly in the U.K., lament the passing of the Apollo years, or, as in Canada, satirize the wildly optimistic literature that baby boomers were raised on.

Peaks in the numbers of songs produced occurred in the 1960s for the U.S. and the USSR. This is not surprising, because the space race was on. But by 1971, the 10th anniversary of cosmonaut Yuri Gagarin's first flight, the top-down music culture directed by the Communist Party was dead. It appears that Soviet culture, in terms of the production of space music, was rather anemic, whereas in contemporary bottom-up Russian popular music, space themes are literally rocketing to new heights. Also on a steep ascent are songs in the aggregate from countries other than Russia and the U.S. Meanwhile, U.S. production of space-themed songs may be in decline after having reached a second peak in the first decade of this century.

In the U.S., the later peak likely reflects the various discoveries concerning Mars made in the late 1990s and early 2000s; public interest in the Hubble space telescope, space shuttle, and ISS news; and policies about returning to the Moon and sending humans to Mars. The downturn seems to track with decisions on retiring the shuttle, withdrawing from the ISS, and shutting down the Constellation program.

> ***"…a recent analysis of 1,027 space-themed popular songs from around the world has provided a useful gauge of the public mood toward space over time, beginning with the start of the space race."***

Despite the slump in space-themed songs from the former space race rivals, such music from the aggregate of other countries has demonstrated steady growth and is now in almost as sharp an ascent as that of modern Russia. What can this mean? It is likely reflective of the investment by other nations in the civil space enterprise: China has orbited taikonauts, India has mastered splashdown technology, and a supranational Europe has taken the lead in partnering with other nations on space projects.

by **Marilyn Dudley-Flores** and **Thomas Gangale**

Economics

The aerospace industry saw many positive developments this year, including a recovery in air transportation, progress on programs with potentially large economic implications, and increased use of export financing by the space industry. However, the approaching end of the shuttle era and a sluggish economy are causes for concern.

The economic recovery aided a rebound in the air transportation industry. By June, the International Air Transport Association was forecasting that commercial airline industry volume will grow over 7% for passenger markets and almost 19% for cargo markets. The industry is on track to achieve an estimated $2.5 billion in profits this year as compared to estimated losses of $9.9 billion in 2009 and $16 billion in 2008. In addition, Boeing's 787 Dreamliner made progress. Following up on its first flight in December of 2009, the 787 entered into an extensive flight test program, with over 500 flights and 1,500 flight hours through the end of August. Scheduled for first deliveries in 2011, the 787 has the potential to impact airline industry economics significantly. Among the benefits the plane will provide, says Boeing, are 20% less fuel consumption, 30% lower maintenance costs, 10% lower cash operating costs, and an increase in cargo revenue capacity of over 40%.

Another milestone marking progress in industry economics was the successful flight of SpaceX's Falcon 9 launcher. On its inaugural launch in June, Falcon 9 attained a nearly perfect orbital insertion and accomplished all of its primary mission objectives. SpaceX claims that the launcher represents the lowest mission price for its vehicle class, listing prices of about $50 million-$60 million per launch. Demand for more cost-effective launch services appears strong, with SpaceX announcing that it has over 40 launches under contract, including a $492-million deal to launch satellites for mobile satellite services provider Iridium's upcoming NEXT constellation—the largest single commercial launch deal ever signed. In addition, the first demonstration flight of the Falcon 9 for NASA's COTS program, aimed at developing a commercial space transportation system capable of providing cargo to the ISS, is scheduled for late this year.

Despite lower interest rates for corporate bonds and modest easing of lending standards, companies still faced a constrained credit environment compared to the pre-crisis period. However, several satellite operators were able to turn to export credit agencies (ECA) for substantial portions of their financing needs, continuing a trend that started with Globalstar's credit facility from Coface, France's ECA, in 2009. Hughes Communications received Coface backing for about $90 million in financing for the launch of its Jupiter Ka-band broadband satellite aboard an Ariane rocket. Coface also guaranteed $1.7 billion of a credit facility for Iridium's NEXT mobile satellite system constellation, under development by Thales Alenia Space. In addition, Inmarsat is seeking U.S. Export-Import Bank support for the $500-million cost of three Boeing Ka-band satellites for its Global Xpress mobile broadband system.

Boeing's 787 has begun an extensive flight test program

With the end of the space shuttle era approaching and its replacement, the Constellation program, cancelled, the space industrial base is confronting a difficult period. According to the Dept. of Labor, the end of the shuttle program could result in the loss of 20,000 jobs, with implications for the health and sustainability of the industrial base. United Space Alliance, the prime shuttle contractor, has already sent out layoff notices to over 1,300 workers, about 15% of its workforce. Furthermore, the economy appears to be weakening, with GDP slowing this year and other economic indicators fading. Looking toward 2011, a cautious outlook for the aerospace industry is warranted.

by **Scott Isara** and **Marilee Wheaton**

Management

A review of the issues aerospace management grappled with in 2010 starts with formulating and prioritizing lists. However, while lists are easy to create, in reality it is much more difficult to segregate issues into topics that can be succinctly discussed. Further consideration of the top issues reveals that not only are all interrelated, but each compounds the effects of the others. The unavoidable conclusion is that none of these issues can be addressed alone. And even though each issue on the list is important in and of itself, we can only briefly examine the most critical of these issues here.

•***Developing a vision for the future of aeronautical sciences*** may be the most important endeavor in the first half of the 21st century. Just as the development of aeronautics in the late 18th and early 19th centuries paved the way for change that still affects each of us today, the aeronautical sciences will have a profound effect on our lives far into the future.

Aeronautics literally means "navigation of the air"; however, the aeronautical sciences have produced a broad plethora of goods, services and knowledge beyond aircraft, from navigation/communication systems to cookware for home use. Any vision for the future of aeronautical sciences cannot and should not focus solely on air transportation. Just as each of management's top issues affects all the others, the aeronautical sciences will continue to affect much more than our mobility through the air.

> ***"Any vision for the future of aeronautical sciences cannot and should not focus solely on air transportation. Just as each of management's top issues affects all the others, the aeronautical sciences will continue to affect much more than our mobility through the air."***

•***Management of crisis,*** in the broader context of a "top issue," is different from many of the crises in the history of aerospace. The focus of this issue is not a single vehicle or incident. Rather, the focus is on the relationship between technology, people, knowledge, and risk. What is really important about this issue is how each of these four areas compounds the complexity of, the required response to, and recovery from a crisis.

Even though not associated with aerospace, the 2010 oil spill in the Gulf of Mexico illustrates the interrelatedness of these areas. It shows how rapidly advancing technology, decreasing budgets/staffing, as well as increasing system complexity all challenge our ability to sustain critical knowledge and manage risk holistically. It also demonstrates how spillovers—unintended consequences—impact other industries that then have to respond.

•***Cultural change.*** Change is that all encompassing, ubiquitous thing that we've all come to…love. What is interesting and important about this issue is the diversity of areas now effecting cultural change: a multigeneration workforce, intense global competition, a stressful economic environment, loss of experience on the contractor and the government sides, much more complex systems, and more rapidly evolving (that is, changing) requirements, to name only a few. How well we are able to manage cultural change will largely determine how successful we are in each of these areas in the future. Furthermore, how well we manage cultural change will have a direct impact on our resilience, for example, on how well we are able to manage crises in the future. Again, the relationships and the interface between these very important issues are recognized as crucial.

Developing a vision for the future of aeronautical sciences is deeply interrelated with our industry's practice of knowledge management and depends heavily on our management of cultural change. Absent an effective system for maintaining current expertise and skills, our future may simply be relegated to reinventing the past. The challenge in aerospace management continues to be one of recognizing and understanding these complex issues. Management remains committed to sharing insights and best practices on these topics—distilling their essence—in a way that advances our industry.

In aerospace, our culture, our knowledge, how we think about and manage risk, and in reality our future, all depend on our vision.

by **Marvine Hamner**

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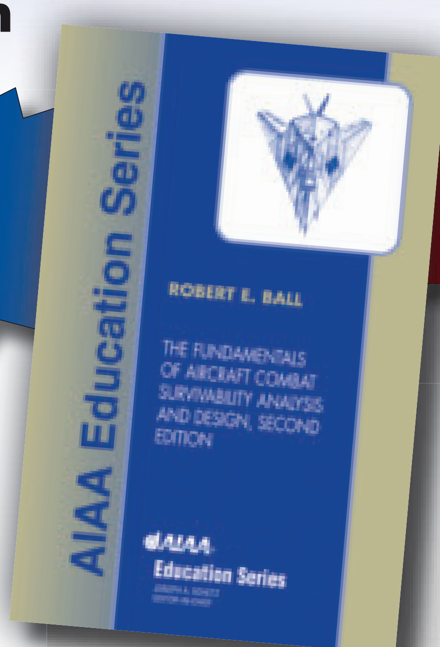

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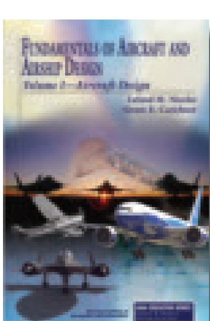

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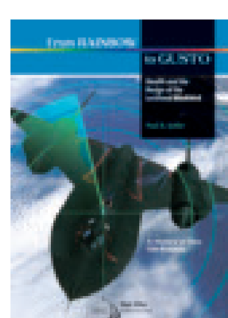

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Software systems

Software continues to play an increasingly important role in the development of new aerospace platforms and breakthrough platform capabilities. Of significance here are software systems—both resident on flight systems and executing on the ground—that control, manage, and otherwise interact with flight systems. This year saw some notable examples of the important role that software has played in this area.

Flight tests were conducted on a demonstrator aircraft to prepare it for an attempt to break the world speed record for a helicopter (400 kph, set in 1986). Decades ago, an early flight of an original concept demonstrator had resulted in a crash landing after a sudden pitching motion forced the pilot to land on the aircraft's tail. For this year's attempt at the record, CAD software tools were used to redesign the airfoils, rotors, and fuselage. Software was written to implement necessary stability augmentation functions to dampen unwanted pitch and roll when the plane was under pilot control, and simulation software was used to estimate vehicle performance and to drive pilot-in-loop training prior to live flight. The aircraft, a Sikorsky X2, reached 250 kt in level flight.

In April a major domestic airline modified the cockpit software in a majority of the airplanes in its fleet to allow for precise satellite-based navigation approaches to airports. This leverages the emerging concept of RNP (required navigation performance) routes to enable fuel savings, reduce noise, and shorten arrival delays.

Also this year, work for NASA resulted in the building of software to fix blurred images received from space telescopes. The concept involves calculating optical aberrations that will be used to sharpen incoming images. This software will be coupled with future telescopes having flexible mirrors that can bend and move on command; the combination will enable identification of a sensor's own errors and implementation of subsequent compensation. There is even thought of extending this software to enable vision scientists on Earth to enhance human eyesight.

Software is used to trigger and synchronize an increasing number of onboard functions on an increasing number of onboard processors. For example, published reports from this year indicate that the F-35 fifth-generation fighter will have about four times as much software code as the F-22 has. This larger volume of code will be executing on a significant number of processors on the aircraft, all orchestrated by onboard software.

Safety is a paramount concern for aerospace systems. Newer systems are becoming more complex in response to customers' needs for better performance and more features, and software plays a major role in implementing this emergent, complex functionality. But with added functionality comes an even larger burden, that of ensuring the safety of these increasingly complex implementations. Flight systems are safe today in part because of the sound development processes and effective partnerships that have been forged between systems/software developers and customer oversight/regulatory bodies, all of whom have a keen interest in the development and operation of safe flight systems.

"Flight systems are safe today in part because of the sound development processes and effective partnerships that have been forged between systems/software developers and customer oversight/regulatory bodies, all of whom have a keen interest in the development and operation of safe flight systems."

To help deal with this increasing complexity and to ensure system safety, organizations such as the National Science Foundation, NASA, and DOD laboratories have made some important investments in software development methodologies and in V&V (verification and validation) technologies for software. Investment areas include cyber-physical systems, model-based development for flight software, studying the use of formal methods for code analysis, formal languages for software requirements, research on software design-for-certification, and research on provably correct autocode generators.

These research areas can be important for supporting continued development of increasingly complex and safe aerospace systems, all enabled by software that can be developed affordably.

by **Jim Paunicka**

Intelligent systems

This was a year of exciting advances for intelligent systems in both aviation and space.

In aviation, DARPA funded Rockwell Collins to design damage tolerant control (DTC) technology to mitigate common UAV failures such as surface damage, airframe damage, and complete engine failure. A series of flight tests were performed with a subscale F/A-18 to showcase key aspects of the DTC technology. DTC's unique, software-based approach to vehicle control has been developed and evolved over the past decade. Flight tests demonstrated completely autonomous flights with loss of ailerons, loss of 60% of a wing and 30% of vertical and horizontal stabilizers, engine-out condition, and 80% wing loss. The combination of all-attitude control and an emergency mission management system provided these UAVs with unprecedented robustness against otherwise catastrophic failures.

Robust adaptive flight control was an area of particular emphasis this year. A collaboration by Wichita State, Kansas State-Salina, Missouri University of Science and Technology, and Hawker Beechcraft demonstrated another adaptive flight control technology for general aviation aircraft. The team, funded by NASA, is advancing model reference adaptive control techniques, investigating adaptation in the presence of aeroelastic modes, and using flight simulation flown by student pilots. Their first flight test on board the Hawker Beechcraft Bonanza AGATE/SATS fly-by-wire testbed showed promising results.

Researchers in the Diagnostic and Prognostic Group at NASA Ames' Intelligent Systems Division, in collaboration with California State Polytechnic University, have designed and built an innovative airborne testbed for conducting research into prognostic health management of electromechanical actuators. Use of such actuators in aerospace vehicles is expected to increase for safety-critical functions. Several experimental flights of the testbed have been conducted aboard USAF C-17 aircraft and Army UH-60 helicopters. During flight tests, the testbed's nominal and fault-injected test actuators mimicked the motion and load profiles that the aircraft's actuators were experiencing, while health management algorithms evaluated conditions in real time.

Southwest Airlines streamlined its operations thanks to NASA technology transfer. This year NASA open-sourced many key data mining algorithms for analysis of output from flight data recorders through DASHlink (dashlink.arc.nasa.gov), a Web 2.0 portal for the world. Using Miner and Orca, two advanced anomaly detection techniques, Southwest was able to uncover operationally significant events that would not be triggered by their existing methods. Orca alone analyzed 7,200 flights from 10,000 ft to touchdown, revealing data quality issues, high roll and pitch events near final approach fix, and hard nose-over prior to landing, leading to everyday changes in the commercial airline's operation.

On the space side, the University of Wyoming pushed the state-of-the-art in evolving intelligent systems that enhance control, stability, and robustness during autonomous assembly of large complex structures in space. The components of an evolving system self-assemble to form new components and are augmented with additional local controls to ensure system stability during assembly. Evolving systems enable modular system design and the reuse of components where scale, complexity, and distance preclude astronaut assistance because of inherent risks and costs. The evolving systems framework provides a scalable, modular architecture to model and analyze subsystem components and connections.

"The combination of all-attitude control and an emergency mission management system provided these UAVs with unprecedented robustness against otherwise catastrophic failures."

Enabling astronauts to make better informed decisions, researchers at NASA Johnson and Jet Propulsion Lab unveiled and field tested a new onboard energy management advisory system. It combines an intelligent planner with real-time estimation to provide detailed projections of battery energy across complex activity plans. The onboard planner continually revalidates the activity plan as it is executed and can inform astronauts when projection models indicate that the planned activities will lead to an unsafe state or will jeopardize a contingency plan; the system then suggests recovery options.

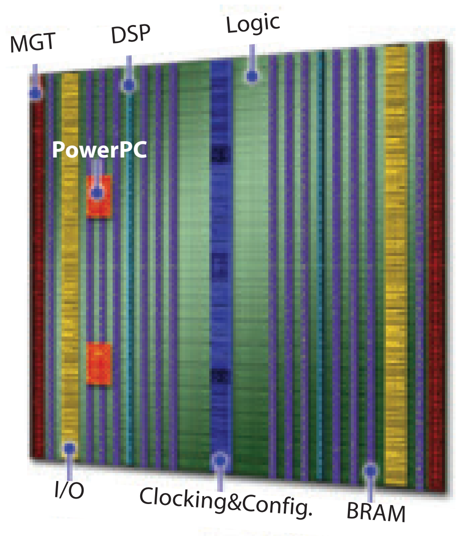
by **Seth Harvey, Michel Ingham,** and **Kristin Yvonne Rozier**

Computer systems

by **Rick Kwan** and **Jim Lyke**

Transformative advances in computing continue unabated. Aerospace and advanced mobile technologies have hit the consumer market. Computational science and engineering are turning to high-performance graphics for new methods of supercomputing. A new radiation-hardened FPGA (field programmable gate array) is becoming available for spaceborne applications. And space plug-and-play architecture is proving itself in orbit.

GPS-enabled navigation has become essential to drivers on the road. Accelerometers have revolutionized game consoles such as the Nintendo Wii. Today so-called "smartphones" integrate sensor and computing technology that would normally be expected in a UAV. Both the Apple iPhone and Google Android-based devices have GPS receivers, accelerometers, and gyro or solid-state compasses. They also add digital cameras and radios to support wi-fi, Bluetooth, and 3G communication, along with a sophisticated operating system and its array of "apps." This low-cost, mass-marketed integrated package has caused some aerospace researchers to adopt smart phones as their starting point for "faster, cheaper, better" vehicle or small satellite design.



The Virtex-5 field programmable gate array consists of various functions embedded in a columnar architecture. (Courtesy Xilinx.)

In recent years, computational science and engineering have migrated to massive clusters of multicore microprocessors for supercomputing power. Now graphics processing units (GPUs) that normally power real-time 3D visualization are being added to the mix. GPU leader NVidia provides a common interface to its GPUs through its Compute Unified Device Architecture, or CUDA. The Khronos Group, which maintains the specification for OpenGL, now has a cross-platform Open Computing Language, OpenCL.

As of June, the fastest supercomputer in the world (according to http://top500.org) is Jaguar (1.759 tFLOPS), at Oak Ridge National Laboratory. Built by Cray, it is a vast array of multicore 64-bit AMD Opteron processors. The second-fastest supercomputer is Nebulae (1.271 tFLOPS), at the National Supercomputing Centre in Shenzhen, China, using a mix of multicore 64-bit Intel processors and NVidia Tesla GPUs. Third-fastest is RoadRunner (1.042 tFLOPS), at Los Alamos National Laboratory, using IBM PowerXCell (a variant of the CELL broadband engine) along with multicore 64-bit Opteron processors.

The need to shorten protracted development times for spacecraft is driving the development of plug-and-play architectures analogous to those in personal computers. TacSat-3, launched in 2009, flew the first space demonstration of AFRL space plug-and-play architecture. In June, it was handed over to the Air Force as a full-time operational asset.

Spaceborne electronics are susceptible to effects of radiation. Mitigating these effects is a complex problem involving techniques such as error correction, redundancy, shielding, latch-up current monitors, and watchdog timers. Xilinx, a major provider of programmable logic devices, was funded by AFRL's Space Vehicles Directorate to create the Virtex-5QV, a rad-hard version of the Virtex V FPGA. The 1-billion-transistor chip is the most complex circuit ever designed for space. It allows rad-hard designers to use the same tools currently used in nonhardened designs. The result should revolutionize the implementation of high-performance computation in space. But the niche market for rad-hard devices keeps their prices well above those of their commercial counterparts.

Space weather forecasters say a storm season is approaching, noting that the Sun is waking up from an unusually long dormancy. The next solar maximum is expected in early 2013. This is the first since widespread consumer adoption of GPS technology. The previous solar max (2000) was preceded by a surge in cell phone adoption. Now, however, developing countries are skipping land lines in favor of cell towers.

A solar max is accompanied by coronal mass ejections (CMEs). Given the wrong polarity, it could necessitate shutdown of airborne and spaceborne electronics while the associated plasma storm passes by the Earth.

Communications systems

This is the fifth consecutive year of robust activity for the satellite industry, with 20-25 commercial awards projected and 14-16 launches. With large backlogs, the outlook for the satellite manufacturing and launch industry continues to be healthy.

By mid-October, Space Systems/Loral (SS/L) had been awarded six satellites, and Boeing increased its backlog with the win of Inmarsat-5. Lockheed, Thales, Astrium, and Orbital received one or two awards each.

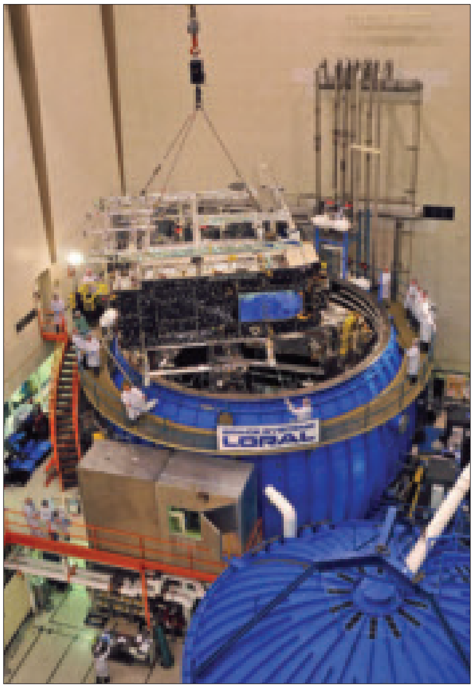
Launch services became a duopoly between ILS and Arianespace, but this is changing. Sea Launch returned to the market after emerging from Chapter 11 with a Russian investor, and SpaceX's Falcon 9 had a successful maiden launch. The U.S. EELV manifest includes only government launches, except for GeoEye-2, which will launch on an Atlas.

For satellite broadband, in the U.S., both ViaSat and Hughes continue to add subscribers and have next-generation high-throughput satellites on order from SS/L. KA-SAT and HYLAS-1, both manufactured by Astrium, are scheduled for launch late this year for service in Europe, and the Australian government indicates that satellites will be included in its national broadband plan.

In the direct broadcast market, DIRECTV and the Dish Network continued growing their fleets. Dish launched two spacecraft, DIRECTV ordered DIRECTV-14, and SIRIUS XM Radio launched XM-5. Regarding FSS satellites, Telesat ordered Anik G1 and SES Astra continued its expansion with the launch of Astra 3B. In Asia, the AsiaSat and EchoStar joint venture started HDTV service in June.

MSS (mobile satellite service) provider TerreStar made its 3G satellite phone commercially available through ATT. SkyTerra, rebranded LightSquared, is ready to launch its SkyTerra-1 satellite, and is paying Inmarsat to move its traffic to share spectrum efficiently. The first Thales-provided second-generation Globalstar spacecraft launched, and Iridium selected Thales to build its NEXT system, with construction financed by COFACE, the French export agency. An order of three Ka-band spacecraft for the Inmarsat-5 program signaled a shift for the mobile L-band operator.

The top four FSS (fixed service satellite) operators are completing a major satellite replacement cycle. New entrant ABS is operating five spacecraft procured on-orbit and ordered a new satellite from SS/L in October. A new regional operator, Vietnamese VNPT, ordered its second satellite from Lockheed Martin.



ViaSat-1 is lifted into the thermal vacuum chamber at the Space Systems/Loral satellite assembly, integration, and test facility in Palo Alto, California.

In the government sector, the Air Force placed the third Boeing WGS into operation. WGS 4, 5, and 6 continue production, and long-lead funding for a seventh WGS has been authorized. The USAF could acquire up to 12 WGS satellites for the wideband capabilities lost with the TSAT cancellation last fall. The Air Force is studying commercial procurement practices as a faster and less expensive way to meet requirements. Lockheed Martin launched the first Advanced EHF satellite; however, a propulsion anomaly was identified and will delay its entry into service. The second and third AEHF satellites are scheduled to be launched in 2011 and 2012, respectively.

In August, Intelsat announced that its IS-27 spacecraft, being manufactured by Boeing, will include a UHF-hosted payload to complement existing UFO (UHF Follow-On) and future MUOS (mobile user objective system) programs.

Among emerging technologies, higher power continues to be important, with Thales and Astrium integrating Alphasat I-XL for Inmarsat, and SS/L qualifying its 25-kW spacecraft. Flexible payloads providing on-board routing and beamforming have limited application because of the cost premium, but modest implementations such as IRIS on Intelsat-14 are demonstrating benefits. For "bent-pipe" payloads, the quantity of equipment required for two-way broadband and mobile applications is likely to drive more hardware miniaturization.

On the regulatory side, the FCC issued a notice that could lead to terrestrial use of portions of MSS spectrum for wireless broadband. The U.S. is reviewing its export control policies, which may result in some process streamlining. At WRC-12, satellite issues to be addressed include long-term spectrum for aeronautical MSS, spectrum usage of the 21.4-22-GHz band for BSS, and new MSS frequency allocations.

by **Christopher F. Hoeber**

Digital avionics

At Oshkosh AirVenture 2010, the huge general aviation air show, the FAA NextGen Data Communications (Data Comm) program introduced new technology that promises major savings in time, money, fuel, and environmental effects. Data Comm avionics were among the FAA's key NextGen exhibits. The technologies introduced there by Data Comm included its new air traffic control (ATC) and Boeing 737 cockpit simulators. Both simulators demonstrate the emerging digital data communication avionics and controller tools being developed for ATC and aircrews.

All smiles in the cockpit as Secretary of Transportation Ray LaHood enjoys "flying" with FAA Administrator and former airline pilot Randy Babbitt. Babbitt is at the controls of the FAA NextGen Data Comm Boeing 737 flight simulator. The simulator has built-in cockpit display units, which demonstrate the transfer of Data Comm digital data communications from air traffic controllers to the aircrew. Photo courtesy FAA Data Communications Program.

Transportation Secretary Ray LaHood and FAA Administrator Randy Babbitt were two of the first Oshkosh AirVenture participants to fly the new Data Comm B737 cockpit flight simulator. Babbitt, a lifelong aviation enthusiast and former airline pilot, demonstrated his piloting skills at the controls of the simulator by easily taking off, flying, and landing on a simulated flight between Miami and Ft. Lauderdale, Florida, aided by the simulator's new Data Comm technology.

Data Comm is a key transformational program within the FAA NextGen effort. To meet future demand and avoid gridlock in the sky and at airports, the NextGen Data Comm program is designed to advance today's analog voice-only air-to-ground communications system to one in which digital communications become an alternative, and eventually a predominant, mode of communications.

Data Comm is necessary for fully realizing the NextGen vision of trajectory-based operation in the National Airspace System (NAS). The technology will automate repetitive tasks, supplement voice communications with less workload-intensive data communications, and enable ground systems to use real-time aircraft data to improve traffic management. Data Comm will provide two-way data exchange between controllers and flight crews for clearances, instructions, advisories, flight crew requests, and reports. This new FAA technology will enhance air traffic safety by providing more timely and effective clearances, leaving more time for controllers and pilots to think and select appropriate actions. It will also enable more orderly communications during peak traffic and more reliable messaging, thereby reducing the number of operational errors associated with voice communications.

In addition, Data Comm will improve controller and aircrew productivity by enabling more efficient operations, faster revised departure clearances, trajectory-based routing, optimized profile descents, and automation of repetitive tasks. This will lessen ground delays, taxi time, fuel use, greenhouse gas emissions, and operational costs. By reducing voice communications congestion and related errors, the FAA estimates the digital data communications will enable controllers to safely handle approximately 130% of current traffic.

With these improvements, ATC will evolve from short-term tactical control to managing flights strategically gate-to-gate. Once implemented, Data Comm will provide data transmissions directly to pilots, who can autoload the messages into their flight management systems. This will increase air traffic efficiency, capacity, and throughput. Use of Data Comm technology in the NAS is scheduled to begin in 2014.

The FAA projects that domestic air travel will grow substantially by 2015. By 2022, according to the agency's estimates, failure to fund and implement NextGen would cost the U.S. economy $22 billion annually in lost economic activity. The number will grow to more than $40 billion annually by 2033 if it is not implemented. The FAA believes investment in NextGen Data Communications technology is the critically important next step for improving air safety, reducing delays, increasing fuel savings, improving the environment, and leading U.S. aviation into the 21st century.

For more information on the NextGen Data Communications program, please contact Sandra Anderson, manager, Air/Ground Data Communications Group at sandra.anderson@faa.gov.

by **John Gonda, Everett Zillinger,** and the **AIAA Digital Avionics Technical Committee**

Sensor systems

Aerospace sensor systems provided vital data in a variety of settings this year, allowing improved responses to natural and man-made disasters, giving new data on the universe, providing greater safety in combat operations, and improving system performance.

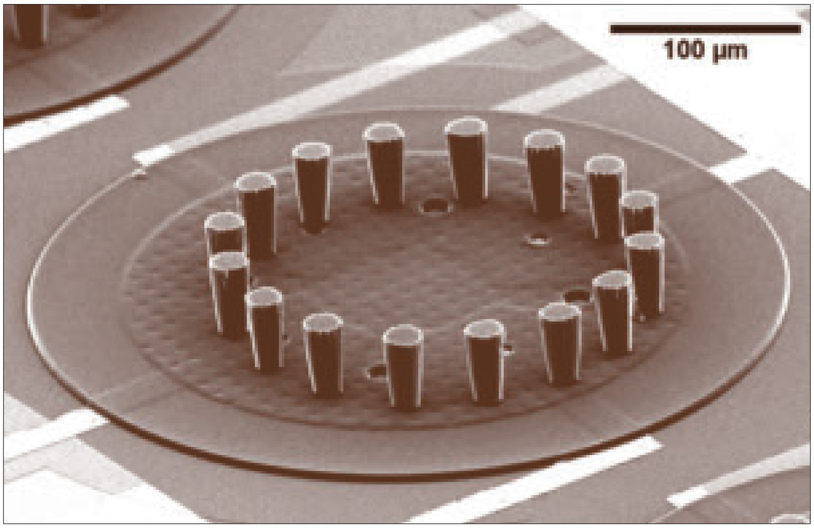
Sensing technologies ranging from satellite sensor systems to laboratory particle image velocimetry (PIV) techniques played a role in measuring British Petroleum's oil spill in the Gulf of Mexico. The MISR (multiangle imaging spectroradiometer) instrument aboard NASA's Terra spacecraft, the advanced synthetic aperture radar aboard ESA's Envisat Earth observation spacecraft, and Raytheon's MODIS (moderate resolution imaging spectroradiometer) on board NASA's Terra and Aqua satellites all provided data on the spill. Laboratory experiments and analysis, including the work of Steve Wereley of Purdue University and Tim Crone of Columbia's Lamont-Doherty laboratory, were used to interpret the underwater photographs of the leaking well-head, leading to revised estimates of the spill's magnitude. This information was critical for planning the response to the spill.

A similar approach was used to assess the threat to aviation created by the eruption of Iceland's Eyjafjallajokull volcano. Space-based sensing included thermal imaging from MODIS on board Aqua and SEVIRI on board Eumetsat's Meteosat Second Generation satellite, along with lidar (light detection and ranging) observations from NASA's CALIPSO (cloud-aerosol lidar and infrared pathfinder satellite observations) spacecraft. These were used, together with ground-based lidar measurements and airborne sampling, to estimate the extent of the ash cloud.

NASA's WISE (Wide-Field Infrared Survey Explorer) spacecraft began its mission at the end of 2009. This year the satellite captured images in mid-infrared wavelengths of objects ranging from brown dwarf stars, distant ultraluminous galaxies, and dangerous near-Earth objects. As it began to run out of coolant in August, the satellite shifted to the "warm" mission, aiming at new targets and imaging in different wavelengths.

Several new sensor system technologies were demonstrated this year. The F-35 Joint Strike Fighter and the UH-60 Blackhawk helicopter will benefit from distributed-aperture electrooptical systems. These systems use multiple sensors around the vehicle, providing the pilot with a "look through" the airframe spherical image. Northrop Grumman's IR DAS (infrared distributed-aperture sensors) and Raytheon's ADAS (advanced distributed aperture system) have already demonstrated the capability of this technology.

A team from Carnegie-Mellon Innovations Lab, NASA Ames, and the U.S. Geological Survey implemented a payload-directed control system to show that mission sensors can control unmanned systems directly. The experiment used a commercial magnetometer on a NASA unmanned ground vehicle and demonstrated the use of sensor data for both real-time feedback control of vehicle motion and geophysical mapping. Magnetic anomalies were used to map subsurface fault zones in a test area in Northern California. This sensing concept may be applied with UAVs such as NASA's Exploration Aerial Vehicle.



A scanning electron microscope reveals a prototype MEMS shear sensor design that is currently under development by researchers at Tufts University and Spirit Aerosystems.

Microscale sensor systems allow measurement of the turbulent boundary layer encountered in aerospace systems. Researchers at Tufts University and Spirit Aerosystems are collaborating on the development of surface pressure and shear sensor array-on-a-chip devices for characterization of the pressure and shear spectrum in the turbulent boundary layer. These silicon-based microsystems incorporate up to 64 individually addressable microphones or shear sensors on a 1-cm^2 chip. System electronics allow the array to be reconfigured on the fly. Careful packaging ensures low-profile interconnects, minimizing the effect of the sensor system on the properties of the flow. The systems have been demonstrated in the laboratory, and will be wind-tunnel tested in the coming year.

by **Wei-Jen Su, Michael Martin, Robert White, Tim Howard,** and **Jeffery Puschell**

Gas turbine engines


Rolls-Royce's Trent XWB powers the Airbus A350 XWB.

This was a busy year for military propulsion development. The Pratt & Whitney F135 engine achieved its first-ever vertical landing as part of the STOVL (short takeoff/vertical landing) variant of the Joint Strike Fighter, and an F119 engine demonstrated full life requirements in 8,650 cycles of accelerated mission testing.

Meanwhile, under the adaptive versatile engine technology (ADVENT) program, Rolls-Royce North American Technologies and GE Aviation continued to develop variable-cycle engine technologies that will enable significant reductions in fuel consumption across the flight envelope. Both companies produced variable fan rigs, and Rolls-Royce initiated testing at Wright-Patterson AFB. In addition, the Air Force selected Rolls-Royce to proceed with integration of various advanced technologies, component testing, and development of a technology demonstrator core and engine. GE Aviation was selected to continue work on a demonstrator core, including component development/integration and demonstration. In May, the GE38 turboshaft engine, which powers the CH-53K helicopter, produced over 7,500 shp while exceeding production performance margins for fuel consumption.

Commercial development has been busy as well. The GE Aviation GEnx-2B had its maiden flight on the Boeing 747-8 on February 8 and received its FAA type certification in July after accumulating more than 2,600 hr of testing. Rolls-Royce Trent 1000 engines powered the Boeing 787 Dreamliner's first flight in Seattle, Washington, on December 15, 2009, and the GEnx-1B made its first flight on the Dreamliner on June 16.

GE's CF34-10A engine, which will power the new ARJ21 regional jet from COMAC (Commercial Aircraft Corporation of China), received its FAA type certification in July. The new H80 turboshaft for business and general aviation began its certification testing in early March and met or exceeded all power ratings in multiple runs at GE Aviation's facility in Prague, Czech Republic. On February 2 Williams International received FAA type certification for its 3,600-lb-thrust FJ44-4 engine, which powers the Cessna CJ4 business jet. Also achieving its first run was the latest member of Rolls-Royce's Trent aero engine family, the Trent XWB, which powers the Airbus A350 XWB family of aircraft.

A strong focus on energy and the environment marked propulsion development activities. The ADVENT and HEETE (highly efficient embedded turbine engine) programs continued to progress at AFRL, and NASA continued work under the Environmentally Responsible Aviation project, with both agencies aiming to make significant improvements in aircraft engine efficiency. The FAA's continuous lower energy, emissions and noise (CLEEN) technologies program made significant progress, having awarded Rolls-Royce a $16-million contract to perform aero engine test demonstrations. These focus specifically on reduced fuel burn technologies and on evaluating alternative aviation fuels. The CLEEN program's goals are to achieve a 33% reduction in fuel burn, against a baseline of current performance technology, and to advance sustainable alternative aviation fuels by 2015.

AFRL successfully completed a 12-month Phase-1 program for an effort called Development of Combustion Rules and Tools for the Characterization of Alternative Fuels. Its working group consisted of GE Aviation, Honeywell, Pratt & Whitney, Rolls-Royce, Williams International, and various consultants. The program met all objectives, including establishing a database of alternative fuel testing experience, reviewing the current fuel evaluation process to identify improvements, developing an improved methodology/process for fuel evaluation, and developing a multiphase program approach to bring the evaluation methodology to maturity. Phase II, expected to begin in 2011, includes the testing of baseline and alternative fuels in combustor rigs, engines, and fundamental experiments, as well as analytical tool development.

by the **Gas Turbine Engines Technical Committee**

Solid rockets

Progress in solid propulsion included significant milestones and technology breakthroughs this year. In May, Raytheon Missile Systems delivered the 100th Standard Missile-3 Block IA to the Missile Defense Agency. On the tactical side, the Army selected Raytheon to finalize the design for the next-generation 1.55-mm precision-guided projectile during the next phase of the Excalibur Ib program.

The production milestones continue for solid propulsion as Lockheed Martin delivered the 1,000th Joint Air-to-Surface Standoff Missile to the Air Force.

Lockheed Martin and Aerojet teamed on the Joint Air-to-Ground Missile (JAGM) program and achieved a technological breakthrough by successfully completing full temperature range testing and validation to support a single rocket motor solution for all JAGM fixed-wing and rotary-wing platforms.

Aerojet provided the missile segment enhancement (MSE) advanced two-pulse solid rocket motor that provided the energy management for Lockheed Martin Missiles and Fire Control's successful Patriot Advanced Capability-3 (PAC-3) MSE guided test flight-1B (GTF-1B). This was the first successful MSE test in which a target simulating a tactical ballistic missile was intercepted in the MSE extended battlespace.

ATK was awarded an R&D contract for the Counter Air/Future Naval Capabilities program by Naval Surface Warfare Center/China Lake to develop new technologies that can be incorporated into next-generation air-to-air missiles such as AMRAAM and like systems.

Aerojet's advanced third-stage technology demonstration motor and advanced second-stage motor were successfully tested by the Air Force in altitude static tests. Meanwhile, ATK successfully static tested its internally funded CASTOR 30 motor, being developed to support commercial resupply missions to the ISS, at the Air Force's Arnold Engineering Development Center in Tennessee.

July 20 marked the 50th anniversary of the Navy Strategic Systems Programs' first underwater launch of a fleet ballistic missile. Today's Trident II D5, a three-stage, solid-propellant, inertial-guided ballistic missile, has achieved 134 consecutive successful submerged test launches since 1989, the last four having occurred on June 8 and 9 of this year.

Orbital Sciences successfully launched its first Minotaur IV rocket for the Air Force on April 22, and NASA successfully launched the Ares I-X rocket on October 28, 2009, from the Kennedy Space Center.

The Orion launch abort system and attitude control motor, both manufactured by ATK, undergo static testing.

In support of the Ares I first-stage five-segment solid rocket motor development, ATK conducted two successful ground static tests: DM-1 September 2009, and DM-2 in August of this year. The five-segment rocket motor has been identified as a key element of NASA's future heavy-lift launch vehicle.

As some programs begin, others are winding down. The shuttle program conducted its final ground test of the reusable solid rocket motor (RSRM) at ATK's facility in Promontory, Utah. The test marked the end of a 30-year program that continuously improved the RSRM's performance and safety features. This year, three successful shuttle launches have taken place; one is left on the manifest.

Data from flight tests of the Ares I-X will enable NASA to improve the vehicle's design and safety.

On May 6, NASA successfully tested the Orion crew module abort system. Conducted at the Army's White Sands Missile Range in New Mexico, it was the first fully integrated test of the launch abort system (LAS). The LAS included three solid rocket motors: abort, attitude control, and jettison. The abort motor, manufactured by ATK, propelled the crew module from the pad. The attitude control motor, also built by ATK, fired simultaneously with the abort motor and steered the vehicle. The jettison motor, built by Aerojet, pulled the entire LAS from the crew module, clearing the way for the parachute deployment and landing.

by **Clyde E. Carr Jr.** and **Barbara A. Leary**

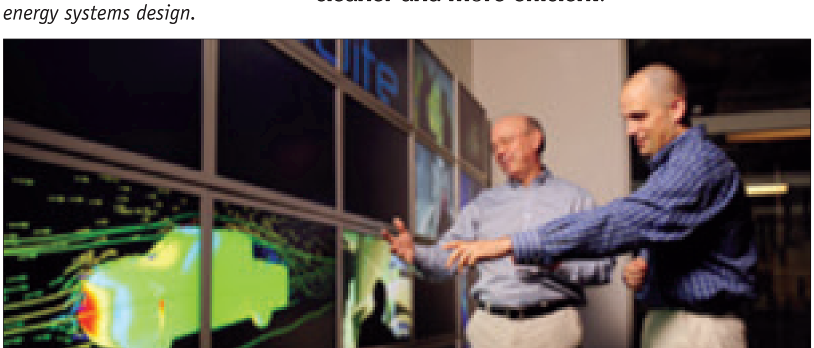
Terrestrial energy systems

This year significant efforts focused on the development of sustainable energy technologies, including alternative fuels, renewable power, advanced fossil power generation, and carbon capture and sequestration. Among several alternative fuel options, biofuel has the best near-term potential. Researchers at the University of Oklahoma are using molecular engineering and designer catalysts to tailor the properties of biomass-derived fuels to closely match gasoline, diesel, and jet fuels. They have also developed experimental techniques for rapidly characterizing the combustion behavior of biofuels.

Currently available power plant design tools are highly discipline specific. However, tomorrow's zero-emission power plants are highly integrated, complex systems. Their design and development processes require engineers with diverse expertise. Recently, Ames Laboratory scientists have developed virtual engineering software to facilitate power plant design processes within a multidisciplinary framework. The software combines CAD models, process simulation, and CFD analyses to allow real-time design review and changes.

Coal remains the primary source of fuel for most of the electricity generation in the U.S. An aggressive portfolio of technologies is emerging to make the future coal power system cleaner and more efficient. Enabling technologies such as advanced gasification, high-hydrogen fuel turbines, oxy-fuel turbines, and carbon sequestration not only will allow existing systems to meet stringent environmental regulations but also will make the future plants cleaner and more efficient.

Prof. Mark Bryden (left) of Iowa State University shows the new virtual engineering tool for energy systems design.



At the University of Maryland, researchers are investigating flameless combustion technologies for zero-emission and energy-efficient gas turbine engines. They are also developing biofuels using membrane technology and examining their combustion characteristics for clean and efficient use in current engines. Research groups at the University of Texas at El Paso are developing fuel-flexible turbine combustors and next-generation thermal barrier coatings (TBCs) for future zero-emission coal power systems. Some notable advances in this area include identification of flame flashback due to combustion-induced vortex breakdown, and development of nanostructured hafnium-based TBCs.

CFD tools are essential for all aspects of designing terrestrial energy systems. Researchers at institutions around the world are working to develop and validate next-generation CFD tools such as large-eddy simulation (LES). Because of the significant spatial and temporal variations of flow variables, the presence of large-scale coherent vortical structures, and other inherently transient physical and chemical processes in gas turbine combustors, LES models appear to be much more promising than Reynolds-averaged Navier-Stokes models. LES provides detailed time-dependent spatial data, which are valuable for development/evaluation of new combustors and the design of reliable control strategies.

The CFD group at Michigan State University has been involved in modeling and large-scale simulations of turbulent reacting flows in realistic flow configurations. More recently, the group has developed a novel subgrid combustion model called FMDF. This model can handle the two-way interactions between the turbulence and combustion in LES and is applicable to various turbulent flames (nonpremixed, premixed, partially premixed, slow, fast, and so on). The LES/FMDF methodology provides a basic framework for implementing important physical and chemical processes into the simulations. It can also be continuously and systematically improved and applied to increasingly complex systems.

Finally, it is worth noting that during the past two decades, the U.S. energy R&D enterprises have experienced a "missing generation" of energy engineers and professionals. There are simply not enough graduate students enrolled in energy disciplines at U.S. universities to replace the engineers and scientists who plan to retire within the next five to eight years. This has now become a serious workforce crisis and poses a threat to the nation's energy security and sustainability. To meet the workforce demand, the U.S. must invest more in this area so that universities can continue to train and educate future leaders in energy science and engineering programs.

by **Ahsan Choudhuri**

Electric propulsion

The Aerojet/Lockheed Martin Space Systems BPT-4000, a 4.5-kW Hall thruster system, was launched for the first time aboard the USAF Advanced Extremely High Frequency satellite. It also completed over 10,000 hr of ground testing, marking the most throughput ever demonstrated on a Hall thruster. Acceleration channel erosion was reduced significantly after about 5,600 hr. Numerical simulations at JPL revealed with potentially breakthrough implications that by properly shaping the magnetic field near the channel walls, their erosion can be practically eliminated.

In 2010, three science missions featured EP in flight. The Hayabusa spacecraft's ion engine system powered it back to Earth after a seven-year mission to asteroid Itokawa. The system logged 39,637 engine-on hours, including 14,830 hr on a single engine. Aerojet has entered into an agreement with NEC to market this system in Japan and the U.S.

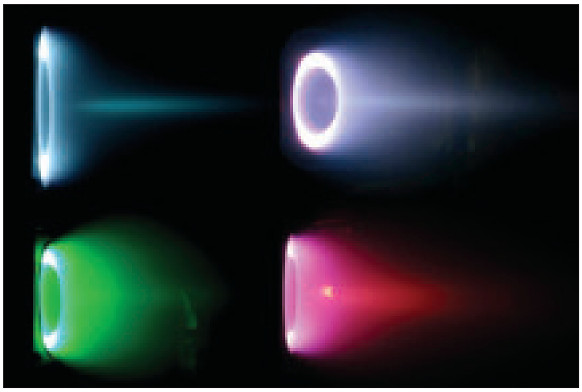
By the end of August, the three-engine ion propulsion system (IPS) on NASA's Dawn spacecraft had operated in flight for 16,500 hr and delivered a delta-V of 4.8 km/sec while consuming 183 kg of the original 425 kg of xenon propellant. Dawn is scheduled to rendezvous with Vesta in July 2011 and Ceres in 2015.

ESA'S GOCE satellite is providing unique data on Earth's gravity field and geoid using two T5 ion thrusters. The ion propulsion assembly from QinetiQ is operating well.

ESA's LISA Pathfinder, scheduled to launch in 2012, features a drag-free system using micronewton EP provided by ESA and NASA. BepiColombo, a Cornerstone mission to Mercury to launch in 2014, will rely on a 4.5-kW T6 IPS from QinetiQ.

Space Systems/Loral (SS/L) has launched six spacecraft with stationary plasma thrusters (SPTs). The SPT subsystems in flight have together logged over 11,000 hr of thruster operation. They incorporate four Fakel SPTs and two SS/L power processing units. The last three satellites feature new SPT modules with greater range of motion. SS/L has five SPT subsystems delivered to spacecraft scheduled to launch through 2011, and five more to be delivered to spacecraft under construction.

At Snecma, Safran Group, the last two of four PPS 1350-G thrusters for Alphasat were delivered. Production of thruster module assemblies has attained significant milestones: By the end of the year, flight model 16 will be delivered, with orders or options up to model 20. Twenty years in-orbit and 12,000 hr of thrusting time have been accumulated. For the small GEO EP thruster assembly, eight SPT-100 thrusters have been procured, and Snecma will begin integration activities. Developed under ESA, small GEO satellites will rely on Hall thrusters from Snecma, or on HEMPT units from Thales.



Testing of advanced metal propellants for EP took place at Michigan Technological University. From upper left and going clockwise the propellants are xenon, bismuth, zinc, and magnesium. Courtesy Michigan Technological University.

At over 31,500 hr of operation, NASA's evolutionary xenon thruster—a 7-kW ion engine developed by NASA Glenn and Aerojet—became the longest lifetime thruster of any type ever, with a total propellant throughput over 520 kg and total impulse over 19 MN-sec.

The high-voltage Hall accelerator, a high-specific-impulse engineering model thruster built by Aerojet and NASA Glenn, has undergone performance testing. The thruster incorporated a life-extending discharge channel replacement innovation. The testing of the NASA-300M Hall thruster was performed for power and voltage levels up to 20 kW and 600V with xenon and krypton propellants.

The French GDR research group (CNRS/CNES/Snecma/universities) continued Hall thruster physics investigations, with partnerships with the Charles University of Prague and the IPPLM institute of Warsaw. With Snecma, ONERA, and IPPLM, the GDR will design, manufacture, and test a 20-kW Hall-effect thruster within the HiPER European research program on high-power EP. Testing will begin in 2011.

Princeton Plasma Physics Laboratory, with Aerospace Corporation, examined performance improvements for cylindrical Hall thrusters (CHTs). The lab built low-power permanent magnet CHTs with improved magnetic design, which demonstrated superior performance over CHT with electromagnets during measurements at NASA Marshall. With a larger volume-to-surface ratio over conventional Hall thrusters, the CHT potentially offers less erosion and longer lifetime.

by **Olivier Duchemin**

Propellants and combustion

by **Joanna Austin, Charles F. Brink, James Edwards,** and **Yiguang Ju**

The X-51A scramjet engine demonstrator (see page 57) made its first flight on May 26. The WaveRider is a USAF/DARPA-funded research project managed by the AFRL Propulsion Directorate with participation by NASA, Boeing, and Pratt & Whitney Rocketdyne. The goal is to demonstrate that the hydrocarbon-fueled scramjet engine has taken a major step toward reaching TRL 6 (technology readiness level six) and is ready for powered flight tests.

This year the program met several significant milestones, including successful completion of dress rehearsal flights in preparation for WaveRider's first flight; completion of assembly of all four flight test vehicles; and, most important, successful first flight.

A C-17 Globemaster III takes off August 27 on a flight test to examine how it performs with different combinations of biofuels. The aircraft is powered by 50% JP-8, 25% by hydro-treated renewable jet fuel, and 25% by a Fischer–Tropsch fuel. The 418th Flight Test Squadron conducts flight tests during the week using different combinations of regular JP-8 and the HRJ. Air Force photo by Kenji Thuloweit.

The flight went as planned: The ATACMs booster accelerated the vehicle at over 6 *g* to the engine start envelope, where a nominal stage separation and scramjet ignition on ethylene occurred. Transition to JP-7 went as expected. The vehicle had nominal performance except for isolated internal temperature rises. After 143 sec of the 240-sec planned scramjet engine operation, the vehicle began to decelerate and descend in what appeared to be a glide. The mission was an unqualified success. Analysis of the flight continues.

The WaveRider achieved flight conditions between approximately Mach 4.7 and Mach 4.90 and cruised at those conditions for over 170 sec, of which 143 sec provided good engine data. (During the last roughly 25 sec of powered flight, significant data dropouts occurred.) This is over 10 times longer than any previous scramjet operation in free flight within Earth's atmosphere. Of particular note, engine performance, operability, and thermal balance characteristics were all as expected, comparing quite favorably with those of ground tests. The flight made history, already having being compared to the first flight of the jet engine, and has ignited serious interest in applications for future operational vehicles using hydrocarbon fuels. Three additional flights are tentatively planned between this month and May 2011.

Air Transport World awarded the Joseph F. Murphy Industry Achievement Award to CAAFI, the Commercial Aviation Alternative Fuel Initiative, for the overall coordination of alternative aviation fuel efforts. The aviation industry formulated a system-level gated risk management process (fuel readiness level) as well as an environmental analysis framework developed by a U.S. Interagency Working Group that included DOE, the Air Force, and the FAA. Both these initiatives were submitted to the International Civil Aviation Organization and adopted as best practices.

The FAA's Partnership for Air Transportation Noise and Emissions Reduction (PARTNER) released the first quantitative "ground to wake" report on alternative jet fuel greenhouse gas life-cycle emissions, as part of continuing research under the FAA-funded PARTNER Center of Excellence at MIT. Following successful adoption of the alternative jet fuel specification (ASTM D7566) in 2009, a number of alternative fuel flights were conducted this year. On April 30, United Airlines conducted the first flight (in the U.S.) of a commercial aircraft using natural-gas-derived Fischer-Tropsch synthetic paraffinic kerosene (SPK), a jet fuel produced by Rentech.

In March and April, the USAF and Navy conducted a significant ground and flight testing program with a hydrocarbon aviation biofuel—hydroprocessed renewable jet or bio-SPK—on the A-10 and F-18. The C-17 also was flight tested with this fuel in August. The USAF/Navy fuel was competitively procured from UOP by the Defense Energy Support Center. Several alternative jet fuel production agreements also were announced this year. In parallel, the Princeton-led AFOSR-funded surrogate fuel Multi-University Research Initiative project has developed and tested a generic approach to constructing surrogate jet fuel models for real fuels from alternative sources. This partnership and the progress in jet surrogate fuel modeling will support the development and deployment of commercially viable, environmentally friendly alternative aviation fuels.

Hybrid rockets

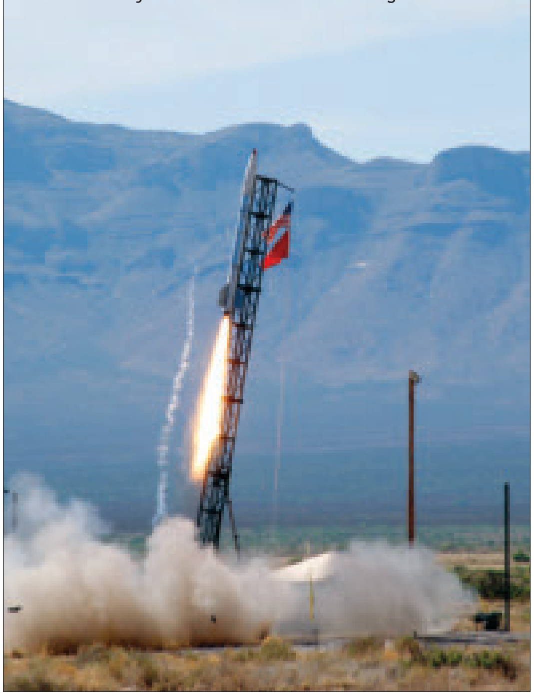
Several organizations made important contributions to hybrid rocket research this year. Scaled Composites has completed five successful static firing tests of the hybrid rocket motor for SpaceShipTwo, including an increased duration firing in August. On October 10, the vehicle completed its first piloted glide flight. The craft, under development by Virgin Galactic, will be transported by a new composite aircraft to the upper atmosphere, where the hybrid motor will ignite and propel space tourists, scientists, and payloads into space. Suborbital trajectories of up to 65-mi. altitude are expected.

Under a contract from AFRL, Space Propulsion Group (SPG) has continued its development of high-performance LOX/paraffin-based hybrid rocket motor technology. Over the course of the year, more than 15 motors in the 7,000-lb-thrust class have been fired. Excellent combustion efficiencies and good motor stability behavior have been demonstrated without the addition of external heat or the injection of pyrophoric liquids. In addition, SPG has successfully fabricated several 22-in.-diam paraffin-based fuel grains, each weighing over 1,500 lb. The new grains will be burned in a 30,000-lb-thrust LOX hybrid motor. Static firing of this large motor is planned for the end of this year.

IN Space, along with partners Purdue University and General Kinetics, investigated the catalytic decomposition of oxidizers in hybrid rockets to improve energy management while increasing fuel-grain regression rates and limiting fuel slivers. Using a catalyst bed to decompose the oxidizer before injection, a laboratory-scale hydrogen peroxide/polyethylene hybrid motor achieved characteristic velocity efficiencies of up to 100%, regression rates up to 50% higher compared to a different ignition method, and a 10:1 throttling range with stable combustion. For a liquid injection configuration, catalytic fuel grains were static fired with 90% hydrogen peroxide, resulting in rapid ignition and regression rates 2.5 times those of uncatalyzed fuel grains. This project was funded by the Air Force at AFRL.

Fredericksburg High School (FHS) in Fredericksburg, Texas, is continuing its aeroscience program, led by Brett Williams. This program educates high school students through theoretical study and hands-on experience in rocket propulsion. Working with hybrid motors provides a relatively safe and inexpensive way for the students to learn. The program and its curricula are being replicated across Texas. NASA provided funding to FHS to support alternative hybrid fuel and nozzle material development. This year, FHS successfully tested nine alternative fuels at the school's Humble-Bowden Propulsion Research Center. Using a fuel grain and nozzle material from its R&D work, FHS designed and built a 525-lb hybrid-propelled sounding rocket capable of lofting a 25-lb telemetry research payload to 75,000 ft by producing 2,500-lbf of thrust for 26 sec.

A hybrid sounding rocket built by Fredericksburg High School was launched from White Sands Missile Range.

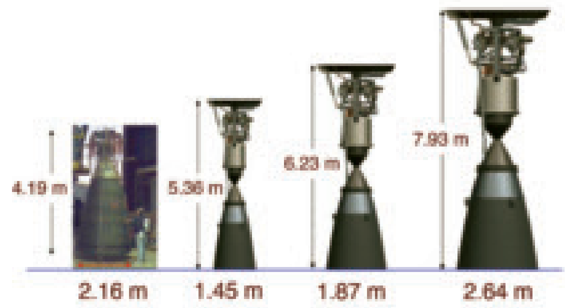


Orbital Technologies (ORBITEC) continued developmental testing of a 10,000-lbf-thrust-class vortex hybrid motor. The 14-in.-diam motor uses aluminized HTPB (hyroxyl-terminated polybutadiene) solid fuel and liquid oxygen injected in a swirling fashion to generate a vortex flow field in the fuel port to drive fuel regression rates that are both fast and axially uniform. The high regression rates allow for a single-port, cartridge-loaded fuel grain to provide low operations costs and rapid turnaround. The test program aims to demonstrate the functionality of the vortex hybrid design, stable and efficient combustion, high reliability, and the potential for low recurring costs. Testing to date has indicated stable, efficient combustion, with characteristic velocity efficiencies of about 97%.

Rocket Lab of New Zealand successfully developed and launched a hybrid suborbital-class sounding rocket with the aim of reaching 120-km altitude. The sounding rocket was an all-carbon-composite construction, including composite linerless pressure vessels, in-house-developed aerothermal ablatives, and composite combustion chamber and nozzle. The propellants used were nitrous oxide and Rocket Lab's in-house-developed fuel, hybrid 90A. The company says this fuel offers equivalent regression rates to HTPB but with superior mechanical properties that enable complex grain geometries without web supports.

by **Steven Frolik**

Nuclear and future flight propulsion



The performance and size of the RL10B-2 chemical engine can be compared with different thrust NTR engines.

Atmospheric mining in the outer solar system was investigated as a means of fuel production for high-energy propulsion and power. Fusion fuels such as helium 3 (3He) and hydrogen can be wrested from the atmospheres of Uranus and Neptune.

In 2009 Case Western Reserve, assisted by NASA Glenn, undertook six aerospace design studies of such mining. Both 3He and hydrogen were the primary gases of interest, hydrogen being the main propellant for nuclear thermal or nuclear fusion rocket-based atmospheric flight. Four teams addressed issues associated with atmospheric cruiser-based and balloon-based mining vehicles. Two teams focused on outer planet moon mining for the gases. Many of the cruiser designs were effective in gathering 3He in less than one year.

Using nuclear thermal propulsion, or NTP (with primarily closed-cycle gas core rocket technology), effective flights into and out of the atmospheres of Uranus and Neptune were possible. Outer planet moon mining vehicles were also designed and parametric analyses of 3He concentration conducted. A central power system supported multiple miners, making the mobile miners lighter than those with onboard power. Some teams concluded that NTP must focus on very high specific impulse closed-cycle gas core powered vehicles. Uranus' and Neptune's vast reservoirs of fuels are more readily accessible than those of Jupiter and Saturn and, with the advent of nuclear fusion propulsion, may offer the best option for the first practical interstellar flight.

Laser-driven inertial confinement fusion (ICF) is extremely attractive for deep-space propulsion and has been the subject of several conceptual design studies. However, these were based on older ICF technology using either "direct or indirect X-ray-driven" type target irradiation. This leads to rather low energy gains. Moreover, traditional deuterium tritium fusion was selected, requiring tritium breeding and delivering 80% of the fusion energy in neutrons that cannot be directed through an exhaust nozzle.

However, important new directions have developed for laser ICF in recent years following the development of "chirped" lasers capable of ultrashort pulses with powers of terawatts up to a few petawatts. This has led to the exciting concept of "fast ignition," where the petawatt laser beam strikes a precompressed target, creating a hot spot in the interior of the target burn that propagates outward into the surrounding fuel. This then greatly increases energy gain, because part of the required input energy is replaced by the propagating burn. Fast ignition is very efficient in giving very high gains while maintaining a low electron temperature, allowing ignition of more demanding fusion fuels such as p-11B. The University of Illinois and the Los Alamos National Laboratory conducted this work.

NASA's recent Mars DRA (design reference architecture) 5.0 study examined mission, payload, and transportation system options and requirements for a human Mars mission in the 2031-2033 timeframe. A proven technology, NTP could potentially enable future human Mars missions with reasonable initial mass in LEO and a reasonable number of Ares V launches. However, to recapture, mature, and flight qualify NTP systems in time to support future cargo and crewed Mars missions in the post-2030 timeframe will require meaningful, sustained investments beginning in the next several years.

These investments will attempt to establish firm NTP engine system requirements using updated Mars mission analysis and payload estimates; recapture composite Rover/NERVA fuel element technology, and mature uranium dioxide in tungsten metal "cermet" fuel technology; perform high-fidelity modeling, design, and engineering of candidate engine systems; prepare test facilities; and conduct the required nuclear/nonnuclear demonstration tests of NTP fuels, components, and subsystems in preparation for "contained" full-scale ground testing of both demonstration and flight-type engines.

Assuming five years of technology preparation and then a 10-year development phase, NTP flight testing can begin in the late 2020s, in time to support initial human Mars flights in the 2031-2033 timeframe.

by **Bryan Palaszewski** and the **AIAA Nuclear and Future Flight Propulsion Technical Committee**

Energetic components and systems

On August 31, Alliant Techsystems and NASA conducted a second successful ground test (DM-2) of the Ares-I five-segment development motor. This test was an important milestone in the development of the next generation of U.S. launch vehicles.

Initial test data indicated that the motor, which had been chilled to a 40 F core temperature since early July, performed as designed, burning for just over 2 min and producing approximately 3.6 million lb of thrust and about 22 million hp. The test collected 764 channels of data to accomplish 53 test objectives.

The DM-2 test was designed to expand the envelope of operating conditions for the five-segment motor by firing it at cold temperature to test its redesigned joints. The joints had been modified after the 1986 space shuttle Challenger accident, with joint heaters added to keep the O-rings flexible at cold temperatures. Since then, engineers have developed O-rings with a new material that is far more resilient at colder temperatures than the old materials, to the point where the joint heaters are no longer necessary. A major part of the DM-2 test was to confirm the performance of the joints at these colder temperatures. Test data indicate the new joint design performed properly.

The CAD/PAD (cartridge actuated device/propellant actuated device) R&D and PIP (product improvement program) Branch at the Indian Head Division, Naval Surface Warfare Center, is leading a multiyear development program to find an environmentally friendly replacement for the primary explosive lead azide, specifically RD-1333. The result of this effort is a novel compound, copper(I) 5-nitrotetrazole, also called DBX-1, which has been synthesized and characterized by Pacific Scientific Energetic Materials (PSEMC) in Chandler, Arizona. Testing of this material has shown that it has sensitivity and safety characteristics that are similar to those of lead azide, and slightly greater output characteristics. In addition, DBX-1 has been tested in a variety of detonator applications, with results that indicate it may serve as a drop-in replacement for lead azide.

PSEMC is currently working to scale the compound up to larger batch sizes. The center is attempting to establish a manufacturing capability for this material. Once the material fabrication is scaled up, the center will produce material in support of DOD and commercial applications.

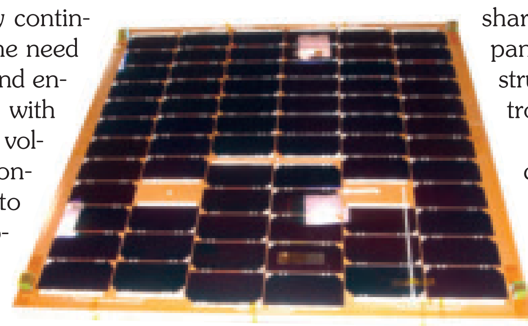

Alliant Techsystems and NASA conducted a second successful ground test of the Ares I five-segment development motor.

NASA successfully boosted the Orion Launch Abort System (LAS) at the Army's White Sands Missile Range on May 6. At ignition, the motor produced 500,000 lb of force that pulled the Orion capsule mockup off the pad and accelerated it skyward to about 445 mph in less than 3 sec. The motor, with its four nozzles, continued to burn for a total of about 6 sec, boosting the system to an altitude of nearly 4,000 ft and putting it on a ballistic trajectory with a predicted high point of roughly 6,000 ft. The revolutionary attitude control module (ACM), a solid motor with eight computer-controlled exhaust ports, helped maintain the craft's stability during the initial climb away from the launch pad.

Ten seconds after takeoff, the ACM began repositioning the vehicle to a capsule-first orientation, and as the craft passed through the apex of its trajectory, the burned-out LAS was jettisoned. Drogue parachutes then deployed from the capsule to slow and stabilize it before three 116-ft-wide parachutes unfurled for the final descent. The heavily instrumented capsule hit the ground at 16 mph, 2 min 14 sec or so after launch and 6,919 ft from its takeoff point.

by **Donald Jackson**

Aerospace power systems



Mars Science Laboratory has successfully completed testing of a new solar array qualification coupon.

Power system technology continues to advance to meet the need for higher performance and enable high-power missions with reduced mass and stowed volume for launch. AFRL continued its research into high-efficiency, flexible applications using inverted metamorphic (IMM) solar cells to achieve efficiencies of over 32% with a "thinned" multijunction cell. Current efforts focus on applying these advanced cells to space arrays using an integrated blanket interconnect system. AFRL's array initiatives for incorporating the IMM cell include Boeing's high-performance solar array, ATK's ultraflex array, the DSS roll-out solar array, and MicroSat Systems' folded integrated thin-film stiffener array.

DARPA's Fast Access Spacecraft Testbed (FAST) program aims at developing an ultralightweight high-power-generation system that can generate up to 175 kW. The goal of the program is to demonstrate a suite of critical technologies, including high-efficiency solar cells, sunlight-concentrating arrays, large deployable structures, and ultralightweight solar arrays. These technologies enable lightweight, high-efficiency, high-power satellites. When combined with electric propulsion, FAST will lay a foundation for future self-deployed high-mobility spacecraft to perform ultrahigh-power communications, space radar, satellite transfer, and servicing missions.

Modular solar panels promise improved cost, standardization, and qualification traceability compared to today's customized technology. DR Technologies' MOSAIC modules are sized as a single string of standard high-efficiency cells and integrate into body-mounted and deployable panel configurations; a flight on FalconSat 6 is planned. SpaceQuest has provided its modules for FASTSAT, a joint activity of NASA and the Dept. of Defense.

NASA and the Dept. of Energy continue to conduct research and subsystem testing aimed at enabling fission power in space or on planetary surfaces. This year nearly all planned subsystems technology readiness demonstrations were completed. The subsystems included a no-moving-parts electromagnetic annular linear induction pump for controlled flow of liquid metal NaK at 525 C, a prototype NaK-to-NaK heat exchanger built by Advanced Methods and Materials, and a pair of Sunpower 1-kWe Stirling engines with thermodynamically coupled shared working fluid expansion space to reduce structural weight and control complexity.

Development also continues on the advanced Stirling radioisotope generator (ASRG) for potential use in NASA's Discovery 12 mission in 2015. The ASRG reduces Pu-238 requirements by a factor of four over current RTG (radioisotope thermoelectric generator) systems. The ASRG engineering unit has been in extended testing at NASA Glenn, accumulating over 13,000 hr of extended operation and supporting controller development with Lockheed Martin, DOE's ASRG system integrator. NASA Glenn has also received four pairs of next-generation advanced Stirling convertors. These are hermetically sealed and include all the necessary interfaces. Testing of these devices includes extended (24 hours a day) operation to provide additional data on life, reliability, and durability and to enable further controller development.

NASA is improving battery performance and safety for human missions. This effort includes development of "non-flow-through" proton-exchange-membrane fuel cells and electrolyzers, coupled with low-permeability membranes for high pressure operation; high-energy battery cells using lithiated mixed-metal-oxide of NMC (Ni-Mn-Co) cathodes; electrolytes that are both high-voltage stable and flame resistant; cathode coatings to reduce exothermic reactions; and a reversible thermal switch for overtemp conditions. For the NASA extravehicular mobility unit, ABSL delivered four long-life battery assemblies for integration into astronaut spacesuits designed for use on the ISS. Each battery assembly has an energy density in excess of 180 Wh/kg.

Mars Science Laboratory (MSL), scheduled to launch in the fall of 2011 and land on the red planet in August 2012, includes the largest rover ever sent to Mars. MSL has successfully completed the integration and test of upgraded power system electronics, testing of a new solar array qualification coupon, and fabrication of the first EM lithium-ion battery assembly with the new higher capacity rover battery assembly unit containing two 43-amp-hr batteries.

by the **AIAA Aerospace Power Systems Technical Committee**

Liquid propulsion

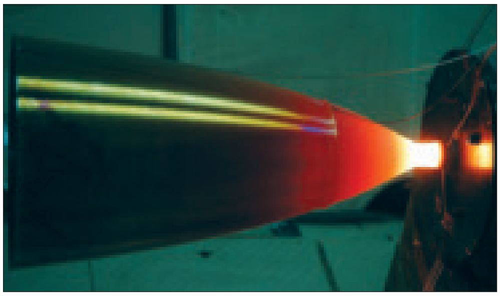
In support of next-generation manned spaceflight, Pratt & Whitney Rocketdyne's Common Extensible Cryogenic Engine (CECE) demonstrated a throttling range from 104% of rated power down to 5.9%. CECE is a 15,000-lbf thrust class rocket engine designed as a technology demonstrator for throttling and use of LH_2/LO_2 or CH_4/LO_2. This latest test was the fourth in a series conducted in West Palm Beach over the past five years. The CECE program is funded by the NASA Propulsion and Cryogenics Advanced Development project under a contract to demonstrate cryogenic engine technologies that could be used for space exploration activities, including landing on the moon, an asteroid, or another planet.

The 17.7-to-1 throttling capability demonstrated by CECE is a first for a cryogenic engine. Other cryogenic firsts achieved include closed-loop control throughout the throttle range, engine start at 10% power level, and rapid restart at varying power levels. The total run time for the most recent test series was 2,403 sec, bringing the program's total engine run time to 7,436 sec.

There was also progress on the liquid propulsion system for the Orion crew and service modules. Aerojet's R-1E 25-lbf bipropellant engine completed hot-fire test sequences including more than 17,250 sec of total burn time, demonstrating its ability to operate under a broad variety of conditions expected for the Service Module. In support of the Crew Module, Aerojet successfully tested an up-rated MR-104 160-lbf monopropellant hydrazine thruster under three times the previously qualified vibration loads. Subsequent hot-fire testing demonstrated life and high thrust for contingency operations during launch abort.

The Japan Aerospace Exploration Agency (JAXA) and IHI Aerospace qualified two new pressure-fed, bipropellant rocket engines. The 500-N design is the main engine for JAXA's cargo transfer vehicle to the ISS, commonly known as the HTV. The 120-N engines are used for HTV's reaction control system. IHI Aerospace also completed manufacturing of the HTV-3 flight engines, scheduled to launch in 2012.

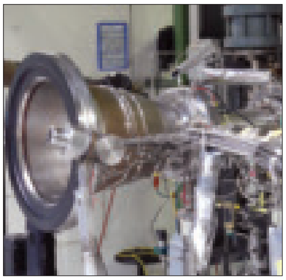
Two improved unmanned propulsion designs debuted in summer 2010. On May 20, the world's first ceramic rocket engine was launched aboard Japan's Venus Climate Orbiter, also known as the Akatsuki spacecraft. Akatsuki will begin transfer into Venus orbit in December 2010 using this 500N bipropellant engine built by IHI Aerospace. One week after the Akatsuki launch, Aerojet celebrated the launch of its highly modular propulsion system on the inaugural GPS IIF spacecraft.



The HTV main engine undergoes hot-fire testing.

The European Space Agency (ESA) continued to develop the 180-kN Vinci expander cycle engine designated to power the future upper stage of the Ariane 5 launcher midlife evolution (A5ME). As part of various design adjustments related to A5ME requirements, Snecma conducted additional tests on the P4.1 high-altitude bench at DLR Lampoldshausen. The main objectives of these tests were to explore the engine's entire flight domain with firing time beyond 700 seconds, and to operate the large area ratio extendible composite nozzle in line with its deployment mechanism.

ESA's Future Launcher Preparatory Program (FLPP) refined system studies were initiated in 2010 to more specifically trade different launcher candidates in view of a next-generation space transportation system. An important focus area was FLPP's main stage propulsion technology program. By midyear, EADS/Astrium had successfully hot-fired a high pressure liquid hydrogen cooled subscale nozzle (SCENE), designed and manufactured by Volvo Aero Corporation (VAC). The engine employed laser-welded sandwich technology in its construction and achieved a chamber pressure of 140 bar on the P8 test bench at DLR Lampoldshausen. Earlier in the year, VAC had set a novel achievement in European nozzle technology when a full-scale liquid hydrogen cooled sandwich nozzle was successfully hot-fired on a Vulcain 2 engine at DLR's P5 test bench in support of the ESA Ariane 5 research and technology accompaniment program. In parallel, Snecma flight tested several cost-saving technology breakthroughs on a Vulcain-scale gas generator and hydrogen turbo-pump assembly, confirming the technological readiness levels for these components.



A SCENE nozzle demonstrator mounted on an EADS/Astrium 40-kN subscale chamber awaits testing at the DLR P8 bench.

by the **AIAA Liquid Propulsion Technical Committee**

Air-breathing propulsion systems integration

NASA Glenn's wind tunnels are enabling the current NASA/GE collaborative testing of counterrotating fan-blade systems for open-rotor jet engine designs.

This year has seen interesting developments in hypersonic propulsion systems and green aviation.

The Air Force Research Lab (AFRL) completed a series of successful experiments demonstrating Aerojet's combined-cycle integrated inlet, an enabling technology for integrated turbine-based combined-cycle (TBCC) engines. The tests took place at NASA Glenn following earlier high-Mach tests performed at Langley. Transonic wind tunnel testing of this inlet, completed under AFRL's multidisciplinary Robust Scramjet Program and in partnership with NASA's Hypersonics Project, will improve understanding of TBCC engine operation and performance capacity. This first-of-its-kind test activity measured subsonic through combined-cycle propulsion mode transition and collected 8,000 data points for an integrated TBCC inlet.

The X-51's historic 200-sec hypersonic flight on May 26 marked an important advancement in scramjet development. Powering the X-51 is the hydrocarbon-fueled SJY61 Pratt & Whitney Rocketdyne scramjet engine, which features fuel-cooled walls operating in an endothermic cycle. JP-7 fuel is pumped from a holding tank through all four walls of the engine to provide cooling. In the process of cooling, the fuel is vaporized and eventually is partially cracked for combustion.

Boeing's Phantom Eye high-altitude long-endurance UAV passed a key testing phase of its propulsion system, which comprises two hydrogen-fueled Ford 150-hp, 2.3-liter, four-cylinder internal combustion engines. Liquid hydrogen stored in tanks is boiled off and then passed through a heat exchanger and fed into the engines at near room temperature. The engine, turbochargers, and engine control system successfully completed an 80-hr test in an altitude chamber.

The Navy's Ion Tiger, a small electric UAV, recently set a 26-hr endurance record. This aircraft, which can carry a 5-lb payload, features an onboard electric fuel cell propulsion system comprising a 550-W Protonex PEM (proton exchange membrane) fuel cell fueled by hydrogen from high-pressure and lightweight hydrogen storage tanks. It boasts quiet operation and high efficiency. The fuel cell has about four times the efficiency of a comparable internal combustion engine, and the system provides seven times the energy in the equivalent weight of batteries.

The United Technologies Research Center completed a pioneering system study for NASA assessing embedded, boundary-layer-ingesting (BLI) propulsor technologies for hybrid wing body aircraft. Results indicate that embedded propulsors, with BLI inlet airflow distortion effects mitigated adequately, provide up to 5% reduced fuel burn compared to advanced conventionally configured turbofan engines, and 10% (or more) reduced fuel burn with increased levels of BLI.

An 18-month NASA effort to explore concepts for 2030-era subsonic single-aisle commercial aircraft has produced interesting findings. A Boeing-led study that presented five designs indicates that hybrid electric engine technology is a clear winner that can meet NASA's goals of reduced fuel burn, NO_x emissions, and field length. A portfolio of advanced technologies (nicknamed SUGAR Volt), including an electric battery gas turbine hybrid propulsion system, was found to reduce fuel burn by more than 70% relative to today. MIT/Aurora/Pratt&Whitney presented a concept featuring a "double-bubble" design and a three-engine BLI propulsion system with ultra-high-bypass ratios above 20. Two versions are being considered, one using existing technologies and another using advanced technologies. The latter design's engines have compressor exit corrected flows of roughly 1 lb/sec; the definition of appropriate configurations to provide these high-efficiency small cores is a technology challenge remaining to be addressed.

The NASA/General Electric collaboration on open rotors ended its first phase with completion of aerodynamic and acoustic testing in the NASA Glenn 9x15-ft low speed wind tunnel. Six blade sets were evaluated for performance at takeoff and approach conditions. Detailed measurements using technologies such as acoustic phased array and stereo particle image velocimetry also were performed. These provided the historical baseline blade-set data required for a comprehensive database that will support modeling and simulation. Testing for performance at cruise speed has begun in Glenn's 8x6-ft high-speed wind tunnel and will continue through this winter.

by **Dyna Benchergui, Jeffrey Flamm,** and **Richard Wahls**

High-speed air-breathing propulsion

Air-breathing hypersonic propulsion entered a new era this year. The 7.9-m-long X-51A WaveRider, powered by the Pratt & Whitney Rocketdyne scramjet engine, made aviation history on May 26 with the longest ever scramjet-powered flight.

"This first flight test brings aviation closer than ever to the reality of regular, sustained hypersonic flight," said Curtis Berger, director of hypersonic programs at Pratt & Whitney Rocketdyne. "We are very proud to be part of the team that made this possible."

The X-51A program is a collaborative effort of AFRL, DARPA, Boeing, and Pratt & Whitney Rocketdyne. During its flight, the WaveRider was carried beneath an Air Force B-52 and dropped from an altitude of 50,000 ft. A rocket booster propelled the cruiser to a speed greater than Mach 4.5, creating the supersonic environment necessary for starting its flight. Separating from the booster, the SJY61 scramjet ignited, initially on gaseous ethylene; it then transitioned to JP-7 fuel.

The achievement is significant, because this is the first hypersonic flight by a hydrocarbon-fueled scramjet. "We are ecstatic to have accomplished many of the X-51A test points during its first hypersonic mission," declared Charlie Brink, X-51A program manager with AFRL. Brink called the leap in engine technology "equivalent to the post-WW II jump from propeller-driven aircraft to jet engines."

Aerojet also made progress on advancing scramjet technology. Under contract with AFRL, the company completed ground testing of a scramjet combustor, demonstrating a new thermal management technique. Called core burning, it forces the combustion flames away from walls, thereby reducing overall heat loads. Core burning will enable scramjets to have more thermal margin, use less cooling fuel, and fly faster than they can with conventional thermal management. The engine operated robustly at simulated Mach-3-5 flight conditions.

Pratt&Whitney Rocketdyne and Lockheed Martin completed preliminary design of an actively cooled dual-mode ramjet combustor under the DARPA-funded mode transition demonstrator program.

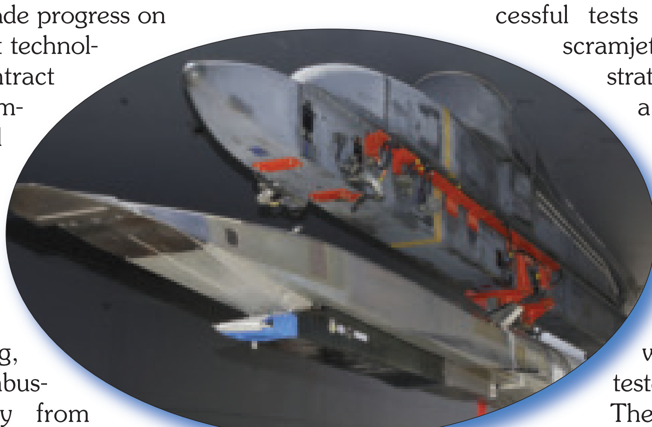
Aerojet's supersonic sea-skimming target ramjet propulsion system successfully completed the first flight test of the Coyote High Diver supersonic target mission. The target vehicle, developed by Orbital Sciences with Aerojet's solid-fueled variable-flow ducted rocket engine, was rail-launched from the ground and boosted by a rocket motor to ramjet-takeover speed. Under ramjet power, the system ascended to 35,000 ft and reached Mach-3.3 cruise speed. At the end of its 110-n.mi. flight, the vehicle executed a planned unpowered dive to its objective.

The international community pushed forward air-breathing hypersonics as well. Brazil's Institute for Advanced Studies (IEAv) continued developing its 14-X, a Mach-10 waverider hypersonic vehicle. IEAv also ground tested air-breathing laser propulsion in collaboration with the Air Force Office of Scientific Research. In France, MBDA and ONERA continued R&T activities in hypersonic air-breathing propulsion, under contract to continue the remaining part of LEA's flight testing program. The experimental vehicle will be flight tested at Mach 4-8 in 2013-2015.

Japan's JAXA tested a rocket-based combined cycle engine at Mach-11 conditions in its High Enthalpy Shock Tunnel, following sea-level static Mach 4-6 tests with a detonation tube supplying combustion gas. At Russia's Central Institute of Aviation Motors, successful tests of a large-scale scramjet model demonstrator integrated with a hypersonic airframe simulator were performed to support development of the axisymmetrical hydrogen-fueled scramjet, which was flight tested in the 1990s.

The complex requirements of faster vehicles will continue to demand advances in hypersonic propulsion. The spectacular flight of the X-51A WaveRider brought scramjet technology a major step closer to practical reality.

Read more about these and other programs at https://info.aiaa.org/tac/PEG/HSABPTC/default.aspx.



The X-51A WaveRider made history on May 26 with the longest ever scramjet-powered flight.

by **Dora Musielak**

Life sciences and systems

The life sciences and systems (LSS) community is conducting numerous aerospace-related efforts focusing on enabling human exploration of space. Science and technology efforts have been under way at space organizations around the world to address the anticipated life support needs for future space endeavors.

Desert RATS simulated lunar exploration in the Arizona desert.

A modular air revitalization system for future manned spacecraft bound for the ISS and other LEO destinations has completed its preliminary design review, clearing the way for work to begin on a ground test unit. Under NASA's CCDev (commercial crew development) project, Paragon Space Development passed the milestone in July with its commercial crew transport air revitalization system.

A panel discussion sponsored by the House Committee on Science and Technology, AIAA, and the American Society for Gravitational and Space Biology was held in September. The panel focused on the emergence of the biological economy and leveraging of telemedicine, agriculture, energy and the environment, and how space biological research enables these terrestrial applications.

In response to requests from Congress, NASA asked the National Research Council to undertake a decadal survey of life and physical sciences in microgravity. Research proposed for the next decade by the life and physical sciences communities would expand use of the space environment to solve complex problems in these areas to deliver both new knowledge and practical benefits for humankind. Their interim report is available on line (http://www.nap.edu/catalog.php?record_id=12944). The final report is due in early 2011.

Desert RATS (research and technology studies) simulation testing was conducted in Arizona to simulate planned operations for future exploration of the Moon or Mars. Desert RATS included two space exploration vehicles (SEVs) and a habitat demonstration unit (HDU) that simulated a pressurized excursion module habitat (with testing of a prototype "space greenhouse"). Two crews, each consisting of an astronaut and a geologist, conducted closed operations in the SEVs for a week, performing several EVAs, then docked with the HDU for simulation of suit maintenance, geology, general maintenance, and food growth experiments.

The flame extinguishment and the smoke aerosol measurement experiments took place on the ISS. Conducted in reduced gravity, they were aimed at improving the reliability of future spacecraft fire suppression and detection. The capillary flow experiment improved our ability to control fluids in two-phase systems; the constrained vapor bubble looked at phenomena important in advanced wickless heat pipes; and IVGen produced medical quality intravenous fluids in reduced gravity.

In late December 2009, ESA astronaut Frank De Winne became the first non-U.S., non-Russian to take command of the ISS. Two Italian astronauts are preparing their missions to ISS: Paolo Nespoli for Expedition 26-27, and Roberto Vittori for STS 134. Vittori will execute life science and radio-biology experiments. ESA is increasing the ECCO (ESA cold container) fleet to allow the return of biological samples to Earth at controlled temperature, without the need of a power supply.

The European Science Foundation has initiated a 24-month project called THESEUS (towards human exploration of space: a European strategy) to develop an integrated life sciences research roadmap enabling European human space exploration in synergy with ESA's strategy to identify potential nonspace applications and dual R&D.

A Russian-led multinational effort to simulate the isolation of a 500-day mission to Mars is under way in Moscow. By September the mission had been in progress for 90 days and had simulated more than 15 million km of transit from Earth but was still 200 million km from Mars.

Systems needed for maintaining breathable air in spacecraft are being developed at several NASA centers. Planning continues on the next tests of the pressure swing amine bed technology intended for use on Orion, Altair, EVA systems, and lunar electric rover applications. A closed-loop CO_2 removal system is being built incrementally to reduce power associated with water recovery and to integrate CO_2 compression with the CO_2 removal function. Technologies for recovery of O_2 from CO_2 and H_2 from methane have progressed significantly this year.

by **Joe Chambliss**

Space tethers

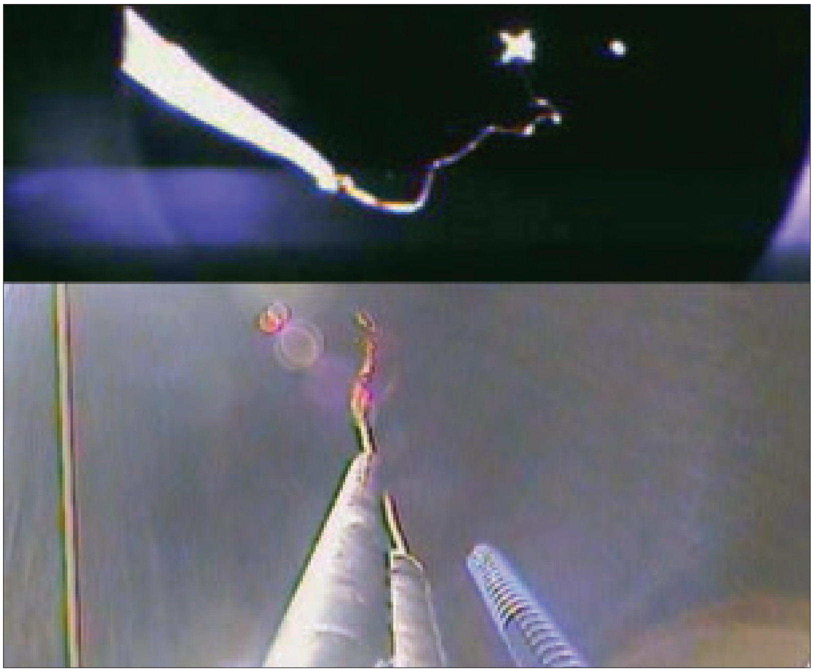
In this past year, the space tethers community launched a sounding rocket payload experiment and continued to prepare several upcoming flight experiments, as well as to develop new applications.

On August 31, a Japanese space tether experiment called T-Rex was launched on sounding rocket S-520-25 from Uchinoura Space Center (near Uchinoura, Japan), reaching a maximum altitude of 309 km. T-Rex was developed by an international team led by the Kanagawa Institute of Technology/Nihon University to test a new type of electrodynamic tether (EDT) that may lead to a generation of propellantless propulsion systems for LEO spacecraft. The 300-m-long tape tether deployed as scheduled and a video of deployment was transmitted to the ground. Successful tether deployment was verified, as was the fast ignition of a hollow cathode in the space environment. Data analysis is ongoing.

Tethers Unlimited (TUI) continued development of its terminator tape deorbit module, a lightweight, low-cost device that uses electrodynamic and aerodynamic drag to enable spacecraft to meet orbital lifetime regulations. The company performed testing of terminator tape prototypes aboard the zero-*g* parabolic flight aircraft, demonstrating successful deployment in microgravity.

An AFOSR-funded team from Penn State, the University of Michigan, and TUI have been examining the use of EDTs for "energy harvesting" on spacecraft. The goal is to develop a better understanding of the power generation capabilities of EDT systems on various scales, and how to store energy in and derive energy from the "orbital battery." Initial results show that large satellites have the potential to harvest as much as kilowatts, and small EDT systems for use on CubeSats could harvest tens of watts of average power for short periods of time—useful, for example, during a ground station overpass. Femtosats, such as ChipSats, could benefit from EDT systems that would enable them to maintain orbit without a significant contribution to size and mass or the need for expendable propellant.

The Naval Research Laboratory (NRL) is planning to fly a Tether Electrodynamic Propulsion CubeSat Experiment (TEPCE) to demonstrate electrodynamic propulsion in LEO. With body-mounted solar cells, TEPCE will be able to change its orbit by 1 km/day. The spacecraft consists of two 1.5U CubeSat end masses with a 1-km-long conducting tether. Recently, NRL completed successful deployment tests of a spring mechanism called a stacer, which pushes the two CubeSats apart at 4 m/sec. TEPCE is planned for flight as a secondary payload in 2012.



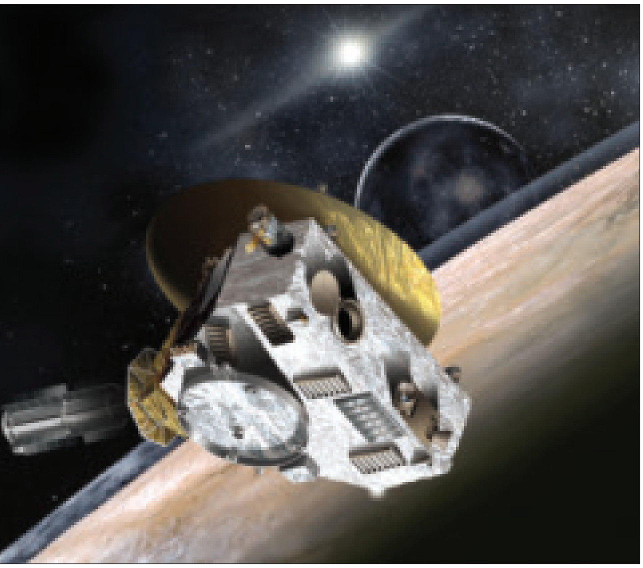
Downlinked video from the T-Rex tether experiment shows successful boom (bottom) and tether (top) deployment.

In support of TEPCE, the U.S. Naval Academy is developing TetherSat, a satellite system with a 1-km-long tether, to test the TEPCE tether deployment hardware in LEO and to analyze the dynamics during and after deployment. Twin end masses are 1.5U CubeSats that will contain GPS and other sensors to accurately measure tether libration and orbital motion data. Although the tether is conductive, it will not be used to generate electrodynamic forces. TetherSat is planned for a flight in late 2011.

Under a Space and Naval Warfare Systems Command Small Business Innovation Research program, Star Technology and Research and Tether Applications are developing a propellantless maneuvering spacecraft using electrodynamic propulsion with a 10-km conductive tape and powered by thin-film solar arrays. The ElectroDynamic Debris Eliminator (EDDE) spacecraft is designed to actively remove large debris objects from LEO using lightweight nets deployed from the ends, at far lower cost than using rockets. EDDE achieves high performance from its patented rotating design, which provides stability and increased thrust. Using data from the TEPCE flight, a Mini-EDDE will be designed for an orbital flight demonstration.

by **Sven G. Bilén** and the **AIAA Space Tethers Technical Committee**

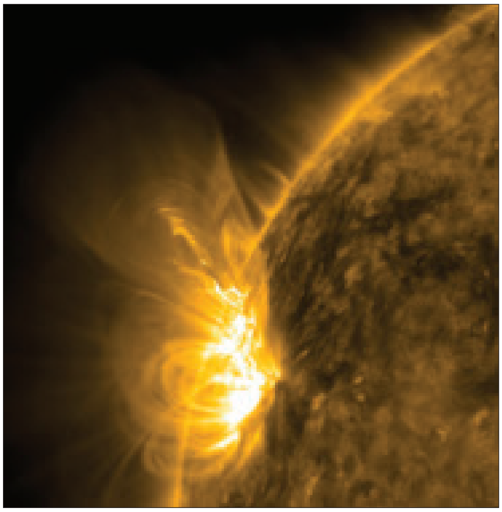
Space systems



The New Horizons satellite is scheduled to arrive at Pluto on July 14, 2015. Image courtesy JHUAPL/SwRI.

Innovative satellite systems designed to carry out scientific exploration are a mainstay of our nation's space systems. A steady stream of satellites since Explorer 1, launched in January 1958, has quietly and proudly been expanding the frontiers of human scientific knowledge. In the midst of changes and upheaval that marked the year 2010, we celebrate these achievements, which represent some of the best of human endeavors. Despite the challenges faced by other parts of NASA, its Science Mission Directorate is enjoying one of the most fruitful time periods, with more than 15 science satellites in operation. Worldwide, scientists are getting more data from space-based observations than ever before.

A slew of Earth-observing space systems were launched in 2010 to help further understand our planet and its environment. Managed by NASA Goddard, the Solar Dynamics Observatory (SDO) was launched on February 11 on an Atlas V 401 to a geosynchronous orbit to provide continuous monitoring of the Sun. SDO is providing unprecedented multiwavelength observation of the Sun, continuously downloaded to its own dedicated ground station. High-definition near-real-time images are available to the public on the SDO web site. "By some estimates, SDO will transmit as much as 50 times more science data than any mission in NASA history," says Dean Pesnell of Goddard.



A close-up look at a substantial active region on July 9 shows a hotbed of magnetic activity that leads to a small solar flare bursting out into space. The images were taken by SDO's AIA instrument in the 171-Å wavelength of extreme ultraviolet light. The thin arcing loops are really particles spiraling along magnetic field lines above the active region.

The latest in the Geostationary Operational Environmental Satellite (GOES) series, GOES-P, was launched on March 8 and accepted into service on September 1; it will go by the name GOES-15. It was built by Boeing Space and Intelligence Systems and launched with a Delta IV rocket by ULA. The spacecraft is currently in a parking orbit, ready to take over weather monitoring and tracking should one of the currently active GOES spacecraft experience an anomaly.

The European Space Agency's CryoSat 2 spacecraft was launched on April 8 aboard a Dnepr rocket. It replaces Cryo-Sat, which was lost in a 2005 launch failure. CryoSat 2 is designed to precisely monitor the thickness of ice, both in the ocean and on land. In its most advanced mode, two SAR antennae on the spacecraft use interferometric techniques to accurately measure ice thickness.

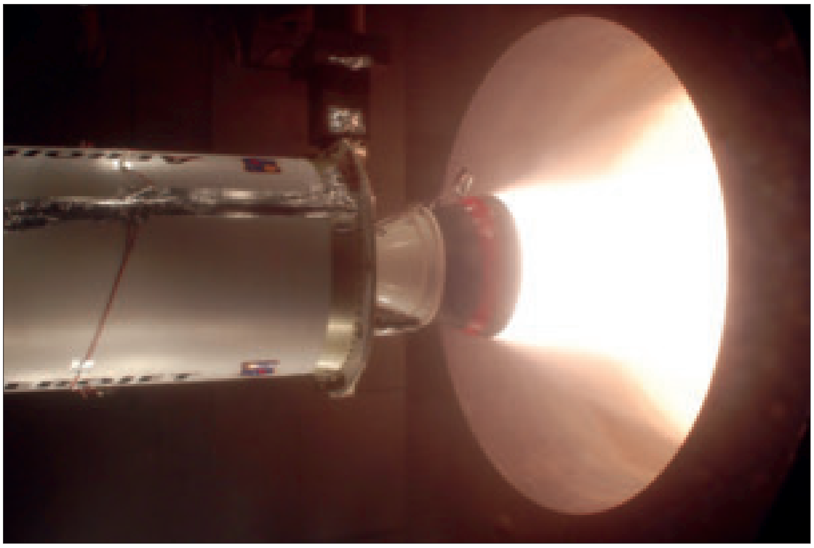
This year marked the half-time point in New Horizon's traverse to Pluto. The small spacecraft, weighing only 478 kg, carries six instruments to conduct observations of Pluto, the once-planetary body and now largest of the Kuiper-belt objects. New Horizons was built jointly by the Applied Physics Lab and Southwest Research Institute. With a destination more than 30 AU from the Sun, New Horizons is powered by a radioisotope thermal generator, supplying about 240 W to the grand-piano-size spacecraft. Communication is done via a large, 2.1-m high gain X-band antenna. At its destination, New Horizon has a roundtrip communications latency of ~9 hr, necessitating a relatively autonomous spacecraft that can manage faults and anomalies recovery with minimal ground contact.

The Japanese Aerospace Exploration Agency launched Akatsuki, a Venus orbiter, on May 20 aboard a JAXA H-IIA 202 rocket from Tanegashima. The spacecraft carries innovative silicon nitride ceramic thrusters developed by JAXA for the 500-N orbit maneuvering engine. Akatsuki ("Dawn") is scheduled to arrive at Venus this month and enter into a 30-hr elliptical orbit. Akatsuki carries a multiwavelength suite of instruments designed to image the Venusian atmosphere from 90 km down to 10 km.

These missions are just a few examples of space systems being built around the world to expand the frontiers of human knowledge.

by **Amy Lo**

Missile systems



The successful performance test of Aerojet's advanced second-stage large solid-propellant rocket motor was the first at simulated altitude conditions.

A number of exciting and important launches and flights took place this year. Both the low-cost guided imaging rocket (LOGIR) program and the Minotaur IV had successful launches. In addition, the X-51A completed the first powered flight of an endothermic hydrocarbon-fueled scramjet engine. The value and advantages of these programs are enormous, enabling the U.S. to maintain its position as a world leader.

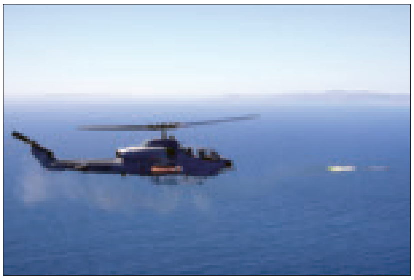
LOGIR, a Navy-developed guidance enhancement capability for rockets, completed its concept demonstration phase at the Naval Air Warfare Center Weapons Division with a successful launch and direct hit. The test involved the air launch of a guided rocket against a fast inshore attack craft target. The launch aircraft was a helicopter equipped with a LOGIR fire control system and LOGIR smart launcher. This test officially shifted the LOGIR project into the joint capability technology demonstration phase, where it will be known as Medusa. Completion of a military utility assessment for Medusa is expected in 2011.

The first Minotaur IV rocket successfully launched in April, deploying DARPA's hypersonic technology vehicle 2 into a suborbital trajectory. The Minotaur IV "lite" launch vehicle leverages the flight-proven heritage of the Minotaur I, Pegasus, and Taurus vehicles to provide an extremely cost-effective and capable space solution. Future Minotaur IV missions will include options such as commercial solid-fuel rocket upper stages and a hydrazine propulsion and attitude control system.

The X-51A made history when it successfully completed its first flight, with acceleration from boost (about Mach 4.5) to about Mach 5. The X-51A is an unmanned scramjet-propelled aircraft developed for advancing air-breathing hypersonic flight technology. A Boeing and Pratt & Whitney Rocketdyne consortium is developing the aircraft for the Air Force and DARPA. In the future, platforms capable of flying at hypersonic speeds will be able to respond almost instantly to strategic and tactical threats. Additional X-51A flights are planned for late this year and 2011 to chase the goal maximum, about Mach 6+.

Testing and development continued for the nation's ballistic missile defense system (BMDS). The operationally configured terminal high-altitude area defense (THAAD) missile system conducted its seventh successful intercept test. Representatives from several missile defense assets and emerging technologies observed the launch and gathered data for future analysis. The THAAD system continues to undergo development and testing to provide a robust layered defense against ballistic missiles of all ranges in all phases of flight.

For the third time, a Japan Maritime Self-Defense Force ship conducted a successful intercept flight test in cooperation with the U.S. Navy. The test was a significant milestone in the growing cooperation between Japan and the U.S. in the area of missile defense. Also, the Aegis BMDS successfully completed a series of exercises. The second-generation Aegis BMDS brings the capability to engage increasingly longer range and more sophisticated ballistic missiles. A two-stage ground-based interceptor (GBI) was also successfully flight tested. This GBI is undergoing developmental testing as part of the DOD's strategy of investing in a new missile defense option that can contribute to homeland defense.



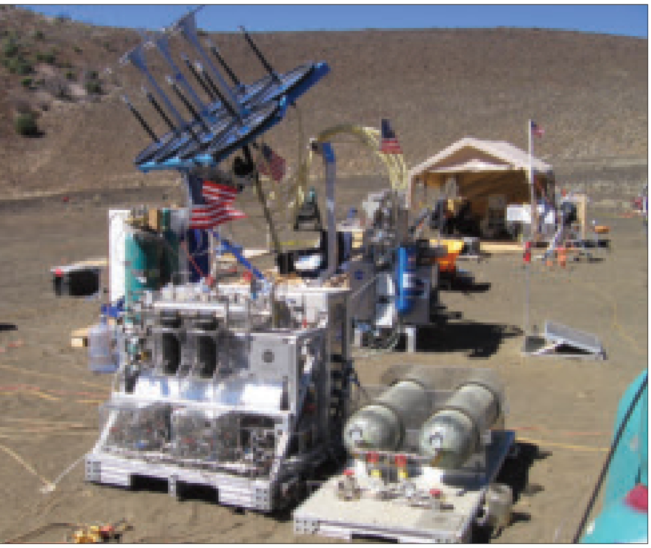
An AH-1W attack helicopter launches a guided imaging rocket during a test at the NAWCWD Point Mugu sea range.

Two new propulsion systems underwent simulated altitude testing at the Air Force's Arnold Engineering Development Center. The successful performance test of Aerojet's advanced second-stage large solid-propellant rocket motor was the first at simulated altitude conditions following a 2009 sea-level test at Edwards AFB. ATK's Castor 30 motor, designed to support a "family of motors" product line for possible DOD and NASA applications, was also successful, operating for over 150 sec. This first-ever test of this upper stage motor was the longest firing in the test facility's 16-year history.

by the **AIAA Missile Systems Technical Committee**

Space resources

In another exciting year for the space resource utilization community, several technologies advanced from laboratory prototype to complete operating system. Many of these technologies were integrated for the first time and tested at the 2010 International Lunar Surface Operations and ISRU (in-situ resource utilization) Analog Test. This field test took place from January 25 to February 12 at a lunar analog test site operated by PISCES (Pacific International Space Center for Exploration Systems) at an elevation of 9,000 ft on the slopes of Mauna Kea. NORCAT (Northern Center for Advanced Technology) led the test, with funding from the Canadian Space Agency. NASA's Science Mission Directorate funded resource characterization instruments.



The integrated regolith processing system located at a lunar analog test site on Mauna Kea is remotely operated from NASA Johnson.

The major participants in the field test were NASA (Kennedy, Johnson, Langley, Goddard, Ames, JPL, and Headquarters), DLR (the German space agency), ORBITEC, Honeybee Robotics, PSI, ASRC Rocket, WASK Engineering, the NORCAT-led SRCan team (Neptec, Xiphos, Ontario Drive and Gear, UTIAS, Electric Vehicle Controllers, Virgin Technologies, Natural Resources Canada, PACEAS Technologies, and YUM Culinary Academy/Cambrian College), the University of Hilo, Arizona State University, UC Davis, McMaster University, the University of Mainz, and the University of Washington.

The field test was a unique opportunity to integrate many different capabilities required for space resource utilization—active vision systems, drilling, robotic mobility, robotic manipulators, communications, and ISRU processing technologies—into a single demonstration. Several instruments characterized the geotechnical, chemical, and mineral features of the tephra at the test site. Instruments included the RESOLVE (regolith and environment science and oxygen and lunar volatile extraction) drill, a combined Mossbauer/XRF, several cone penetrometers, a heat flow probe, a multispectral microscopic imager, an X-ray diffraction instrument, a borehole X-ray fluorescence instrument, and the VAPoR (volatile analysis by pyrolysis of regolith) and RESOLVE systems for volatile analysis.

Multiagent teaming of rovers was used to autonomously prepare a landing pad at the test site. Concentrated solar energy and electric resistance heaters mounted on a rover were used to sinter the tephra surface to increase stability. The geotechnical properties of the sintered surfaces were measured before they were tested with the exhaust plume from an LCH_4/LOX thruster. Tephra was also collected with an automated rover powered by a fuel cell and delivered to a carbothermal reduction plant, where it was inserted into the reactor with a pneumatic lift system. The tephra was processed using concentrated solar energy, producing water that was electrolyzed. The hydrogen produced was stored in metal hydride canisters, while the oxygen was liquefied and later used to operate the LCH_4/LOX thruster. The stored hydrogen was used to operate a fuel cell that powered the carbothermal reduction plant and other support equipment.

The field test was very successful and met all its major objectives. Equipment from several organizations was successfully integrated at the test site to create a true end-to-end demonstration of space resource evaluation and utilization. Prototype equipment was operated in a harsh terrestrial environment for long periods as a precursor for flight hardware development. Several systems were monitored and operated remotely through a satellite communications link that provided telemetry, situational awareness, command and control, and data management. Outreach and public education events were held during the field test to share the exciting work with local residents, students, and the general public.

NASA Kennedy coordinated and hosted the inaugural Lunabotics Mining Competition. This event, sponsored in part by the AIAA Space Resources Technical Committee, included designing and building a remote-controlled or autonomous excavator (lunabot) for competition, writing a systems engineering paper, coordinating informal education outreach to K-12 students, a lunabotics mining slide presentation, and a team spirit evaluation.

Finally, an Ohio State University/NASA Marshall/NASA Kennedy/ASRC Aerospace team demonstrated the full removal of metallic and lunar oxide melts by countergravity casting from a molten regolith electrolysis furnace.

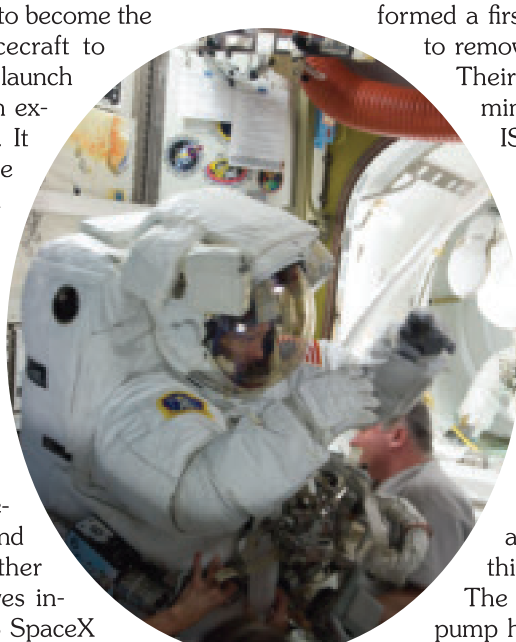
by **Robert Gustafson**

Space logistics

Space logistics is the theory and practice of driving space system design for operability, and managing the flow of materiel, services, and information needed throughout a space system life cycle. The shuttle's impending retirement will significantly affect space station logistics processes—the original ISS operations and support concept was designed with continued shuttle operations in mind. The imminent cancellation has driven significant ISS sustainment concept changes, which now involve greater reliance on spares prepositioning, on-station ORU (orbital replacement unit) repairs, and the loss of capacity for returning large, high-value parts to Earth for repairs. In sum, the shuttle's retirement will severely challenge our ability to address satellite servicing and significant unplanned ISS system repairs.

Soyuz and Progress flights continue to transfer crews and materiel to the ISS, and Soyuz will become the only vehicle capable of crew and limited cargo return when the shuttle retires. The automated transfer vehicle Johannes Kepler is slated to become the second European spacecraft to reach the ISS, with the launch via an Ariane 5 mission expected early next year. It offers significantly more cargo capacity than Progress, with up to 5.5 metric tons of freight and supplies, 840 kg of water, 100 kg of gases, and 4 metric tons of fuel for ISS orbit correction. ESA is also investigating a reusable reentry vehicle variant that is designed to return crew and materiel to Earth. Other ISS resupply alternatives include the NASA COTS SpaceX Dragon and Orbital Sciences Cygnus vehicles and the JAXA HTV, all of which are planning flights to the ISS in the next few years. Dragon brings the potential for significant downmass capacity.

Major tasks remaining for the ISS international partnership include coordinating flight schedules, cargo manifests, docking port availability, and reverse logistics; maintaining a robust set of spares; and the timely delivery of consumables.



Expedition 24 flight engineer Tracy Caldwell Dyson, attired in her extravehicular mobility unit spacesuit in the ISS Quest airlock, completed three spacewalks with flight engineer Doug Wheelock to remove and replace an ammonia pump module that failed July 31.

The challenge of ISS spares and preposition planning is overcoming the uncertainty in failure rate estimates and minimizing the risk of inaccurate failure predictions. To mitigate this problem, the ISS logistics and maintenance team and ISS reliability and maintainability team use Bayesian inference to update mean time between failure estimates with ORU performance history. As with previous updates, the 2009-2010 operating period generally shows on-orbit hardware performing better than initially predicted. The Bayesian update process will likely continue to be a critical tool for ISS sustainment plans extending to 2020 and beyond.

ISS prepositioning, sustainment, and repair capabilities were showcased in August after an ammonia pump module on the starboard-side truss failed. One of the station's two cooling loops was brought down, necessitating a reduction in power consumption by noncritical systems and payloads. Planning began immediately for removing the broken pump and replacing it with an available spare.

Expedition 24 flight engineers Doug Wheelock and Tracy Caldwell Dyson performed a first spacewalk on August 7 to remove and replace the pump. Their excursion lasted 8 hr 3 min, making it the longest ISS-based spacewalk and the sixth-longest spacewalk in history. Their repair tasks originally included removing the failed pump module and retrieving a spare from an external stowage platform, but an ammonia leak necessitated a second EVA to finish removing the failed pump and prepare a spare for installation in a third and final spacewalk. The 780-lb spare ammonia pump had been delivered in July 2006 via STS-121 and placed on an external stowage platform. The repair and replacement tasks took a total of 22 hr 49 min during the three spacewalks.

The extensive EVA work also highlights the need for implementing EVR (extravehicular robotics) and EVA/EVR cooperative maintenance for other external ORUs (orbital replacement units) using the Canadian Space Agency's special-purpose dexterous manipulator, fondly referred to as Dextre.

by **Alan W. Johnson**

Space colonization

by **Ram Ramachandran** and **Anita Gale**

Expanding human presence beyond Earth is the long-term goal of the manned spaceflight program—a goal clearly recognized by the Augustine commission, and against which every foray into space should be measured. Progress toward future space settlements is measured in small ways, mostly as incremental changes in perception and in advances in supporting technology development. This year was full of mixed signals, with commercial entities continuing to make progress toward cargo/crew launch and the U.S. government trying to reinvent the human space program priorities and approaches.

Russia, ESA, Japan, China, and India all have proposed ambitious missions, including manned missions, to the Moon and planets. The announced finding of substantial amounts—perhaps a billion gallons—of water and other volatiles from the Lunar Crater Observation and Sensing Satellite (LCROSS) 2009 impact mission has come as a stunning revelation that warrants a second look at the Moon. The presence of ammonia in the impact ejecta is another key finding for facilitating future extended human presence on the lunar surface.

SpaceX and Orbital Sciences made continued progress in the development of commercial launch vehicles via NASA-funded programs. Several other firms reported programs for suborbital launches that could be leased for research and/or promoting science, technology, engineering, and mathematics education.

Findings from the LCROSS 2009 impact mission reveal the presence of large amounts of water on the Moon.

The year also brought significant progress in the space tourism arena. A Virgin Galactic/Scaled Composites team demonstrated a suborbital test flight of VSS Enterprise in a bid to achieve commercial manned suborbital flight. Bigelow Aerospace, teamed with Orbitec Technologies, embarked on human rating the environmental control and life-support system to be used on the Sundancer inflatable habitat in space, scheduled for a 2015 launch.

ISS activities included research on human physiology and radiation protection; microgravity disciplines such as materials science, fluid physics, and combustion; Earth observations; and education outreach.

Space settlement concepts and infrastructure supporting future space settlement were featured at the AIAA Space 2010 Conference and AIAA Aerospace Sciences Meeting as well as at the National Space Society International Space Development Conference, where the focus was on key technologies required for space colonization.

Evidence of popular acceptance of space settlement concepts is increasing. The AIAA-sponsored International Space Settlement Design Competition involved over 1,000 high-school students worldwide in designing large space settlements in a solar cycler orbit crossing the orbits of Earth and Mars Earth orbit, in Mars lunar orbit, and on the surface of Mars. The National Space Society Space Design Contest attracted hundreds of entries, primarily from individual students.

This year we have seen the U.S. space program become a political football, with passions running high in both camps. The U.S. has spent billions of dollars on developing a shuttle replacement, only to see the program fundamentally changed in midcourse. It is time for us to realize that the space program is no longer a discretionary one but rather a strategic one that is multifaceted, providing a key stimulus for technical innovation and enterprise, showcasing technical prowess and leadership, and challenging the next generation to pioneer the next frontier.

The key to success in space will be a coherent, sustained vision, adequate funding, and relentless effort. NASA should embark on the Moon-first path while keeping open the later opportunity to visit other near-Earth bodies. Moon-Base 2020 should be an engineering testbed for technologies applicable to long-term exploration missions on Mars and elsewhere. Without these technologies and demonstrable milestones, long-term exploration goals will remain elusive.

Space transportation

While the space shuttle program is winding down, NASA has entered a particularly critical period in its effort to reshape its human spaceflight program. All this activity is generating a lot of media attention and discussion, as the decisions being made in Congress now may very well affect the agency for years to come.

STS-130 delivered the Tranquility connecting node and the cupola to the international space station. The cupola is a module with seven windows to provide a unique view around the station. STS-131 carried a multipurpose logistics module with supplies and experiments for use aboard the ISS. STS-132 carried the Russian mini-research module 1, to be attached to the Zarya module. And STS-133 delivered the express logistics carrier, a multpurpose logistics module, and critical spare components.

The Orion pad abort test was launched at White Sands Missile Range, New Mexico; it was the first fully integrated flight test of the launch abort system. The Orion crew exploration vehicle parachute assembly system performed a successful airdrop test at the Yuma Proving Grounds. The second full-scale demonstration test of the five-segment solid rocket booster was successfully conducted.

The first SpaceX Falcon 9 launch vehicle was successfully launched in June, marking a key milestone for the commercial spaceflight industry. Preliminary data indicated that Falcon achieved all of its primary mission objectives, culminating in a nearly perfect insertion of the second stage and Dragon spacecraft qualification unit into the targeted circular orbit. A second launch under the COTS program is planned before year's end.

A United Launch Alliance Delta IV delivered GOES-P for NASA and NOAA. The weather satellite will monitor conditions across the U.S. Another ULA Delta IV launched the Air Force's first Block-2F navigation satellite for the GPS system. A ULA Atlas V launched NASA's Solar Dynamics Observatory; another launched the U.S. military's X-37B, a prototype spaceplane. A third Atlas V launched the first advanced extremely high frequency satellite. One each of the Delta II and Delta IV Heavy vehicles, two Atlas Vs, and two Minotaur launches are also scheduled for this year.

As of mid-2010, three Ariane 5 launches had been conducted, with three remaining before the end of the year. Future payloads include the second ATV, Johannes Kepler, to the ISS. The first Soyuz launch from Guiana is planned for December.


The WhiteKnightTwo carrier aircraft, with SpaceShipTwo, made its first long-distance captive-carry flight in October.

Japan has achieved a significant "first" in space transportation with the successful recovery in Australia of its Hayabusa probe in June. Launched seven years ago, Hayabusa landed on asteroid Itokawa in November 2005. An H-II-A rocket launched Akatsuki, the first Japanese probe to Venus, in May; the payload included the Ikaros satellite, equipped with a 20-m-wide solar sail.

India launched its first GSLV Mk2 D3 with an indigenous cryogenic upper stage, but it failed during its initial ascent. The Indian polar satellite launch vehicle launched the Cartosat 2B remote sensing satellite and multiple secondary payloads. A GSLV Mk1 launch was planned for the last quarter of 2010. The second attempt to send a South Korean satellite with a KSLV launcher failed in June. The vehicle exploded toward the end of first-stage operations.

Seven Chinese Long March launches were conducted this year, the last with China's second lunar orbiter probe, Chang'e 2. Russia is still launching at a high rate, totaling 17 by midyear (including ILS launches). In June, Israel launched its Ofeq 9 reconnaissance satellite with a Shavit rocket.

Virgin Galactic's WhiteKnightTwo carrier aircraft, with SpaceShipTwo, made its first long-distance captive-carry flight to the Spaceport America runway dedication in conjunction with the October ISPCS meeting in Las Cruces, New Mexico, following a successful first free flight of the SpaceShipTwo vehicle.

XCOR is continuing to develop the Lynx suborbital spaceplane that is expected to begin prototype flight tests in mid-2011. Masten Space Systems, meanwhile, is developing suborbital vehicles of its own design.

by **Carl Ehrlich** and the **AIAA Space Transportation Technical Committee**

Weapon system effectiveness

This GBMD interceptor was launched from Vandenberg AFB on January 31. Missile Defense Agency photo.

This year marks the 27th anniversary of President Reagan's visionary speech on strategic defense, where he announced that the U.S. was capable enough that mutually assured destruction was no longer a morally tenable defense position. He said, "I've become more and more deeply convinced that the human spirit must be capable of rising above dealing with other nations and human beings by threatening their existence."

In this initial speech, Reagan recognized that "[creating a strategic defense] will take years, probably decades of efforts on many fronts. There will be failures and setbacks, just as there will be successes and breakthroughs."

Defensive systems are still proving to be the most demanding weapon systems. Missile defense systems strike incoming warheads, objects that are less than 1 m across, at velocities ranging from subsonic (300 m/sec) to above 5 km/sec (over 10,000 mph).

As to complexity and difficulty on the upper intercept velocity end, the U.S. is still testing its deployed ground-based midcourse defense (GBMD) segment. On January 31, the U.S. had a test failure of the installed system: a target missile was successfully launched from Kwajalein, and the interceptor missile was successfully launched from Vandenberg AFB, but there were problems with sea-based X-band radar and an intercept did not occur. On June 6 there was a successful launch of a ground-based interceptor, again from Vandenberg. The various elements of the partially deployed system are still undergoing test and integration.

Midcourse defense intercepts long-range missiles while they are ballistic, the missiles having used up their fuel. There is ongoing research on destroying missiles earlier, during boost, just after launch during their acceleration phase, while they are still burning fuel. On February 11, the airborne laser test bed (ALTB) destroyed two missiles during launch within 1 hr of each other, one a liquid-fueled rocket and one a solid-fueled rocket. The ALTB has an oxygen-iodine laser housed in a Boeing 747-400 freighter. On September 1, a test was terminated as the laser beam veered and the system software shut down the beam.

In the terminal intercept regime, where the missile warheads are on their way down toward the target, this year saw another successful test of the terminal high-altitude area defense (THAAD) missile defense system with a successful intercept of a target missile off the coast of Hawaii on June 28. The target represented a short-range ballistic missile. Also for short-range missiles and artillery shells, the Iron Dome system is under development by Israel with U.S. support.

Historically, the primary defense for individual soldiers and ground vehicles has been inaccuracy of incoming fire. Unfortunately, in Afghanistan and Iraq, explosive devices are being placed in close proximity to the target, negating this historical defense. Thus, our soldiers and vehicles need equipment to protect against impacts and close-range blast. After the initial, and successful, delivery of vehicles such as MRAP, we are now in a position to begin devising vehicles that are designed from the ground up with impact and blast defense in mind. Ideas such as "floating" the cabs to prevent soldiers' legs from being shattered during a blast event, and incorporating new materials and safety systems into the vehicles, are under development.

From the systems perspective, we need to understand all the demands on the vehicles, including mobility, stability, electrical power requirements, cooling, and what information and devices need to be accessible by the crew since additional objects in the cab become hazards during extreme events. When the Weapon System Technical Committee first formed in 1995, its main focus was missile defense, requiring the most complex systems yet created. Now ground systems need increased sophistication. The art of effective weapon system design is most challengingly expressed in these defensive systems.

by **James D. Walker**

Space operations and support

This year has been marked by a number of significant scientific advances in the field of spacecraft operations, including a number of asteroid mission successes. Deep Impact's flyby of Earth in June as part of its extended investigation activity en route to comet Hartley-2 was followed closely by Rosetta's flyby of asteroid Lutetia in July.

The most remarkable of the asteroid missions was undoubtedly the Japanese Hayabusa mission. Japan had already enjoyed a significant scientific operations success in May with the launch of its Akatsuki satellite to Venus. But Hayabusa became the first mission to take a sample from the surface of an asteroid (Itokawa) and return it to Earth.

The mission's success was all the more remarkable considering the issues the operations team had to overcome. The spacecraft's rover, Minerva, could not be dispatched and Hayabusa itself, which was not intended to land on the asteroid, landed for 30 minutes. The particle collection mechanism failed, but asteroid dust was collected as a result of the landing. A failure in one of the engines resulted in a loss of communications with the spacecraft for seven weeks, and JAXA needed a further 16 months to regain control. Finally the craft had to use ion thrusters to return to Earth after the chemical thruster failure.

Space debris and situational awareness remained very active topics. The widely publicized control communications failure of the Galaxy 15 satellite while maintaining transponder broadcasting in April, resulted in significant interference to neighboring spacecraft as it drifted uncontrolled in front of active geostationary orbital slots over the subsequent months. This not only caused significant disruption to the geostationary communications sector, but highlighted a less cited but equally important domain of spacecraft control failure mitigation and end-of-life strategies, compared to past years' dramatic debris events.

End-of-life passivation guidelines highlight the need for disabling intentional transmitters, and although Galaxy 15 was not being placed into an end-of-life configuration, it demonstrated very clearly the need for such guidelines during both these and mission contingency activities.

Progress in space situational awareness included the first operations of the Space Data Center, set up in 2009 as a nonprofit organization looking at conjunctions of satellites owned by its participating operators, and the expected first launch of the USAF's space surveillance satellite.

JAXA's Hayabusa overcame a series of problems before successfully returning its probe to Earth.

Commercial spaceflight has made steady progress this year, most notably by SpaceX with the successful maiden flight of its Falcon 9 heavy-lift rocket on June 4 from Launch Complex 40 at Cape Canaveral. The company achieved another major milestone on August 12 with a successful drop test of its Dragon capsule about 9 mi. off the coast of Morro Bay in California. The test validated its parachute deployment system. And though the initial flights will descend for a touchdown on the water, their goal is a land recovery. The combined Falcon 9 and Dragon were designed not only to replace the space shuttle as a cargo carrier but also to transport crew to low Earth orbit. The latter is the so-called "D" option of the Commercial Orbital Transportation Services contract, which NASA has not yet exercised.

The Dragon drop test validated the parachute deployment system.

Elsewhere in private spaceflight, Virgin Galactic's VSS Enterprise made its inaugural manned flight on March 22 in a "captive carry" flight test in which the vehicle stayed attached to the VMS Eve mothership. The flight lasted 2 hr 54 min and achieved a peak altitude of 45,000 ft.

by **Franz Newland** and **J. Paul Douglas**

Green engineering

Green aviation, alternative fuels, sustainability, and energy topics moved to the forefront this year in the aerospace industry.

In one of many key milestones for biofuels, a military helicopter was flown for the first time using a 50/50 blend of biofuel and traditional jet fuel. The flight of a Boeing Apache, piloted by the Royal Netherlands Air Force, lasted 20 min.

The Navy reached a significant landmark in April with the first flight of a naval fighter fueled by a biofuel blend. The Boeing F/A-18 Green Hornet, powered by GE F414 engines, flew for 45 min and performed as expected. Preceding this test were hundreds of hours of component and ground testing.

The Air Force posted key achievements as well, completing altitude tests of an F110 engine using a 50/50 biofuel mix at Arnold Engineering Development Center. The first flight of an A-10 Thunderbolt II using a camelina-derived biofuel blend took place in March.

Dr. Bilal Bomani inspects Salicornia as a potential biofuel for next-generation aviation fuels in the Green Lab at NASA Glenn in Cleveland, Ohio.

CAAFI (Commercial Aviation Alternative Fuels Initiative) is researching the use of alternative fuels as a means of improving energy security and environmental sustainability. It is sponsored by the FAA, the Airports Council International-North America, the Aerospace Industries Association, and the Air Transport Association of America. The coalition also includes members from airlines, airframers, engine manufacturers, and energy producers. In January, CAAFI received the Joseph S. Murphy Industry Service Award, which recognized the partnership's considerable achievements in advancing alternative fuels.

ASTM International will hold a critical committee meeting at the end of the year to discuss an amendment to the D7566 fuel specification. If the vote on the amendment is favorable, it should lead to the approved use of biofuels in commercial aircraft.

The FAA, through its CLEEN (Continuous Lower Energy, Emissions, and Noise) program, is seeking to develop and demonstrate technologies and alternative fuels to meet multiple environmental and energy goals. These include reducing fuel burn by 33%, nitrogen oxide emissions by 60%, and cumulative aircraft noise levels by 32 dB. In June the program announced $125 million in contracts to companies including Boeing, Honeywell, GE Aviation, Pratt & Whitney, and Rolls-Royce North America.

NASA hosted a Green Aviation Summit in September to discuss the challenges, opportunities, and progress associated with its Environmentally Responsible Aviation effort. The event was attended by government, industry, and academia, and highlighted the diverse spectrum of NASA programs aimed at mitigating aviation's impact on the environment.

GE Aviation completed low-speed acoustic testing of its generation-one open rotor blades. The subscale blades were tested at NASA Glenn in the 9x15-ft low-speed wind tunnel. The company expects the final configuration to enable a double-digit reduction in fuel burn. Pratt & Whitney continued development of its geared turbofan, which also promises double-digit improvements in fuel burn. Rolls-Royce made progress this year in its Environmentally Friendly Engine program, which will validate technologies aimed at reducing noise, fuel burn, and emissions. These technologies will undergo testing in a full engine demonstrator.

The newly formed ARPA-E (Advanced Research Projects Agency-Energy) has had a busy year. In March it awarded $106 million in contracts focusing on biofuels, more efficient and cost-effective batteries, and clean coal technology. July brought $92 million in additional funding for 43 potentially transformational energy projects. These contracts center on infrastructure factors such as grid scale energy storage, building efficiency, and power electronics. Later, a September announcement awarded $9.6 million to six projects aimed at increasing building energy efficiency, reducing solar energy costs, and improving power density.

Finally, AIAA formed a Green Engineering Program Committee this year, further reflecting the growing importance of these programs to the aerospace industry.

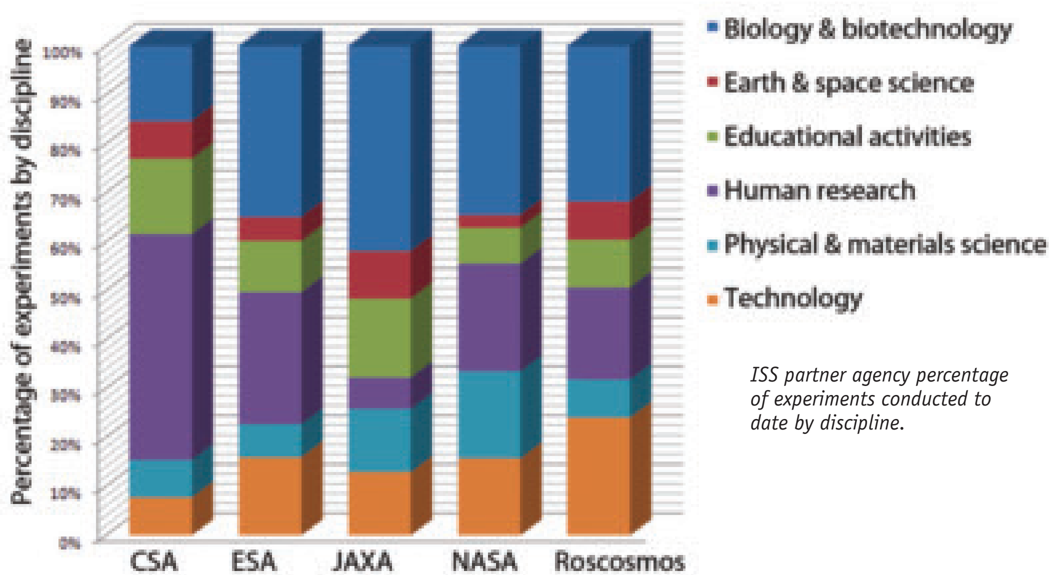
by **Jason Slagle**

The ISS is an international collaborative space venture that includes partnerships between NASA, the Canadian Space Agency, ESA, Roscosmos (the Russian space agency), and the Japanese Aerospace Exploration Agency.

For more than 15 years this partnership has weathered economic, technical, and political challenges, having completed one of the most ambitious engineering projects ever conceived. However, the challenge of successfully utilizing the platform remains. Facilities commissioned in 2009 and 2010 include physical sciences hardware for combustion, materials science, and fluid physics research, as well as additional multipurpose and supporting infrastructure. Discovery's STS-131 mission added the WORF (window observational research facility), which will enable full scientific use of the optical quality window in the Destiny laboratory; the third and final MELFI (-80° laboratory freezer), an ESA-built, NASA-operated freezer for science sample storage; EXPRESS (expedite the processing of experiments to space station) Rack 7, a multipurpose payload rack system that supports experiments in any discipline by providing structural interfaces, power, data, cooling and water; and the MARES (muscle atrophy research and exercise system), which will improve understanding of microgravity's effects on the human muscular system.

Even during the assembly phase, work done on the ISS demonstrated the potential benefits of space-based R&D. These include the advancement of scientific knowledge based on experiments conducted in space, development and testing of new technologies, and derivation of Earth applications from new understanding.

The ISS, with its human-tended capabilities and configurability for experiments, provides a unique platform that supports international research spanning a broad array of areas—physical sciences, biology, medicine, psychology, Earth observation, preparation for human exploration, and technology demonstration. Use of the station's U.S. National Laboratory also promotes the commercialization of space. This year the National Institutes of Health (NIH) awarded three grants to use the ISS National Laboratory facilities for conducting research in the areas of bone, immunity, and disease. The grants, which total over $1.3 million, enable a partnership that takes advantage of the unique microgravity environment aboard the ISS. This environment allows exploration of fundamental questions about important health issues here on Earth while also advancing NASA's exploration goals.



ISS partner agency percentage of experiments conducted to date by discipline.

As ISS research has progressed, the ISS partners have been working together to track the objectives, accomplishments, and applications of the new knowledge gained. To date, there have been 59 countries represented by research and educational activities on the ISS. From 1998 through March of this year, the ISS partner agencies have conducted a total of 552 experiments in the following disciplines: physical and material sciences, biology and biotechnology, human research, Earth and space science, technology development, commercial development, and educational activities. As the era of utilization begins, these numbers are expected to grow.

by **Tara Ruttley, Jacob Cohen, Julie Robinson, Bev Girten,** the **AIAA Space Station Program Committee,** and the **AIAA Microgravity and Space Processes Technical Committee**

Value-driven design

High points this year in the field of value-driven/centric design include a DARPA-funded research program, a series of National Science Foundation workshops on the future of systems engineering, a U.K. research task, and the development of an active network of experts in this field from academia and industry in Europe.

The DECODE UAS is currently undergoing testing.

The DARPA research effort is the fractionated spacecraft program, or system F6. Late last year, after downselecting from four prime contractors at the end of the design phase, DARPA funded Orbital Sciences to perform the detailed design on the spacecraft concept. As part of this program, academics at MIT performed an in-depth analysis of publicly available fractionated satellite value-centric design tools from Phase 1 of the DARPA system F6 program. The first task, a comparative benchmarking study of these four tools, involved modeling several use cases to determine differences in inputs, analysis methods, and outputs. The results found the tools to be substantially diverse in modeling architectures and value interpretation.

The second task applied optimization methods to the Phase 1 PIVOT tool, created by Orbital Sciences to maximize satellite system value. The results showed that solution stability is inhibited by uncertainties introduced via the stochastic objective function. The detailed results were presented at the Space 2010 conference.

A second example of the use of a value-driven/centric design approach is DECODE (decision environment for complex designs), a three-year research program at the University of Southampton funded by the U.K.'s Engineering and Physical Sciences Research Council. The primary aim of DECODE, now in its second year, is to provide a consistent, rigorous method for the activities associated with the design of complex systems. The goal is to complete three full design cycles on a relatively complex but accessible design, and to develop the necessary associated tools. The platform chosen for demonstrating the DECODE concept is a small man-portable UAS (unmanned air system). The two DECODE teams have already produced a round of UASs that are currently undergoing testing.

The National Science Foundation commissioned a series of two one- to three-day workshops on the future of systems engineering and the viability of using value-models as an alternative to the current requirements flowdown process. The first of these workshops was held February 22-24 in Washington, D.C., with a follow-up workshop on September 12 in Ft. Worth, Texas. The Value-Driven Design Institute organized both events. The outcome of the first is now publicly available at the Institute's Web site, where the second workshop's results will also be published at a later date. These workshops focused on the future of systems engineering, specifically the area of complex systems design. They were part of a larger series of workshops commissioned by Christina Bloebaum, program director for engineering design and innovation at the NSF, focusing on several aspects of engineering design and optimization.

There are also some nascent efforts where activity has been accelerating, and these portend well for the future. The first of these is the establishment of a joint academic and industry network in Europe that focuses on education and research into value-driven/centric design methods. The second effort follows developments in a planned DARPA program called Advanced Make. Both efforts appear likely to produce some interesting results. Overall, value-driven design made significant advances this year, and the future holds even more promise.

For more information on the NSF workshops see: http://vddi.org/vddi-home.htm.

by the **AIAA Value-Driven Design Program Committee**

Space exploration

Human spaceflight activities moved in a new direction in 2010, a year marked by both continued progress in exploration systems and uncertainty about the future.

The 2009 Review of U.S. Human Space Flight Plans Committee, which was commissioned by President Barack Obama, determined that the Constellation program could not be executed within the available budget and recommended that NASA pursue a "flexible path" strategy for human exploration. Under this new strategy, human missions would be sent to progressively more distant destinations, such as Lagrange points, near Earth asteroids, and the moons of Mars, before attempting to land on either the Moon or Mars. By first demonstrating the critical capabilities needed for deep space missions, and by deferring the development of landing and surface systems, costs can be spread out in time to fit within the available budget.

In February, the president's FY11 budget request for NASA incorporated many of the recommendations of this committee in plans for several new technology programs. These programs would seek to demonstrate key capabilities for human deep space exploration and would place a new emphasis on developing commercial rockets to transport crews into orbit after the space shuttle is retired. The new technology programs would develop liquid-fueled rocket engines for heavy-lift launchers. They would also demonstrate automated rendezvous and docking, cryogenic propellant storage and transfer, a solar electric transfer vehicle, and habitation systems in spaceflight experiments. Plans also include a series of robotic precursor missions to scout potential destinations for future human activity.

On April 15 the president set a new goal for NASA: sending a human mission to a near-Earth asteroid by 2025. The primary objectives for an asteroid mission would be to test technologies and operational concepts for deep space missions, return samples to increase our understanding of the solar system's formation and evolution, and determine if asteroids can be deflected to prevent them from colliding with Earth.

Meanwhile, the Constellation program continued to make progress despite its uncertain future. On May 6 the first integrated test of the launch abort system for the Orion crew exploration vehicle was successfully conducted at White Sands Missile Range. On August 31 ATK test fired a five-segment solid rocket motor for Ares I to demonstrate operation at cold temperatures. A ground test article of the Orion capsule was fabricated and tested at proof pressure. The Constellation program also completed its preliminary design review.

The Pad Abort 1 test of the Orion launch abort system took place successfully at White Sands Missile Range.

Plans to develop commercial rockets for launching crew and cargo into LEO were given a boost by the successful launch of the Space-X Falcon 9 vehicle on June 4. NASA awarded contracts to begin development of concepts and technologies for commercial crew launch.

In September, the Lunar Reconnaissance Orbiter (LRO) completed its one-year mission to map the Moon and identify potential landing sites and resources for future human missions. LRO's seven instruments have returned over 100 terabytes of data. The orbiter's major accomplishments include finding the coldest spot in the solar system in shadowed craters at the lunar poles, mapping the distribution of hydrogen, acquiring high-resolution images of the Apollo landing sites, and producing a global topographic map with its laser altimeter. The mission will be extended for two more years for lunar science studies.

Two crewed rovers, a large payload transport rover, and a habitat unit were tested in the Arizona desert to simulate operational scenarios for planetary surface exploration. Robonaut 2 was launched to ISS in November to assist the crew in performing tasks.

The year closes with Congress having passed the NASA Authorization Act of 2010, which directs NASA to begin a new heavy-lift launch vehicle program and continue the development of a crew exploration vehicle in 2011.

by **Chris Moore** and **Surendra Sharma**

Hypersonic technologies and aerospace plane

Pollux is the first unmanned space vehicle with a slender configuration to be tested in flight at low speeds.

by **Unmeel Mehta**

In various activities this year, critical test data were collected to verify performance and to determine lessons learned.

A Falcon HTV-2 flight test resulted in a crash nearly 9 min into a 30-min flight over a distance of 5,700 km. A DARPA review board is analyzing the data gathered to determine the cause.

After the HyFly missile with its solid rocket booster was released from an F-15E, its booster engine did not ignite. On detecting low internal battery voltage, the onboard software aborted motor ignition. This was the third failure to demonstrate transonic combustion technology.

On Flight 1, the HIFiRE program conducted two experiments, mostly successfully. The vehicle design consisted of a cone/cylinder/flare configuration. A ballistic trajectory was flown to enable varying Reynolds numbers to be achieved at near-constant Mach number. Data were collected to study boundary-layer transition and shock/boundary-layer interaction.

DLR completed integration of the faceted tip of the experimental sharp-edged spacecraft SHEFEX II. Nine different thermal protection systems, mostly based on ceramic matrix composites, were integrated. SHEFEX II has about 160 gauges for measuring pressure, temperature, and heat flux. Canards are used to control the attitude of the vehicle.

JAXA has completed ground firing tests of a hypersonic precooled turbojet engine to develop a turbine-based combined-cycle engine. Conducting the tests with both horizontal and vertical attitude enabled the evaluation of the effect of gravity force in a free-fall flight experiment. The starting characteristics of the air intake were obtained in a supersonic engine test facility.

MBDA and Onera are to receive a contract from the French administration covering the remaining parts of their flight testing program, LEA. The upgrade of the Onera S4Ma wind tunnel is in progress and will provide a large-scale Mach-6 free-jet test capability. Tests involving fuel-cooled composite structure were conducted in the new MBDA test facility, Methyle.

The objectives of the first orbital flight of the X-37B craft, launched aboard an Atlas V on April 22, are to verify its on-orbit performance, to validate the technologies required for long-duration, reusable vehicles with autonomous entry into Earth's atmosphere and landing capabilities, and to conduct some experiments. Its mission time will depend on the progress of the experiments.

Under Italy's PRORA-USV program, the Italian Aerospace Research Center successfully completed the second mission of the dropped transonic flight test to acquire data on transonic and low supersonic flight. A stratospheric balloon took Polluce (Pollux) up to a drop altitude of 24 km. After it was dropped, it achieved a maximum falling speed of Mach 1.24. The vehicle executed autonomous control laws, performing a series of extremely complex maneuvers. A COTS parachute was used at around Mach 0.14 for water landing.

First flight of X-51A

Around 1980, the ramjet-powered Advanced Strategic Air-Launched Missile was tested. On Flight 1, after it was launched at Mach 2.54 and accelerated to Mach 4.1, the fuel control stuck wide open, further accelerating the missile to Mach 5.6-6.0. During Flight 7, ASALM cruised at Mach 4.0 for 290 sec. In 2004, the scramjet-powered X-43A flew at Mach 9.68 for 11 sec. On May 26 of this year, the X-51A vehicle achieved around Mach 4.9, and the dual-mode scramjet (DMSJ) engine (per the X-51A program's characterization) operated for 143 sec, exhibiting transonic combustion.

This flight of the X-51A was very significant, achieving nearly all test objectives. The fuel-cooled DMSJ engine started on ethylene at Mach 4.7 and successfully transitioned to JP-7 seconds later. The vehicle accelerated at 0.15 g. After the first 25 sec of engine-on flight, it suffered an anomaly. It decelerated to 0.0 g, and during the latter part of deceleration it experienced a pronounced bank angle along with a slight side slip. There was an inlet unstart, followed by engine recovery. At 160 sec into the flight, the X-51A briefly returned to nominal operation, accelerating at 0.15 g. Again, it began to decelerate. Telemetry was lost and the flight was terminated.

The X-51A flew and the thermally balanced engine performed as expected before the anomaly. Measured drag, thrust, angle of attack, and tail deflection angles were extremely close to predictions. The objectives of reaching Mach 5.9 and of operating the engine for 240 sec were not achieved. A fix to the vehicle would be made to achieve these objectives on the next flight.

To fully exploit airbreathing hypersonic flight, engines are needed to cover Mach ranges 0-6, 3-8, 6-12, and finally 0-12. The first flight of X-51A was another major milestone toward that goal.

Aerospace traffic management

Air carriers were experiencing better financial returns, based on an upturn in passenger bookings and the results of "down gauging," in which airlines use smaller aircraft to achieve better load factors. Meanwhile, the eruption of a volcano in Iceland in March caused significant disruptions to air travel across the North Atlantic and in Western Europe for about a month. Concerns that the ash plume would damage engines caused closures of large portions of the airspace, leading airlines to cancel many flights.

The event brought home to travelers, shippers, aircraft operators, and air navigation service providers (ANSPs) the profound influence that environmental factors such as severe weather can have on air operations. It also engendered a lively and continuing debate over the scientific basis for concerns about abrasion in aircraft engines exposed to volcanic ash, and the actions that should be taken to safeguard life and property.

Aviation safety remains at an exceptionally high level, but those few accidents that do happen focus attention on areas where improvement is still needed. The Polish air force Tu-154 crash that occurred in April near the city of Smolensk, Russia, killed all 96 people on board. This was a high-profile event because the victims included the Polish president, along with a large delegation of high-level officials going to a memorial service.

While the cause of the crash is still under investigation, it is clear that the pilot was attempting to land under low-visibility conditions without benefit of an instrument landing system (ILS) to provide lateral and, most important, vertical guidance. In an environment where GPS signals are pervasive and the cost of receivers is low, aircraft landing guidance (vertical and lateral) is easily accommodated by the addition of inexpensive ground installations. Around the world, airports without ILS have recognized this and are acting to implement the needed systems.

The U.S. NextGen program is deploying ADS–B (Automatic Dependent Surveillance–Broadcast) at an accelerated pace. This is one of the enabling technologies that, in combination with other NextGen developments, will allow the National Airspace System to accommodate traffic growth safely through 2025. The deployment, still far from nationwide, has had unforeseen benefits—for example, the resultant improvement in surveillance coverage in the Gulf of Mexico facilitated the heavy air activity that followed this year's massive oil spill in the region.

The ash plume from the eruption of a volcano in Iceland caused widespread disruptions in air travel.

Also in connection with ADS-B, in May the FAA published new rules mandating airspace and avionics performance requirements effective after January 1, 2020, giving aircraft owners approximately 10 years to equip for operations within the designated (busiest) airspace. The avionics perform a function generally known as "ADS-B Out," which transmits precise location and other information about a plane to ground stations and other ADS-B-equipped aircraft. The new rule has added significance because it signals the FAA's resolve to make sure that operators update their aircraft systems (namely avionics) so that NextGen benefits can be fully exploited.

Interest in unmanned air systems (UAS) for commercial use has intensified, putting pressure on ANSPs to establish operating procedures that would allow these aircraft greater access to domestic airspace. An indication of this interest is the rapidly growing number of special authorizations the FAA has issued allowing public entities such as law enforcement to use defined airspace. In addition, the FAA has now asked the private nonprofit corporation RTCA to work with the industry to develop UAS standards centering on issues of command and control and "sense and avoid" so that UAS can safely operate among piloted aircraft without undue restrictions. Unfortunately, the current target date for completion of this work is not unil 2015.

by the **AIAA Aerospace Traffic Management Program Committee**

Directed energy systems

Progress toward development of directed energy weapon systems continued in several major DOD programs, the Airborne Laser (ABL), the Office of Naval Research Maritime Laser Demonstrator, the Navy LaWS (Laser Weapon System), and the Army High Energy Laser Tactical Demonstrator programs. Boeing was selected by the Office of Naval Research (ONR) to develop the design and integration of a 100-kW FEL demonstrator. The Air Force announced initiation of ELLA (Electric Laser on a Large Aircraft), a new program for aircraft integration of a 100-kW-class solid-state laser.

A Missile Defense Agency (MDA) modified Boeing 747 ABL boost-phase missile defense prototype aircraft successfully accomplished kill sequences against instrumented boosting missile targets early this year. ABL's megawatt-class chemical oxygen iodine laser was then tested twice unsuccessfully later in the year against a simulated ballistic missile at a range of over 100 mi. Citing technical and operational issues, Defense Secretary Robert Gates opted to continue using that single platform as a testbed rather than to proceed with acquiring additional platforms.

The MDA's modified Boeing 747 ABL boost-phase missile defense prototype aircraft successfully accomplished kill sequences against instrumented boosting missile targets early this year.

This decision highlights the problem faced not only by directed energy weapons but also by many other innovative emerging technologies: After successful near-prototype demonstrations, acquisition and fielding are deferred because a better technology is always just around the corner.

Despite decades of successful high-power chemical laser demonstrations, attention has shifted to electrically driven lasers to overcome the issues of chemical reactant storage, transportation, and effluent. The first generation of 100-kW-class solid-state weapons is moving out of the laboratory and into field testing. But proponents of even more advanced technologies continue to develop more advanced, more efficient concepts that offer promise when budget pressures take precedence over operational needs.

The head of the MDA announced that solid-state lasers would not achieve the megawatt-class power levels needed to shoot down ballistic missiles, and that the next generation of hybrid electric/gas lasers (diode-pumped heavy metal vapor such as alkali) might be the desired option. The power levels of these lasers, first demonstrated in July, are orders of magnitude below the megawatt class needed and many years away from weapons-class use.

The ONR/NorthropGrumman Maritime Laser Demonstration program continued to make progress on integrating a 100-kW-class solid-state laser on a seaborne platform for testing against tactical targets. Advanced fiber lasers are also being incorporated into close-range, tactical naval laser weapon systems. After tests against mortar rounds in flight in 2009, the Navy/Raytheon LaWS program successfully engaged and shot down UAVs in maritime environment tests in May at San Nicolas Island.

Nonweapons aspects of directed energy systems involve beamed energy propulsion (BEP), a revolutionary technology for future space transportation. BEP vehicles would be driven by power beamed from remote, reusable, long-range sources. Although most BEP techniques are based on lasers, the scope of this technology also covers other forms of directed energy, such as microwave and X-ray radiation and particle beams. BEP systems could provide unique propulsive characteristics impossible to achieve with traditional, combustion-based engines. Vehicles driven by BEP will be smaller, lighter, faster, and more efficient than any currently existing means of space transportation. Work by the Advanced Propulsion Technology Group, JPL, and NASA continues to advance BEP technology, as reported in the proceedings of the American Institute of Beamed Energy Propulsion.

by **James A. Horkovich**

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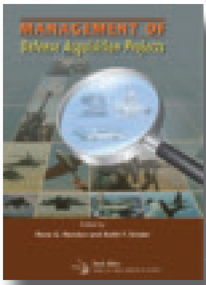

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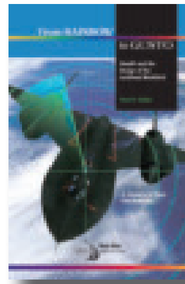

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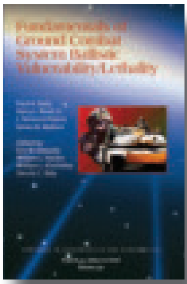

While the focus of this book is on ground combat system vulnerability, many of the principles, methodologies, and tools discussed are also applicable to the air and sea system communities.

Fundamentals of Ground Combat System Ballistic Vulnerability/Lethality

Paul H. Deitz, Harry L. Reed Jr., J. Terrence Klopcic, and James N. Walbert
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25 Years Ago, December 1985

Dec. 7 The China Clipper, a Pan American Boeing 747, arrives in Beijing after departing New York and making a stop in Tokyo. It is the first commercial flight between the U.S. and mainland China since 1949. *Chronicle of Aviation History, 1980-89*.

50 Years Ago, December 1960

Dec. 1 William Allen, president of Boeing, authorizes development of the three-jet-engine Boeing 727 airliner after studying the concept for four years. On December 6 he signs contracts with two airlines, United and Eastern, to build 40 each. The 727 proves highly successful and is produced in greater numbers than any other commercial jet airliner in the world in its time, with 1,832 manufactured. D. Baker, *Flight and Flying*, p. 373; *The 1961 Aerospace Year Book*, p. 445.

Dec. 1-2 The Soviet Sputnik VI is launched with two dogs, Pchelka (Little Bee) and Mushka (Little Fly) on board, as well as other animals, insects, and plant life. However, following a 24-hr orbit of Earth, it descends along an incorrect trajectory, has to be destroyed by a command signal from Earth, and burns up in the atmosphere. *The Aeroplane*, Dec. 9, 1960, pp. 753, 761.

Dec. 5 The Polaris A-2 travels 1,600 mi. in a successful test flight. Its design range is 1,725 mi., compared to 1,380 for the A-1 model. *The Aeroplane*, Dec. 16, 1960, p. 793.

Dec. 8 Howard Hughes transfers control of TWA (Trans World Airways) for the next 10 years under a special agreement. *The Aeroplane*, Dec. 30, 1960, p. 850.

Dec. 10 The Discoverer 18 reconnaissance satellite is successfully "air-snatched" by a C-119 aircraft over the Pacific Ocean near Hawaii. It is the third successful midair catch and also features the first successful use of the KH-2 Itek camera system aboard a satellite. On Dec. 20, Discoverer 19 is launched. *The Aeroplane*, Dec. 16, 1960, p. 812, and Dec. 30, 1960, p. 848; D. Baker, *Spaceflight and Rocketry*, p. 111.

Dec. 15 The three-stage British Jaguar solid-fuel sounding rocket succeeds in the first of a series of hypersonic flights launched to gather basic information on aerodynamic phenomena at hypersonic speeds up to 7,000 mph. The first stage is a Skylark; the second and third stages are newly developed Gosling and Lobster rockets. *The Aeroplane*, Dec. 23, 1960, p. 821.

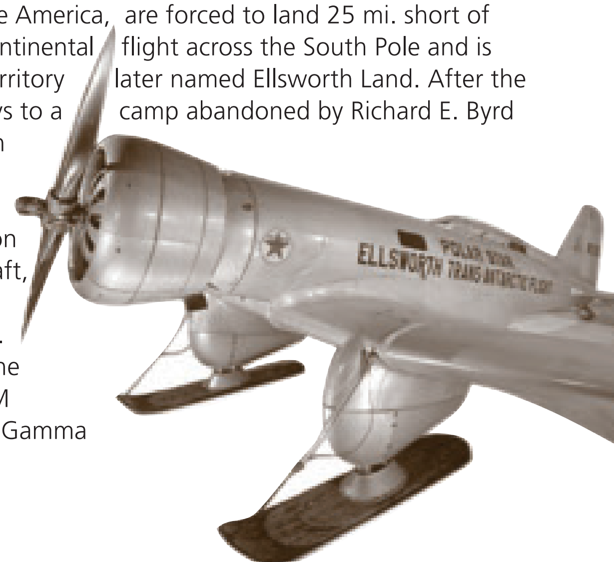
Dec. 19 Martin, the company established by Glenn L. Martin in 1912, delivers its last airplane, a Marlin Patrol Boat, to the Navy. But the Baltimore-based firm remains active in the missile and space fields, building products such as the Titan ICBM and the Mace, Bullpup, Lacrosse, Matador, and Pershing missiles. E. Preston, ed., *FAA Historical Chronology*, p. 69; *Flight*, Jan. 6, 1961, p. 3.

Dec. 20 The first Douglas DC-8 Series 50 aircraft, featuring four 17,000-lb thrust Pratt & Whitney JT3D turbofan engines, makes its first powered flight. D. Baker, *Flight and Flying*, p. 373; *Flight*, Jan. 27, 1961, p. 129.

75 Years Ago, December 1935

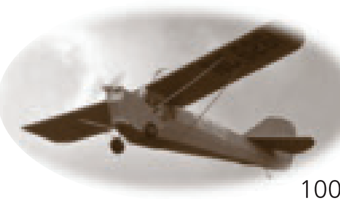
Dec. 3 William Durand is awarded the John Fritz Medal for his distinguished work in engineering and aeronautics. *Aircraft Year Book, 1936*, p. 441.

Dec. 5 Explorer Lincoln Ellsworth and pilot Herbert Hollick-Kenyon, who took off Nov. 23 in a Northrop Gamma Polar Star from Dundee Island in the Weddell Sea headed across Antarctica for Little America, are forced to land 25 mi. short of their goal. This is the first transcontinental flight across the South Pole and is flown largely over unexplored territory later named Ellsworth Land. After the landing, the two walk for six days to a camp abandoned by Richard E. Byrd years earlier. The British Research Society ship Discovery II sights them on January 15, 1936, near the Bay of Whales. Hollick-Kenyon later returns to recover the aircraft, and Ellsworth donates it to the National Air and Space Museum. The total distance flown by on the mission is about 2,400 mi. NASM Aircraft Reference File, Northrop Gamma Polar Star.



Past

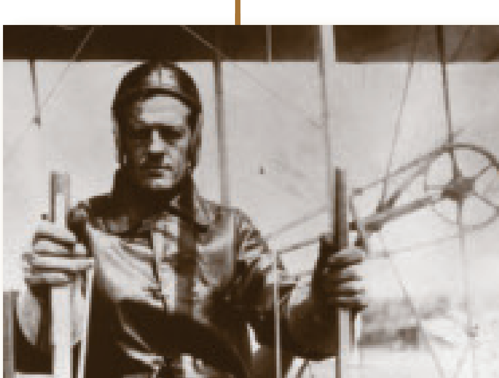
An Aerospace Chronology
by **Frank H. Winter, Ret.**
and **Robert van der Linden**



Dec. 11 Flying an Aeronca C-3, Benjamin King sets a 100-km speed record for seaplanes of 80.931 mph and a 500-km speed record of 70.499 mph for the same category while competing in the Eighth Annual All-American Air Maneuvers in Miami, Fla. *Aircraft Year Book, 1936*, p. 441.

Dec. 12 Flying a Douglas OA-5 amphibian airplane powered by two Wright Cyclone engines, Army Lt. Hugh F. McCaffery and his five-man crew set a distance record of 1,033 mi. for this aircraft class, flying from San Juan, Puerto Rico, to Chapman Field in Miami. *Aircraft Year Book, 1936*, p. 442.

Dec. 17 The Douglas DST, designed by Arthur Raymond on behalf of American Airlines, flies for the first time. The DST is a larger sleeper version of the successful 14-passenger Douglas DC-2. The 21-passenger day version of this new aircraft will become the immortal DC-3. *Aircraft Year Book, 1936*, p. 441.



Dec. 17 Maj. Gen. Benjamin D. Foulois retires. In 1908, Foulois was the first to fly a U.S. government dirigible balloon. He was also one of the first pilots of an Army airplane (purchased from the Wrights in 1909), and he accompanied Orville Wright on the Army acceptance flight from Ft. Myer to Alexandria, Va. Foulois was the only pilot, navigator, observer, and commander in the Army's heavier-than-air division from 1909-1911, and was commander of the First Aero Squadron, which in 1916 was sent on the Mexican Punitive Expedition. He was later chief of the Air Corps. *Aero Digest*, October 1935.

Dec. 18-21 French pilots Gaston Genin and Andre Robert fly their Caudron-Simoun aircraft between Paris and Madagascar in a record time of two days 9 hr 32 min. *Aircraft Year Book, 1936*, p. 442.

100 Years Ago, December 1910

Georges Legagneux

Dec. 8 Georges Legagneux of France sets an altitude record of 1,693 ft in a Bleriot monoplane. A. van Hoorebeeck, *La Conquete de L'Air*, p. 878.

Dec. 10 Romanian aviation engineer Henri Coanda allegedly flies his Turbo-Propulseur airplane accidentally, during taxiing tests at Issy-les-Moulineaux, thus achieving the world's first flight of a jet plane. According to his account given in 1956, he was concentrating on regulating the flow of gasoline in the engine when he saw that he was headed toward army fortifications. To avoid them, he lifted the machine off the ground but then lost control. Injecting more fuel caused the plane to catch fire. Coanda says he cut off the fuel but the aircraft stalled. He was thrown clear as the plane crashed. However, on close examination of his varying accounts, and especially his patent on the Propulseur and descriptions from that time, there is much doubt that the aircraft was a true jet and capable of flight. The plane appears to have had a ducted fan design in which air was sucked into the front by curved blades set in a large nose housing with the smaller end facing forward. The blades were driven by an internally mounted turbine screw driven by a four-cylinder 50-hp Clerget engine. But the patents and contemporary descriptions do not mention fuel injection at all as in a true jet, and there is no record of the alleged flight in aviation journals, or in *Le Figaro.* Although the Hiller Flying Platform did use ducted fans in the 1950s, it barely lifted with two or three 44-hp piston engines, and the Coanda Turbo Propulseur was definitely underpowered. F. Winter, *The Aeronautical Journal of the Royal Society*, Dec. 1980, pp. 408-416.

Dec. 20 J. Tijck of Belgium makes the first aircraft flight in India while travelling in Calcutta. A. van Hoorebeeck, *La Conquete de L'Air*, p. 88.

Subjects

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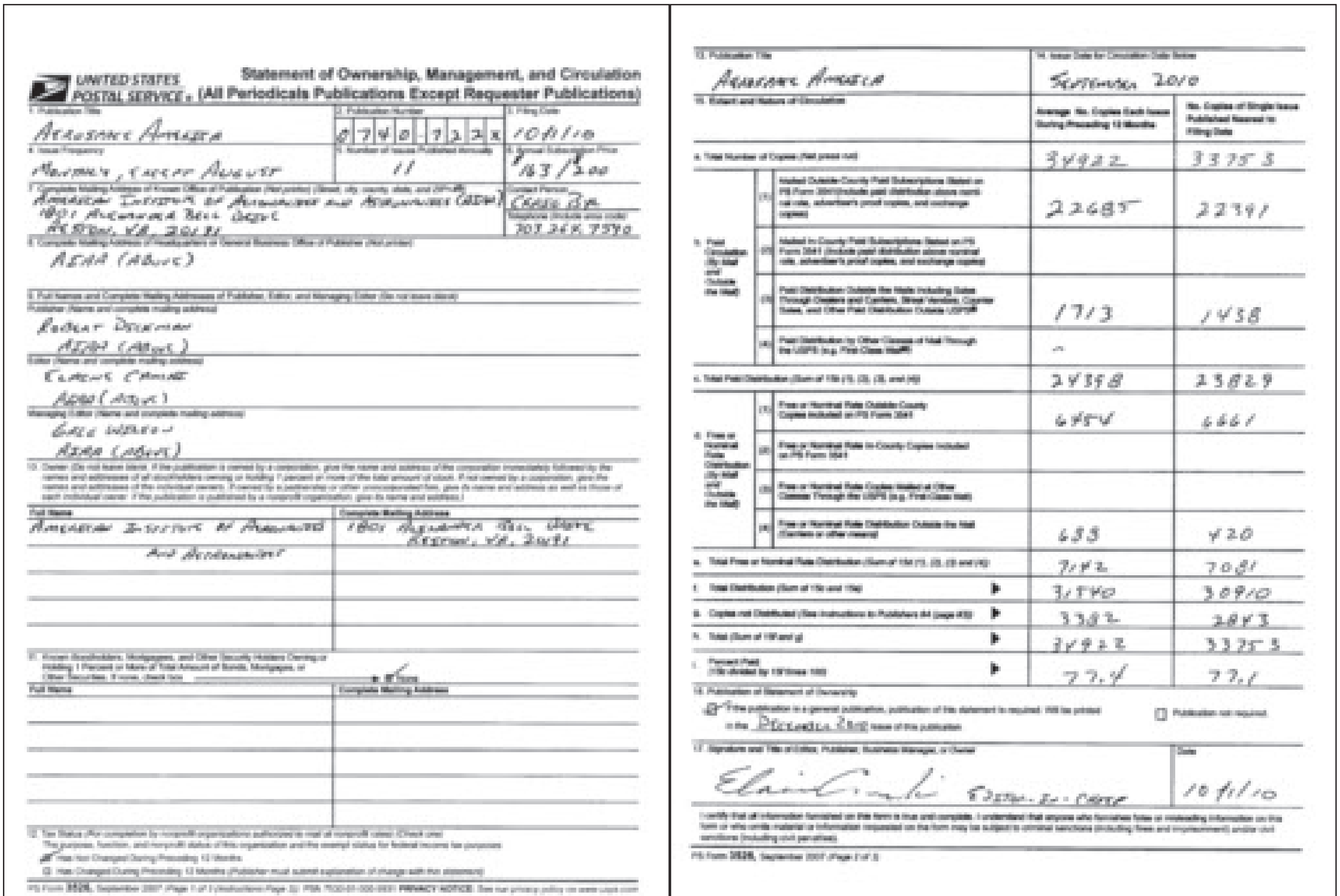

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Virginia Polytechnic Institute and State University

The Department of Aerospace and Ocean Engineering seeks applications for a senior level (associate professor or professor) faculty position in the area of aircraft design. The successful candidate is expected to have substantial experience, preferably with industry relevance, in aircraft design, and to have an established research program in one or more associated areas such as aerodynamics, aircraft stability and control, avionics, multidisciplinary design optimization (MDO), and air traffic control systems.

Applicants must hold an earned doctorate in aerospace engineering or a closely related field. Responsibilities will include teaching at both the undergraduate and graduate levels, directing graduate students, and establishing an externally funded research program. AOE faculty members are active in a number of interdisciplinary research centers and groups, including the AFRL-VT-WSU-UMD Collaborative Center on Multidisciplinary Sciences (http://www.aoe.vt.edu/research/groups/afrl/) and the Virginia Center for Autonomous Systems (http://unmanned.vt.edu). Faculty have access to Virginia Tech's extensive computational resources, including System X, and world-class experimental facilities to support aeroacoustic and high-speed flow measurements, advanced materials characterization, and other activities related to aircraft design.

Virginia Tech, the land-grant university of the Commonwealth of Virginia, is located in Blacksburg, adjacent to the scenic Blue Ridge Mountains. The university has a total student enrollment of 28498, with more than 6000 students in the College of Engineering. Additional information about the department can be found at http://www.aoe.vt.edu. Additional information about Blacksburg, Virginia can be found at http://www.bev.net.

Review of applications will begin on February 1, 2011 and will continue until the position is filled. Interested persons should apply on the web at http://jobs.vt.edu (posting number 0100787) along with a current curriculum vita, a cover letter, teaching and research vision statements and the names and addresses of three references. All enquiries can be sent to: Prof. Rakesh K. Kapania (rkapania@vt.edu), Mitchell Professor, Aerospace and Ocean Engineering, Virginia Tech, Blacksburg, VA, 24061, MC 0203.

Virginia Tech is the recipient of a National Science Foundation ADVANCE Institutional Transformation Award to increase the participation of women in academic science and engineering careers. Virginia Tech has a strong commitment to the principle of diversity and, in that spirit, seeks a broad spectrum of candidates including women, minorities, and people with disabilities. Individuals with disabilities desiring accommodations in the application process should notify Mrs. Wanda Foushee at (540) 231-9057.

West Virginia University

FACULTY POSITION IN THE AREA OF SPACE SYSTEMS
Department of Mechanical & Aerospace Engineering
College of Engineering and Mineral Resources

The Department of Mechanical and Aerospace Engineering (MAE) at West Virginia University (WVU) seeks applications for a tenure-track faculty position at the rank of Assistant or Associate Professor with experience in the general area of Space Systems (Position #5101). This position requires demonstrated expertise in at least one of the following Space Systems specialties:

- Orbital mechanics including Earth orbits, interplanetary missions, orbital decay, trajectory optimization, guidance, navigation, and control,
- Spacecraft and subsystem design including in-space propulsion, attitude determination and control, power, thermal management and protection, command and data handling, space operations, and system design trades,
- Hypersonic planetary entry including Earth reentry vehicles, planetary probes, payload thermal protection, controlled accuracy, and soft landing.

Applicants must hold an earned doctorate in Astronautics, or alternately, Aerospace Engineering, along with strong oral and written communication skills. A proven commitment to innovative engineering education and a strong, demonstrated potential to develop an externally funded interdisciplinary research program are required. The successful candidate will be expected to lead a Departmental effort to develop a Space Systems track in the existing Aerospace Engineering undergraduate curriculum.

WVU is a comprehensive land-grant institution with an enrollment of over 29,000; a Carnegie High Research University at the center of a developing high-technology corridor, providing challenges and opportunities for candidates. The WVU MAE Department is nationally ranked by the National Science Foundation in the top 25 departments of mechanical engineering in research expenditures (NSF, 2008, 2009). It currently employs 29 tenure-track or tenured faculty members and is offering B.S., M.S., and Ph.D. degrees in both Mechanical and Aerospace Engineering to about 450 undergraduate students, 90 M.S., and 80 Ph.D. students. Graduate degree programs in Materials Science and Engineering are also being developed. The department conducts externally sponsored research in a diverse range of specialties, with strong active programs in aerodynamics, flight dynamics, computational fluid dynamics, structures, materials, flight simulations and controls, among others. Additional information may be found on the website of the MAE Department at www.mae.cemr.wvu.edu or by contacting Dr. Jacky Prucz, Interim Chairman, at jacky.prucz@mail.wvu.edu, or regular mail at P.O. Box 6106, Morgantown, West Virginia 26506-6106.

Review of applications will begin on August 16, 2010 and will continue until the position is filled. Electronic applications are required and should be sent to MAEDept@mail.wvu.edu. They should include a cover letter highlighting the applicant's qualifications for the above position, Position #5101, a curriculum vitae, concise descriptions of a research plan and a teaching plan, as well as contact information for three references.

West Virginia University is an Affirmative Action/Equal Opportunity Employer, which encourages applications from women, minorities, and individuals with disabilities, in commitment to building a diverse body of faculty and staff.

UC SAN DIEGO - DEPARTMENT OF STRUCTURAL ENGINEERING

Position Title: Associate/Full Professor
Job Number: JPF00055

Description: The Department of Structural Engineering (http://structures.ucsd.edu) is seeking outstanding candidates in the area of Aviation Safety of Composite Structures to fill a tenured faculty position. Particular emphasis should be on the full-scale behavior and failure of composite structures, structure design, composites processing, crashworthiness and survivability, static and dynamic large-scale testing, bonded and bolted connections, buckling and stability, and damage tolerance. The successful candidate must hold a doctorate or equivalent degree, demonstrate high-quality research and teaching potential, and is expected to develop a strong externally funded research program. Major large-scale experimentation resources are available via the Structural Engineering Department's Charles Lee Powell Laboratories and Englekirk Center. Additional facility space for fabrication, characterization, and testing of full-scale composite aircraft structures is expected via the new Structural and Materials Engineering Building, currently under construction.

The Department of Structural Engineering offers undergraduate and graduate degrees in structural engineering and emphasizes cross-disciplinary research in aerospace, civil, mechanical, and marine structures. Current related research activities include impact damage of large composite structures, full-scale FAA-certified qualification testing, aircraft ground vibration testing, development of long-range unmanned air vehicles (UAV's), NDE, structural health monitoring and damage prognosis in next-generation aircraft, composite ducted fan blade research, computational mechanics, advanced material structural rehabilitation, explosive blast loading, and innovative nano-materials.

The Department of Structural Engineering is committed to building an excellent and diverse faculty, staff, and student body. In addition to having demonstrated the highest standards of scholarship and professional activity, the preferred candidates will have experience or demonstrated contributions to a climate that supports equity, inclusion and diversity. Applicants are asked to submit a summary of their past or potential contributions to diversity in their personal statement. The University of California, San Diego, is an Equal Opportunity/Affirmative Action Employer with a strong institutional commitment to excellence through diversity. For applicants with interest in spousal/partner employment, please see the website for the UCSD Partner Opportunities Program: (http://academicaffairs.ucsd.edu/offices/partneropp/default.htm)

Salary: Level of appointment and salary will be commensurate with qualifications within the University of California published pay scales.

Closing Date: The review of applications will begin on November 1, 2010, and will continue until the position is filled.

To Apply: Please include: 1) a personal statement summarizing teaching experience and interests, leadership efforts and contributions to diversity; and 2) a resume and names/addresses of four professional references to: https://apol-recruit.ucsd.edu/

University of Toronto Institute for Aerospace Studies
Faculty Position in Aerospace Engineering

The University of Toronto Institute for Aerospace Studies (UTIAS) is seeking applications for a tenure-track position at the level of Assistant Professor or Associate Professor in aerospace engineering. The appointment will begin on or after July 1, 2011.

Consideration will be given to applicants with expertise in any area related to aerospace science and engineering. We are particularly interested in applicants whose primary area of research is related to aircraft gas turbine propulsion (e.g. aerothermodynamics of turbomachinery, air breathing propulsion systems, heat transfer and fluid mechanics of gas turbine engines), especially research related to overall propulsion efficiency improvement and emissions reduction. Relevance to the UTIAS strategic focus on reducing the environmental impact of aircraft is an asset. Applicants must have a doctoral degree, typically from an aerospace or mechanical engineering department, and a strong commitment to both teaching and research. The successful candidate is expected to establish and lead a dynamic externally-funded research program, supervise graduate students, teach undergraduate and postgraduate courses, and engage in university service activities. The selection will be based primarily on the applicant's potential for excellence in research and teaching. Salary is commensurate with qualifications and experience. For information about UTIAS, please see our web site (www.utias.utoronto.ca).

Applications should include: (i) a detailed curriculum vitae, (ii) a concise statement (3 pages maximum) of teaching and research interests, objectives and accomplishments, and (iii) examples of publications and material relevant to teaching experience. Applicants are also asked to provide the names and contact information (mailing address, telephone, fax, and email) of five referees who are able to comment on the applicant's experience and ability in teaching and research. Applications must be submitted electronically at http://www.jobs.utoronto.ca/faculty.htm and addressed to Professor D.W. Zingg, Director, University of Toronto Institute for Aerospace Studies, 4925 Dufferin Street, Toronto, Ontario, Canada M3H 5T6. Please direct any questions to Joan DaCosta at dacosta@utias.utoronto.ca. Review of applications will begin on December 31, 2010, and applications will be accepted until the position is filled.

The University of Toronto is located in Toronto, a large multicultural city offering many cultural, professional, and research opportunities. The student body at the University reflects the diversity of the city. The breadth of the University provides numerous opportunities for interdisciplinary collaborative research.

The University of Toronto is strongly committed to diversity within its community. The University especially welcomes applications from visible minority group members, women, Aboriginal persons, persons with disabilities, members of sexual minority groups, and others who may contribute to further diversification of ideas. The University is also responsive to the needs of dual career couples.

All qualified applicants are encouraged to apply; however, Canadians and permanent residents will be given priority.

PURDUE UNIVERSITY

Faculty Openings
Aeronautics & Astronautics

The School of Aeronautics & Astronautics (AAE) at Purdue University seeks outstanding individuals with a Ph.D. and a strong background relevant to aerospace engineering. Currently, AAE faculty members conduct research and teaching in the broad disciplines of Aerodynamics, Aerospace Systems, Astrodynamics and Space Applications, Dynamics and Control, Propulsion, and Structures and Materials. Candidates with interests in these areas are encouraged to apply. Details about the School, its current faculty, and research may be found at the Purdue AAE website https://engineering.purdue.edu/AAE

Candidates should have a distinguished academic record, exceptional potential for world-class research, and a commitment to both undergraduate and graduate education. Tenure-track positions are available at the assistant and associate ranks. For consideration, please submit curriculum vitae, statement of teaching and research interests, and the names and addresses of at least three references to the College of Engineering Faculty Hiring website, https://engineering.purdue.edu/Engr/AboutUs/Employment/indicating interest in AAE. Review of applicants begins 1/15/11 and continues until the positions are filled.

Purdue University is an Equal Opportunity/Equal Access/Affirmative Action employer fully committed to achieving a diverse workforce.

WPI

Worcester Polytechnic Institute

Mechanical Engineering Department
Assistant Professor

Worcester Polytechnic Institute (WPI) invites applications for the position of assistant professor in the Mechanical Engineering Department beginning August 2011.

Required qualifications for the position include: an earned doctorate in Aerospace Engineering, Mechanical Engineering, or a closely related field; a strong commitment to teaching at the undergraduate and graduate levels; a demonstrated record of, or potential for scholarly research, and excellent communication skills. Candidates will be considered from the areas of aerospace structures, aerospace structural dynamics, adaptive aerospace structures, aerospace design & structures, or other closely related areas of the general field of Aerospace Engineering.

Successful candidates will be responsible for teaching courses and advising projects in the Mechanical Engineering Department. The candidates will be expected to develop and sustain an externally funded research program accompanied by strong scholarship.

The ME Department has 31 full-time faculty and offers undergraduate degrees in mechanical engineering and aerospace engineering to more than 600 students. The department offers graduate degrees in mechanical engineering, materials science, and manufacturing to more than 200 graduate students. Information on the ME Department, its undergraduate and graduate programs, and faculty research areas can be found at http://apptrkr.com/163497.

WPI, founded in 1865, is one of the nation's oldest technological universities. WPI is a highly selective private university with an undergraduate student body of over 3,500 and 1,300 full-time and part-time graduate students enrolled in more than 50 Bachelor's, Master's, and Ph.D. programs. Its innovative project-enriched curriculum engages students and faculty in real-world problem solving, often at one of WPI's global project centers. WPI is located one hour west of Boston.

U.S. News and World Report consistently ranks WPI among the top national universities and recently placed WPI in its top 30 for faculty resources.

Applications should be sent to me-recruit@wpi.edu. Applications should include a curriculum vitae, statement of teaching and research interests, and a list of five professional references. Applications from women and minority candidates are especially encouraged. For full consideration, applications should be received by January 31, 2011. Questions can be addressed to sullivan@wpi.edu.

To enrich education through diversity, WPI is an affirmative action, equal opportunity employer.
– A member of the Colleges of Worcester Consortium. –

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across the country,
around the world
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Every day.

When you give blood to
or provide a hot meal
to a disaster victim, train
in first aid or help a member
of our military, you reach out
your hand.

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UNIVERSITY OF ARIZONA

The Dept. of Aerospace and Mechanical Engineering invites applications and nominations for a tenure track faculty positions at the rank of Assistant Professor. Senior positions will be considered for applicants with exceptional stature and professional record. Applicants in all areas of aerospace and mechanical engineering will be considered. Preference will be given to candidates with expertise and interest in: a) space engineering, b) thermal systems/energy and c) multi-scale, multi-physics computation applied to one or more departmental research focus areas which include: aeromechanics, biomedical engineering, energy and micro/nanotechnology. Opportunities for synergy with existing research activities in the department and the University will be viewed favorably.

The Department offers excellent opportunities to interact with other programs on campus such as the Department of Planetary Sciences, the School of Sustainable Engineered Systems, the Arizona Health Sciences Center, the Bio5 Institute for Collaborative Bioresearch, the College of Optical Sciences and the Program in Applied Mathematics, all of which enjoy international recognition as centers for world-class academic programs and research.

Successful candidates will be expected to teach at the undergraduate and graduate levels and to establish active research programs. Previous teaching experience is expected for senior candidates, and desirable in all cases. Opportunities exist for fully as well as partially funded state lines. In the partially-funded model, entrepreneurial individuals would be expected to fund a portion of their salary from research income in exchange for reduced teaching responsibilities and higher than comparable salaries. Required qualifications are a Ph.D. degree in Aerospace or Mechanical Engineering or a closely related discipline and demonstrated research potential or accomplishments.

Review of applications is currently ongoing and will continue until the position is filled. Interested applicants should consult the university website URL:https://www.uacareertrack.com/ and enter job #46415, then follow instructions to make a formal application for this position. The University of Arizona is an EEO/AA employer-M/W/D/V. Women and minorities are encouraged to apply.

Department of Mechanical, Materials and Aerospace Engineering
Department Chair Search

The Illinois Institute of Technology (IIT) invites nominations for, and expressions of interest in, the position of Chair, Department of Mechanical, Materials and Aerospace Engineering (MMAE) (http://www.iit.edu/engineering/mmae/).

The Armour College of Engineering at IIT has entered an exciting period under the new leadership of Dean Natacha DePaola. Dean DePaola, appointed in August 2009, has embarked on an ambitious agenda to build upon Armour's accomplishments and reputation by growing the research portfolio, continuing excellence in undergraduate and graduate education, increasing campus diversity, expanding facilities, and undertaking major capital improvements across the campus. The individual selected for MMAE department chair will be expected to support Dean DePaola's initiatives and continue to grow the department's student base, as well as foster excellence in engineering research and education. The MMAE Department has 26 full-time faculty members, approximately 400 undergraduates, and 160 graduate students. ABET accredited degrees are offered in Mechanical Engineering, Metallurgical and Materials Engineering and Aerospace Engineering. Advanced degrees at the MS and Ph.D. level are also offered. The department has significant research programs in dynamics and control, fluid dynamics, materials science, solid mechanics, and biomechanics.

Candidates for the position of department chair are expected to merit appointment as full professor and have a record of distinguished research and educational achievements. The position of department chair offers highly competitive compensation and benefits. For full consideration, applicants should submit a letter of interest outlining their experience and qualifications for the position, a curriculum vitae, and the names and contact information of at least three references. Application materials or nominations should be submitted electronically to mmae_search@iit.edu. Questions and enquiries should be directed to the Search Committee Chair, Dr. Vincent Turitto, Director of the Pritzker Institute of Biomedical Science and Engineering, at 312-567-7984 or turitto@iit.edu. Illinois Institute of Technology is an Affirmative Action/Equal Opportunity Employer.

ASSISTANT/ASSOCIATE PROFESSOR ASTRONAUTICS

**CALIFORNIA STATE UNIVERSITY, LONG BEACH
MECHANICAL AND AEROSPACE ENGINEERING**

The Department of Mechanical and Aerospace Engineering at CSU, Long Beach invites applications for a tenure track Assistant/Associate Professor focused on Astronautics. A Ph.D. degree in Aerospace Engineering, Astronautics, or a closely related discipline, with a specialization in the area of Astrodynamics; Aerospace System Design; or Guidance, Navigation and Control (GN&C) is required. The successful candidate will be expected to develop and teach courses in the field; supervise student projects and theses; develop a research program which complements and enhances ongoing multi-disciplinary research activities in space transportation related fields; and participate in academic governance. Applications (required documents are listed in the link below) and/or requests for information should be addressed to:

**Chair, Astronautics Search Committee
Dept. of Mechanical and Aerospace Engr.
California State University Long Beach
1250 Bellflower Boulevard,
Long Beach, CA 90840-8305
E-mail submissions/inquiries to:
me-info@csulb.edu
http://www.csulb.edu/colleges/coe**

Review of applications to begin January 15, 2011.

In addition to meeting fully its obligations of nondiscrimination under federal and state law, CSULB is committed to creating a community in which a diverse population can learn, live, and work, in an atmosphere of tolerance, civility, and respect for the rights and sensibilities of each individual, without regard to economic status, ethnic background, political views, or other personal characteristics or beliefs. CSULB is an EO Employer.

THE AIAA SUGGESTION PROGRAM

AIAA welcomes suggestions from members on how we can better serve you.
All comments will be acknowledged. We will do our best to address issues that are important to our membership.
Please send your comments to:

Mary Snitch
VP Member Services
AIAA
1801 Alexander Bell Drive
Suite 500
Reston, VA 20191-4344

AIAA

A Tenure Track Faculty Position In Fluid Mechanics

THE OHIO STATE UNIVERSITY DEPARTMENT OF MECHANICAL AND AEROSPACE ENGINEERING

The Department of Mechanical and Aerospace Engineering at The Ohio State University invites applications from outstanding individuals for a tenure track faculty position in fluid mechanics. The anticipated start date is September 2011, but the search will continue until the position is filled.

Successful applicants for the position will complement significant existing strengths in the recently merged Department of Mechanical and Aerospace Engineering, namely fundamental fluid mechanics with a focus on propulsion and aerodynamic applications. Research specialization areas under consideration include (but are not limited to): propulsion, combustion, UAV aerodynamics, fluid/structure interactions, and wind turbine aeromechanics. While candidates are primarily sought at the assistant professor level, exceptionally qualified applicants at the associate professor level may be considered.

The Ohio State University is an affirmative/equal opportunity employer. Women, minorities, and people with disabilities are encouraged to apply and build a diverse workplace. Columbus is a thriving metropolitan community, and the University is responsive to the needs of dual career couples.

Qualifications

Candidates must have an earned doctoral degree in aerospace or mechanical engineering or a closely related field by the start date. The new faculty member will be expected to teach core undergraduate and graduate courses in their discipline, develop new graduate courses related to their research expertise, develop and sustain active sponsored research programs, and become a recognized leader in his/her research field. Screening of applicants will begin immediately and continue until the position is filled. Interested candidates should send a complete curriculum vitae, a 2-3 page statement of research and teaching goals, and the names and addresses of four references to:

Krishnaswamy Srinivasan
Chair, Mechanical and Aerospace Engineering
N350C Scott Laboratory, 201 West 19th Avenue
Columbus, Ohio 43210
Emailed applications to **srinivasan.3@osu.edu** are welcome.

VirginiaTech *Invent the Future®*

Faculty Position in Aerospace Propulsion
Aerospace and Ocean Engineering
Virginia Polytechnic Institute and State University

The Department of Aerospace and Ocean Engineering seeks applications for a faculty position at any rank in the area of aerospace turbomachinery propulsion systems. Candidates are sought with expertise and a record of achievement in relevant areas of aerospace propulsion, including experimental or computational aerodynamics, thermodynamics and combustion, or multidisciplinary interaction among such areas as fluid and structural mechanics, control theory, materials and computational science as applied to the analysis and design optimization of aerospace propulsion systems. This search is being conducted as part of an extensive relationship that Virginia Tech is developing with Rolls-Royce, a leading global provider of power systems and services for the civil aerospace, defense aerospace, marine and energy markets. The relationship involves the development of two major research centers in the fields of aerospace propulsion and advanced manufacturing. Additional details on the partnership can be found at http://www.eng.vt.edu/overview/clusterhire.php. Exceptional candidates with a high level of accomplishment may be considered for an endowed professorship.

Applicants must hold an earned doctorate in aerospace engineering or a closely related field. Responsibilities will include teaching at both the undergraduate and graduate levels, directing graduate students, and establishing an externally funded research program in the area of aerospace propulsion. AOE faculty members are active in a number of interdisciplinary research centers and groups, including the AFRL-VT-WSU-UMD Collaborative Center on Multidisciplinary Sciences (http://www.aoe.vt.edu/research/groups/afrl/) and the Virginia Center for Autonomous Systems (http://unmanned.vt.edu). Faculty have access to Virginia Tech's extensive computational resources, including System X, and world-class experimental facilities to support high-speed flow measurements, advanced materials characterization, and other activities related to aerospace propulsion systems.

Virginia Tech, the land-grant university of the Commonwealth of Virginia, is located in Blacksburg, adjacent to the scenic Blue Ridge Mountains. The university has a total student enrollment of 28498, with more than 6000 students in the College of Engineering. Additional information about the department can be found at http://www.aoe.vt.edu. Additional information about Blacksburg, Virginia can be found at http://www.bev.net.

Review of applications will begin on February 1, 2011 and will continue until the position is filled. Interested persons should apply on the web at http://jobs.vt.edu (posting number 0100798) along with a current curriculum vita and the names and addresses of three references. All enquiries can be sent to: Prof. Rakesh K. Kapania (rkapania@vt.edu), Mitchell Professor, Aerospace and Ocean Engineering, Virginia Tech, Blacksburg, VA, 24061, MC 0203.

Virginia Tech is the recipient of a National Science Foundation ADVANCE Institutional Transformation Award to increase the participation of women in academic science and engineering careers. Virginia Tech has a strong commitment to the principle of diversity and, in that spirit, seeks a broad spectrum of candidates including women, minorities, and people with disabilities. Individuals with disabilities desiring accommodations in the application process should notify Mrs. Wanda Foushee at (540) 231-9057.

THE DEPARTMENT OF AEROSPACE ENGINEERING & ENGINEERING MECHANICS AT THE UNIVERSITY OF TEXAS AT AUSTIN

has **three faculty positions** with a start date of September 2011. We invite applications in the following areas:

One Tenured Position (senior Associate Professor or junior Full Professor)

- In the area of **Controls**. Preferred research focus areas are advanced estimation and filtering, and methods for analyzing highly uncertain and nonlinear dynamical systems. Applications to manned and unmanned air, space, ground, and water vehicles.
- Applicants for this position are expected to have a doctoral degree in engineering and to have an established, extramurally-funded research program and excellence in teaching.

One Tenure-Track Position (Assistant Professor)

- In the area of **Mechanics of Solids, Structures and Materials.** We are particularly interested in the area of **Mechanical Behavior of Materials for Extreme Environments** that encompasses light-weight structures and multi-functional materials for application in manned and unmanned air, space and underwater vehicles and structures, and materials and structures related to energy industries such as wind, solar and nuclear.
- Applicants for this position should have received, or expect to receive a doctoral degree in engineering prior to September 2011.

One Tenure-Track Position (Assistant Professor)

- In the area of **Space Research**. We are looking for a candidate with interests in space borne Earth observation instrumentation and/or the associated data processing, data fusion with other remote sensing instrumentation, data interpretation, as well as aspects of orbital mechanics related to the satellite platform motion.
- Applicants for this position should have received, or expect to receive a doctoral degree in engineering prior to September 2011.

Successful candidates for these positions are expected to supervise graduate students, teach undergraduate and graduate courses, develop sponsored research programs, collaborate with other faculty, and be involved in service to the university and the engineering profession. Applications received by **December 31, 2010** are assured full consideration, but the search will continue until the positions are filled. To apply submit an application online at http://www.ae.utexas.edu/facultyjobs, only complete applications will be considered. The University of Texas at Austin is an affirmative action, equal opportunity employer. For more information about The Department of Aerospace Engineering and Engineering Mechanics, please visit http://www.ae.utexas.edu These positions have been designated as security-sensitive, and a criminal background check will be conducted on the applicants selected.

Tenure-Track/Tenured Faculty Positions in Mechanical and Aerospace Engineering Department The University of Texas at Arlington

http://www.uta.edu/mae

MAE

The Department of Mechanical and Aerospace Engineering at The University of Texas at Arlington (UT Arlington) invites applications for positions at the Assistant Professor level. We are particularly interested in candidates with experience in the following areas, although outstanding candidates in other areas and ranks will be considered:
Nanotechnology with applications to energy storage, alternative fuels, Controls and Vehicle Dynamics
Interested candidates should submit by email: a letter of application, a complete resume, a description of research and teaching plans, and the contact information of four references. Applications should be sent in one pdf file to MAEsearch2010@uta.edu.

Candidates should hold an earned doctorate in Mechanical Engineering, Aerospace Engineering, Engineering Mechanics, or a closely related discipline and will be expected to teach at both the undergraduate and graduate levels and to develop a significant externally funded research program. Competitive salaries and research startup funds are available for these positions. Excellent laboratory and computational facilities are available at UT Arlington to support research in these areas, with state of the art fabrication facilities at the NANOFAB (http://www.uta.edu/engineering/nano/) and the Automation and Robotics Institute (ARRI at http://arri.uta.edu/). Opportunities also exist for collaborative research with various other research centers and programs at The University of Texas at Arlington (http://www.uta.edu) and The University of Texas Southwestern Medical Center at Dallas (http://www.utsouthwestern.edu/), as well as with many diverse local industries.

UT Arlington is a doctoral, research-extensive university and is part of the University of Texas System with a current enrollment of nearly 33,000 students. The University is located in Arlington, Texas at the center of the Dallas/Fort Worth Metroplex, one of the leading centers of aerospace, electronics, and telecommunications activity in the U.S. The MAE Department offers BS, MS, and PHD degrees in both Aerospace Engineering and Mechanical Engineering and currently has 33 full time faculty members with 300 graduate students and over 1050 undergraduate students.

Positions are for Fall Semester 2011 but earlier start dates may be possible. Review of applications will begin immediately and will continue until the positions are filled.

UT Arlington is an Equal Opportunity/Affirmative Action Employer. UT Arlington does not discriminate on the basis of race, color, national origin, sex, religion, age, disability, veteran status or sexual orientation in employment or in the provision of services. This is a security sensitive position, and a criminal background check will be conducted on finalists. Effective August 1, 2011, the use of tobacco products (including cigarettes, cigars, pipes, smokeless tobacco and other tobacco products) by students, faculty, staff, and visitors are prohibited on all UT Arlington properties.

NC STATE UNIVERSITY

FACULTY POSITIONS

in the Mechanical and Aerospace Department

The Department of Mechanical and Aerospace Engineering at North Carolina State University moved into a new 248,000 sq. ft. facility this past summer and, as part of the expansion of the College of Engineering and the MAE department, we are seeking applicants to fill both tenure track and non-tenure track faculty positions. This announcement invites applications for tenure-track faculty positions in 1) Adaptive Materials and Structures (#656) includes, but is not limited to multifunctional materials, active materials, bio-inspired smart materials, modeling/simulation/control, energy harvesting, and structural health monitoring/management, (2) Experimental and/or Theoretical Vibrations and Acoustics (#643): includes but is not limited to modeling/simulation/control of sound and vibrations, fluid-structure interaction, nonlinear dynamics and chaos, wave propagation, sound path and source identification, non-linear acoustics, sound quality, and human response to noise, (3) Aerospace Structures (#657): includes but is not limited to advanced composite structures/manufacturing and repair, multifunctional structures, lightweight structures, aero-elasticity, rotorcraft applications and space transportation structures. Candidates must have earned a doctorate in Mechanical Engineering, Aerospace Engineering or a closely-related field. Successful candidates will be expected to teach at the undergraduate level and the graduate level, to advise graduate students, and to establish a high quality, nationally-visible externally funded research program. We also invite applications for a non-track teaching professor position in the area of thermal-fluid sciences. Candidates for this position must have earned a doctorate in Mechanical Engineering, Aerospace Engineering or a closely-related field. It is anticipated that the positions will be filled at the assistant or associate professor level, but higher rank may be considered. Rank and salary are commensurate with experience and accomplishments.

Interested persons should apply online at **http://jobs.ncsu.edu**. Search using the position number listed after each job description above. Attach files of a complete curriculum vitae, cover letter, and the contact information for three references. Additional information is available at **www.mae.ncsu.edu**. For full consideration, applications should be received by 01/01/2011.

Individuals with disabilities desiring accommodation in the application process should contact the MAE office at **(919) 515-2367**. We welcome the opportunity to work with candidates to identify suitable employment opportunities for spouses or partners.

N.C. State University is an equal opportunity and affirmative action employer: all qualified applicants will receive consideration for employment without regard to race, color, national origin, religion, sex, sexual orientation, age, or disability. Women and members of other underrepresented groups are especially encouraged to apply .

Full-Time, Tenure-Track Faculty Position in Aerospace Engineering Department at California State Polytechnic University, Pomona

The Aerospace Engineering Department invites applications at the assistant- or associate-professor level for a tenure-track faculty position beginning September 2011 or January 2012 to teach a broad range of courses in aerospace engineering with primary responsibility in the following areas: aerospace structures, finite-element analysis and mechanics of composite materials. A Ph.D. in aerospace engineering or a closely related discipline is required and industrial and teaching experience is preferred.

Demonstrated interest in curriculum development, computer-based static and dynamic structural modeling and analysis (such as NASTRAN), design of aircraft and spacecraft structures, laboratory development in our B.S. and M.S. programs, pursuing grants and supervising student research. Demonstrated ability to provide hands-on education in a multi-disciplinary environment, as well as excellent oral and written communication skills are required. Research, consulting, and summer employment in aerospace industry are available in the local area. Initial review of applications will begin January 31, 2011 and will continue until the position is filled. Applicants should send a curriculum vitae and a list of teaching and research interests to:

Dr. Ali Ahmadi, Chair
Aerospace Engineering Department
California State Polytechnic University
3801 W. Temple Avenue
Pomona, CA 91768

Request application materials from Carol Christian, Aerospace Engineering Department, at (909) 869-2470 or at cmchristian@csupomona.edu. The University hires only individuals lawfully authorized to work in the United States. The university is an equal opportunity, affirmative action employer.

For full ad see:
http://www.csupomona.edu/~engineering
(Click on faculty searches)

Massachusetts Institute of Technology

Come work with us!

Tenure-Track Faculty Positions

Department of Aeronautics and Astronautics

The Department of Aeronautics and Astronautics is seeking applicants for tenure-track faculty positions with potential starts in September 2011. Department programs encompass aircraft, spacecraft, transportation, information, and communication systems. We are searching for exceptional candidates in any discipline relevant to aerospace. We are particularly interested in identifying top candidates in the following areas: aerospace materials and structures, autonomous systems, aircraft propulsion, and air transportation. Our goal is to hire candidates who have deep expertise in one or more core disciplines and who have the potential and intellectual flexibility to become world leaders through integration of these disciplines to define and address new opportunities. Faculty duties include teaching at the graduate and undergraduate levels, research, and supervision of student research. Further information on this search and Department may be found at http://web.mit.edu/aeroastro/about/jobs.html.

Candidates should hold a Ph.D. in Aeronautics and Astronautics or a related field by the beginning of the appointment period. The search is for the Assistant Professor level, but qualified candidates at all levels will be considered.

Applications must be submitted in PDF format online at https://facsearch.mit.edu. Applicants must submit a cover letter, a curriculum vitae, a 2-3 page statement of research and teaching interests and goals, and the names and contact information of at least three individuals who will provide letters of recommendation. Applicants should request that letters of recommendation be submitted online at https://facsearch.mit.edu by the recommenders. Applications should be addressed to Professor David W. Miller, Chair, Faculty Search Committee, MIT Department of Aeronautics and Astronautics. Applications will be considered complete when both the applicant's materials and at least three letters of recommendation are received. Applicants are encouraged to apply by January 1, 2011.

MIT is an Equal Opportunity/Affirmative Action Employer and encourages applications from qualified women and members of minority groups.

http://web.mit.edu

Multiple Tenure-Track Faculty Positions
University of Alabama in Huntsville

The faculty of the Mechanical and Aerospace Engineering Department at the University of Alabama in Huntsville invites applications for tenure-track faculty positions from professionals with expertise and qualifications in the following areas:

- **Propulsion / Energy Systems** – covering areas in liquid, solid, air-breathing and/or advanced concepts (electric/plasma), with expertise in experimentation preferred. Other areas include plasma engineering for power, advanced propulsion and high energy density physics.
- **Aviation / Aerospace Systems** – including UAVs, missiles, and rotorcraft, with expertise in the fields of aerodynamics, fluid-structure interactions, (macro)composites, vehicle health monitoring, aviation safety and security, and/or aviation disaster preparedness/emergency management.

We expect to fill two positions at the Assistant Professor level. However, candidates with sufficient research and teaching experience at the Associate Professor level will also be considered. In addition, and depending on the pool of applicants, a third position from among the areas listed above will be considered this year. The successful candidates will have a strong commitment to teaching excellence at the undergraduate and graduate levels and demonstrated research capabilities that will enable development of externally-funded research programs within a collaborative, supportive, multi-disciplinary environment. Applicants must have an earned doctorate in Aerospace or Mechanical Engineering or a closely related field from an ABET accredited institution. Previous teaching experience is desirable. The successful candidates should have the ability to work closely with the Defense and Aerospace communities. UAHuntsville is adjacent to the second largest university research park in the nation, and to the U. S. Army Redstone Arsenal, and to NASA's Marshall Space Flight Center, which all provide our faculty and students with outstanding opportunities for collaboration. The MAE Department has 750 undergraduate students and 176 graduate students and offers Bachelors, Masters, and Doctoral programs in Mechanical and Aerospace Engineering. Consideration of applicants will begin immediately, and the search will remain open until the position is filled. Applicants should send (in pdf format) a cover letter, a curriculum vitae, contact information for at least three references, and separate one-page statements of research plans and teaching interests to maesearch@eng.uah.edu. The Department is committed to diversity and fostering a welcoming climate for all. UAHuntsville is an Affirmative Action/Equal Opportunity Employer.

UNIVERSITY OF CALIFORNIA, IRVINE

As part of a strategic growth initiative, the University of California, Irvine has established an Aerospace Engineering Program of Excellence, targeted to advance to top national ranking. The Program builds on the strength of the current aerospace faculty in the Department of Mechanical and Aerospace Engineering, which includes four members of the National Academy of Engineering and one member of the National Academy of Sciences. We are seeking to add one new faculty member in the main thematic area of Aerospace Structures/Solids/Materials. The successful candidate will perform cutting-edge research in one or more of the following areas: light-weight and multifunctional materials and structures, novel composite materials (including functionally graded and hybrid materials), self-healing materials, materials for extreme environments, damage tolerance and durability, structural health monitoring, non-destructive evaluation, innovative structural/materials concepts for unmanned and micro air vehicles.

Applicants must have earned a Ph.D. in aerospace engineering, mechanical engineering, or a closely related field. Successful candidates will be expected to maintain an independent research program with major national and international impacts and to contribute to our B.S., M.S., and Ph.D. programs by teaching courses and performing other academic duties. They must show credentials that will strengthen and advance our Program of Excellence, as well as contribute to the local community of scholars. Nominally, the position will be at the assistant professor level (tenure track), but in exceptional cases senior applicants will be considered. The successful candidate will be considered for a Samueli Faculty Career Development Professorship (junior level) or a Samueli Endowed Chair (senior level).

Selection will begin December 1, 2010, and continue until the position is filled. Completed applications containing a cover letter, curriculum vitae, three to five letters of recommendation, and sample research publications should be uploaded electronically.

Please refer to the following web site for instructions:
http://www.eng.uci.edu/employment
Information about the department can be found at:
http://mae.eng.uci.edu

The University of California, Irvine is an equal opportunity employer committed to excellence through diversity and strongly encourages applications from all qualified applicants, including women and minorities. UCI is responsive to the needs of dual career couples, is dedicated to work-life balance through an array of family-friendly policies, and is the recipient of an NSF ADVANCE Award for gender equity.

AIAA FORMS NEW EARTH OBSERVATION TASK FORCE

AIAA has created a new task force to assist in the formulation of a national road map for the U.S. to address investments in the Earth-observing industry to adequately inform future climate change debates and decisions. Composed of leading experts on policy and climate-monitoring technology from within **AIAA** and in collaboration with other organizations, the task force is developing a strategy to come up with recommendations to help reach this goal.

For more information, contact **Craig Day** at **703.264.3849** or **craigd@aiaa.org**.

AIAA

The World's Forum for Aerospace Leadership